

Tab 1



FS9001E GAS TURBINE

1. INTRODUCTION

a. General

The MS9001E is a single-shaft gas turbine with a 14 combustor, reverse-flow combustion system. The MS9001E gas turbine assembly consists of six major sections or groups:

- Air inlet
- Compressor
- Combustion system
- Turbine
- Exhaust
- Support systems

This portion briefly presents a functional description of how the gas turbine operates and the function that each major component performs in the operation of the gas turbine as air and combustion gases flow through the gas path stream from inlet to exhaust.

The gas path is the path by which gases flow through the gas turbine from the air inlet through the compressor, combustion section and turbine, to the turbine exhaust, as illustrated in the flow diagram, Figure 1. The identification and location of individual turbine components, mentioned in the following description and remaining sections of the book, are shown in relation to the entire turbine assembly in the longitudinal cutaway view, Figure 2.

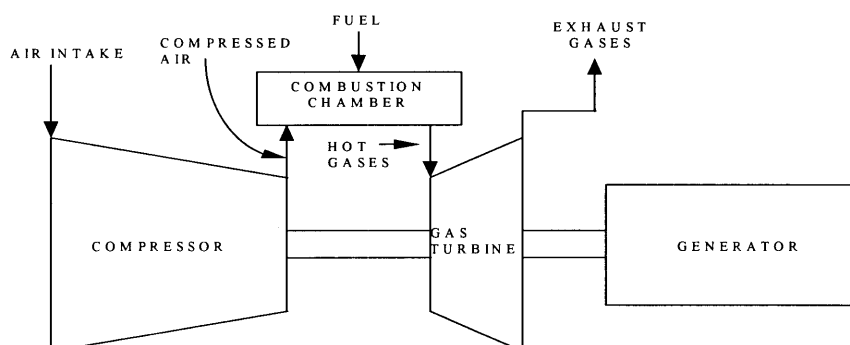


Figure 1 Simple Cycle Gas Turbine Flow Diagram

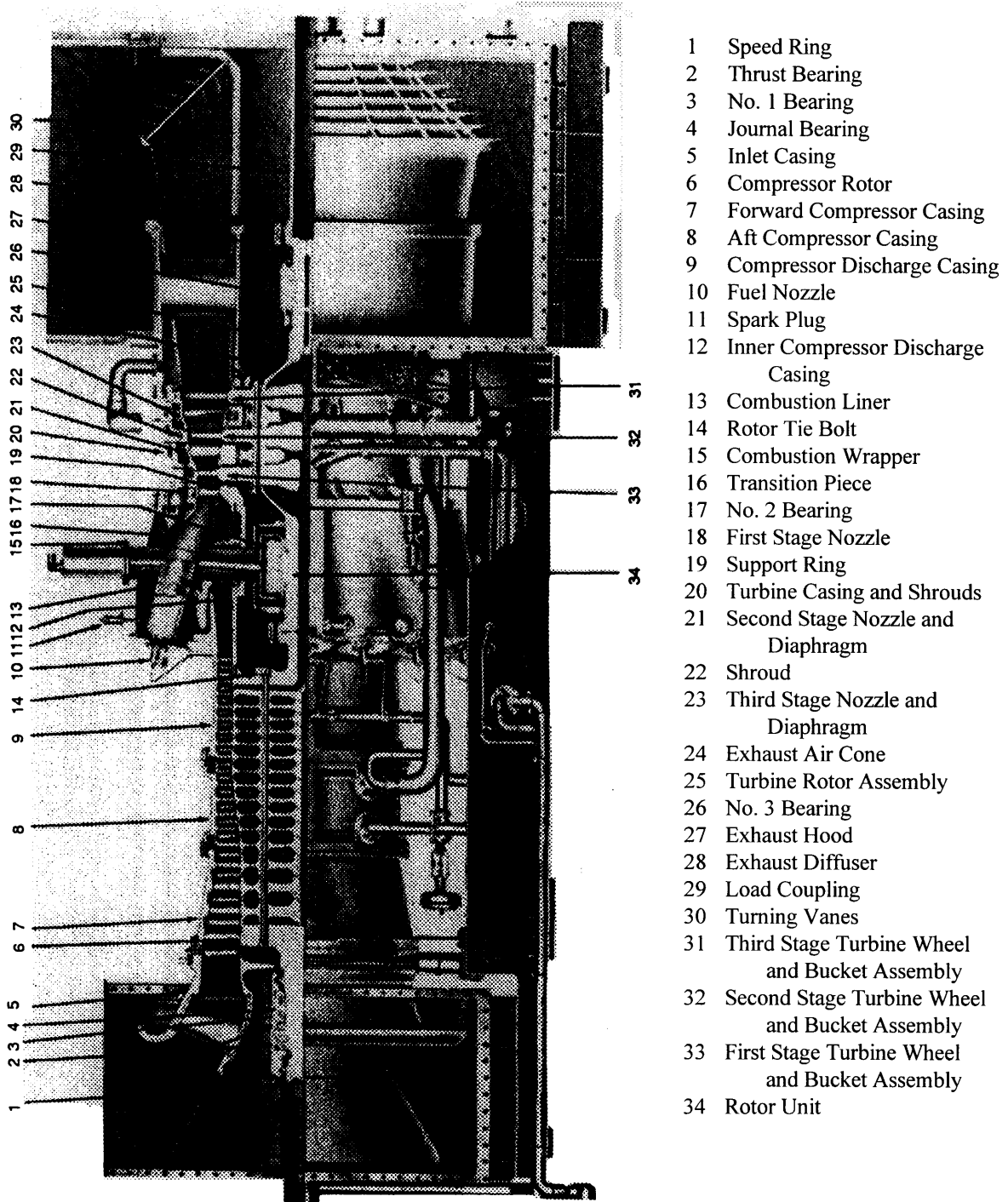


Figure 2 Gas Turbine Component Identification



b. Detail Orientation

Throughout this manual reference is made to the forward and aft ends, and to the right and left sides of the gas turbine and its components. By definition, the air inlet of the gas turbine is the forward end, while the exhaust stack is the aft end. The forward and aft ends of each component are determined in like manner with respect to its orientation within the complete unit. The right and left sides of the turbine or of a particular component are determined by standing forward and looking aft.

c. Gas Path Description

When the turbine starting system is actuated and the clutch is engaged, ambient air is drawn through the air inlet plenum assembly, filtered and compressed in the 17 stage, axial flow compressor. For pulsation protection during start up the 11th stage extraction valves are open and the variable inlet guide vanes are in the closed position. At high speed the 11th stage extraction bleed valve closes automatically and the variable inlet guide vane actuator energises to open the inlet guide vanes to the normal turbine operating position. Compressed air from the compressor flows into the annular space surrounding the 14 combustion chambers. From there it flows into the combustion liners and enters the combustion zone through metering holes in each of the combustion liners for proper fuel combustion.

Fuel from an off base source is provided to 14 equal flow lines, each terminating at a fuel nozzle centred in the end plate of a separate combustion chamber. Prior to being distributed to the nozzles the fuel is accurately controlled to provide an equal flow into the 14 nozzle feed lines at a rate consistent with the speed and load requirements of the gas turbine. The nozzles introduce the fuel into the combustion chambers where it mixes with the combustion air and is ignited by one or both of the spark plugs. At the instant when fuel is ignited in one combustion chamber flame is propagated through connecting crossfire tubes to all other combustion chambers. After the turbine rotor approximates operating speed combustion chamber pressure causes the spark plugs to retract to remove their electrodes from the hot flame zone.

The hot gases from the combustion chambers expand into the 14 separate transition pieces attached to the aft end of the combustion chamber liners and flow from there to the three stage turbine section of the machine. Each stage consists of a row of fixed nozzles followed by a row of rotatable turbine buckets. In each nozzle row the kinetic energy of the jet is increased, with an associated pressure drop, and in each following row of moving buckets a portion of the kinetic energy of the jet turns the turbine rotor. Resultant rotation is used to turn the generator rotor and generate electrical power.

After passing through the third stage buckets the gases are directed into the exhaust hood and diffuser which contains a series of turning vanes to turn the gases from an axial direction to a radial direction, thereby minimizing exhaust hood losses. The gases then pass into the exhaust plenum and are introduced to atmosphere through the exhaust stack.



II. BASE AND SUPPORTS

a. Accessory Base

Most of the mechanical and electrical auxiliary equipment necessary for starting and operating the gas turbine is contained within the accessory compartment.

There are many systems involved in the operation of the turbine, several of which have accessory devices, or mechanisms, located in the accessory section. These may include the starting, fuel, lubrication, hydraulic, cooling water, and atomizing air systems. Several major components of the accessory compartment include the starting means, the torque converter and the accessory drive gear. Besides being the main link between the starting system drive components and the gas turbine the accessory drive gear is the gear reduction unit connected directly to the turbine for driving several of the accessory devices of the gas turbine support systems. These systems and their devices are described in detail in subsequent subsections.

A pressure gauge and switch cabinet is located in the accessory compartment contains panel mounted gauges and switches used with the system mentioned above.

Fabricated supports and mounting pads are welded to the upper surface of the accessory base for mounting the accessory gear, starting device, pumps, and other accessory components. Lifting trunnions installed on the base and mounting pads are provided on the bottom surface of the base longitudinal I-beams to facilitate mounting of the base assembly to the foundation.

b. Turbine Base

The base that supports the as turbine is a structural steel fabrication of welded steel beams and plate. It provides a support upon which to mount the as turbine.

Two lifting trunnions and supports are provided on each side of the base in line with the structural cross members of the base frame. Machined pads, three on each side on the bottom of the base, facilitate its mounting to the site foundation. Two machined pads atop the base frame are provided for mounting the aft turbine supports.

c. Turbine Supports

The gas turbine is mounted to its base by vertical supports at three locations; the forward support at the lower half vertical flange of the forward compressor casing and the aft two on either side of the turbine exhaust frame.

The forward support is a flexible plate that is bolted and doweled to the turbine base, at the forward base cross frame beam, and bolted and doweled to the forward flange of the forward compressor casing.



The aft supports, one on each side of the turbine exhaust frame, are leg type supports. Both vertical support legs rest on machine pads on the base and attach snugly to the turbine exhaust frame mounted support pads. The legs provide centre line support and casing alignment.

Fabricated to the outer surface of each aft support leg is a water jacket. Cooling water is circulated through the jackets to minimize thermal expansion of the support legs and assist in maintaining alignment between the turbine and the generator. The support legs maintain the axial and vertical positions of the turbine while a gib key coupled with the turbine support legs maintains its lateral position.

d. Gib Key and Guide Block

A gib key is machined on the lower half of the turbine shell. The key fits into a guide block which is welded to the aft cross beam of the turbine base. The key is held securely in place in the guide block with bolts that bear against the key on each side. This key and block arrangement prevents lateral or rotational movement of the turbine while permitting axial and radial movement resulting from thermal expansion.

III. COMPRESSOR SECTION

a. General

The axial flow compressor section consists of the compressor rotor and the enclosing casing. Within the compressor casing are the inlet guide vanes, 17 stages of rotor and stator blading and the exit guide vanes.

In the compressor, air is confined to the space between the rotor and stator blading where it is compressed in stages by a series of alternate rotating (rotor) and stationary (stator) airfoil shaped blades. The rotor blades supply the force needed to compress the air in each stage and the stator blades guide the air so that it enters the following rotor stage at the proper angle. The compressed air exits through the compressor discharge casing to the combustion chambers. Air is extracted from the compressor for bearing sealing and pulsation control.

b. Rotor

The compressor rotor is an assembly of 15 individual wheels, two stub shafts (each with an integral wheel), a speed ring, tie bolts and the compressor rotor blades (see figure 3).

Each wheel and the wheel portion of each stubshaft has slots machined around its circumference. The rotor blades and spacers are inserted into these slots and are held in axial position by staking at each end of the slot. The wheels and stubshafts are assembled to each other with mating rabbets for concentricity control and are held together with tie bolts.



Selective positioning of the wheels is made during assembly to reduce balance correction. After assembly the rotor is dynamically balanced to a fine limit.

The forward stubshaft is machined to provide the forward and aft thrust faces and the journal for the No. 1 bearing as well as the sealing surfaces for the No. 1 bearing oil seals and the compressor low-pressure air seals.

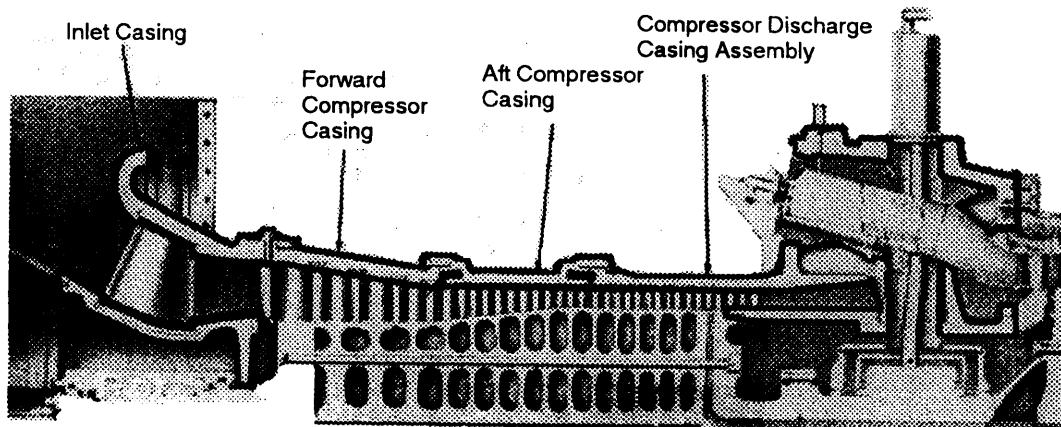


Figure 3 Compressor Cutaway View

c. Stator

1. General

The stator (casing) area of the compressor section is composed of four major sections. These are the:

- Inlet casing
- Forward compressor casing
- Aft compressor casing
- Compressor discharge casing

These sections, in conjunction with the turbine shell, form the primary structure of the gas turbine. They support the rotor at the bearing points and constitute the outer wall of the gas path annulus. The casing bore is maintained to close tolerances with respect to the rotor blade tips for maximum efficiency.



2. Inlet Casing

The inlet casing is located at the forward end of the gas turbine. Its prime function is to uniformly direct air into the compressor. The inlet casing also supports the No. 1 bearing housing, a separate casting that contains the No. 1 bearing. The No. 1 bearing housing is supported in the inlet casing on machined surfaces on either side of the inner bellmouth of the lower half casing. To maintain axial and radial alignment with the compressor rotor shaft, the bearing housing is shimmed, doweled and bolted in place at assembly. The inner bellmouth is positioned to the outer bellmouth by eight airfoil shaped radial struts that provide structural integrity for the inlet casing. The struts are cast into the bellmouth walls.

Variable inlet guide vanes are located at the aft end of the inlet casing. The position of these vanes affects the quantity of compressor air flow. Movement of these guide vanes is accomplished by the inlet guide vane control ring that turns individual pinion gears attached to the end of each vane. The control ring is positioned by a hydraulic actuator and linkage arm assembly.

3. Forward Casing

The forward compressor casing contains the first four compressor stator stages. It also transfers the structural loads from the adjoining casing to the forward support which is bolted and doweled to this compressor casing's forward flange. The forward compressor casing is equipped with two large internally cast trunnions which are used to lift the gas turbine when it is separated from its base.

4. Aft Casing

The aft compressor casing contains the 5th through 10th compressor stages. Extraction ports in the casing permit removal of 5th and 11th stage compressor air. This air is used for cooling and sealing functions and is also used for starting and shutdown pulsation control.

5. Discharge Casing

The compressor discharge casing is the final portion of the compressor section. It is the longest single casting. It is situated at the midpoint between the forward and aft supports and is, in effect, the keystone of the gas turbine structure. The functions of the compressor discharge casings are to contain the final seven compressor stages, to form both the inner and outer walls of the compressor diffuser and to join the compressor and turbine stators. They also provide support for the No. 2 bearing, the forward end of the combustion wrapper and the inner support of the first stage turbine nozzle.

The compressor discharge casing (figure 4) consists of two cylinders, one being a continuation of the compressor casings and the other an inner cylinder that surrounds the compressor rotor. The two cylinders are concentrically positioned by twelve radial struts. These struts flair out to meet the larger diameter of the turbine shell and are the primary load bearing members in this portion of the gas turbine stator.



The supporting structure for the No. 2 bearing is contained within the inner cylinder. A diffuser is formed by the tapered annulus between the outer cylinder and inner cylinder of the discharge casing. The diffuser converts some of the compressor exit velocity into added pressure.

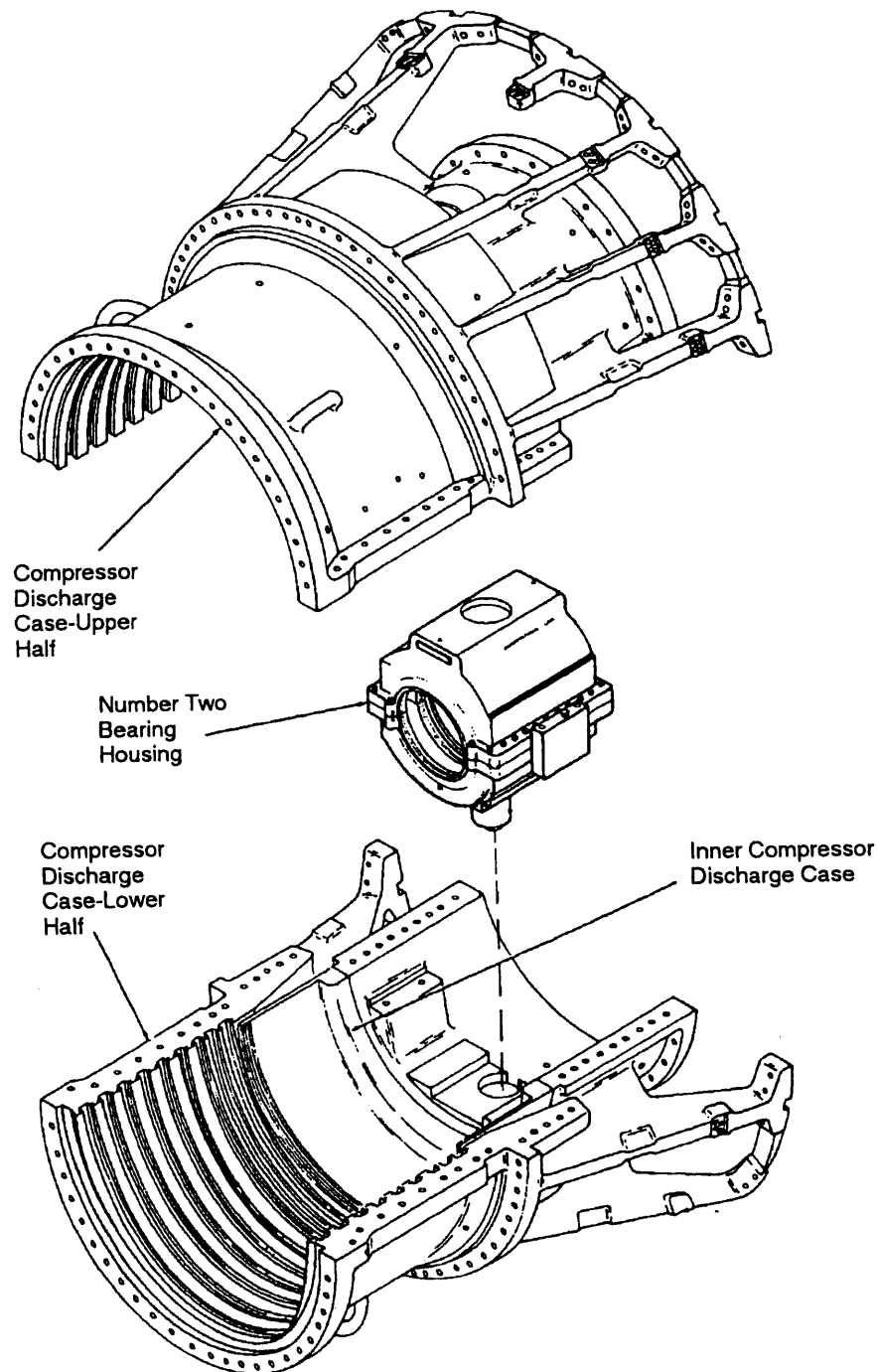


Figure 4 **Compressor Discharge Casing Assembly**



6. Blading

The compressor rotor and stator blades are airfoil shaped and designed to compress air efficiently at high blade tip velocities. The blades are attached to their wheels by dovetail arrangements. The dovetail is very precise in size and position to maintain each blade in the desired position and location on the wheel.

The compressor stator blades are airfoil shaped and are mounted by similar dovetails into ring segments. The ring segments are inserted into circumferential grooves in the casing and are held in place with locking keys. The stator blades of the last nine stages and two exit guide vanes have a square base dovetail that are inserted directly into circumferential grooves in the casing. Locking keys also hold them in place.

IV. COMBUSTION SYSTEM

a. General

The combustion system is a reverse flow type with 14 combustion chambers arranged around the periphery of the compressor discharge casing (figure 5). This system also includes fuel nozzles, spark plug ignition system, flame detectors and crossfire tubes. Hot gases, generated from burning fuel in the combustion chambers, are used to drive the turbine.

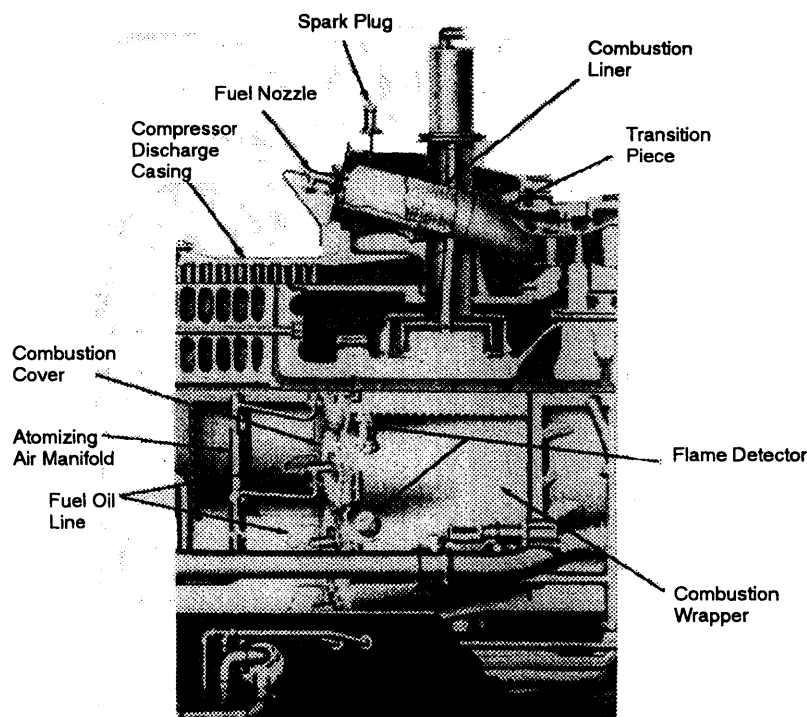


Figure 5 Combustion System Arrangement



High pressure air from the compressor discharge is directed around the transition pieces and into the combustion chamber liners. This air enters the combustion zone through both metering holes (for proper fuel combustion) and through slots (to cool the combustion liner). Fuel is supplied to each combustion chamber through a nozzle designed to disperse and mix the fuel with the proper amount of combustion air.

Orientation of the combustion chambers around the periphery of the compressor is shown on figure 6. Combustion chambers are numbered counter clockwise when viewed looking downstream and starting from the top of the machine. Spark plugs and flame detector locations are also shown.

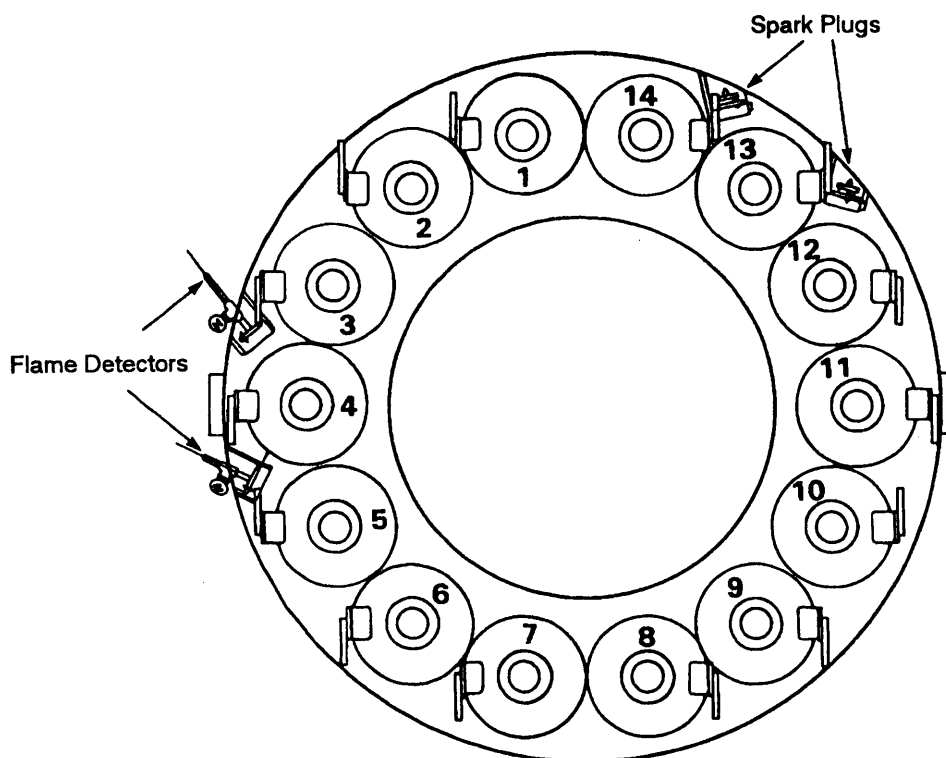


Figure 6 Combustion Chamber Arrangement

b. Combustion Wrapper

The combustion wrapper is a fabricated casing that encloses the combustion area. It provides a supporting surface for the combustion chamber assemblies. A plenum is formed by the combustion wrapper in which the compressor discharge air flow is directed to the combustion chambers. The forward face of the combustion wrapper is slanted at a 13° angle from the vertical and contains the machined openings for mounting the 14 covers of the combustion chamber assemblies (see figure 9 and 10). Support plates for mounting the spark plugs and flame detectors are recessed in wells in the outer wall of the wrapper. The wrapper is supported by the compressor discharge casing and the turbine shell.



c. Combustion Chambers

Discharge air from the axial flow compressor flows into each combustion flow sleeve from the combustion wrapper (figure 7). The air flows upstream along the outside of the combustion liner toward the liner cap. This air enters the combustion chamber reaction zone through the fuel nozzle swirl tip, the metering holes in both the cap and liner and combustion holes in the forward half of the liner.

The hot combustion gases from the reaction zone pass through a thermal soaking zone and then into a dilution zone where additional air is mixed with the combustion gases. Metering holes in the dilution zone allow the correct amount of air to enter and cool the gases to the desired temperature. Along the length of the combustion liner and in the liner cap are openings whose function is to provide a film of air for cooling the walls of the liner and cap. Transition pieces direct the hot gases from the liners to the turbine nozzles. All combustion liners, flow sleeves and transition pieces are identical.

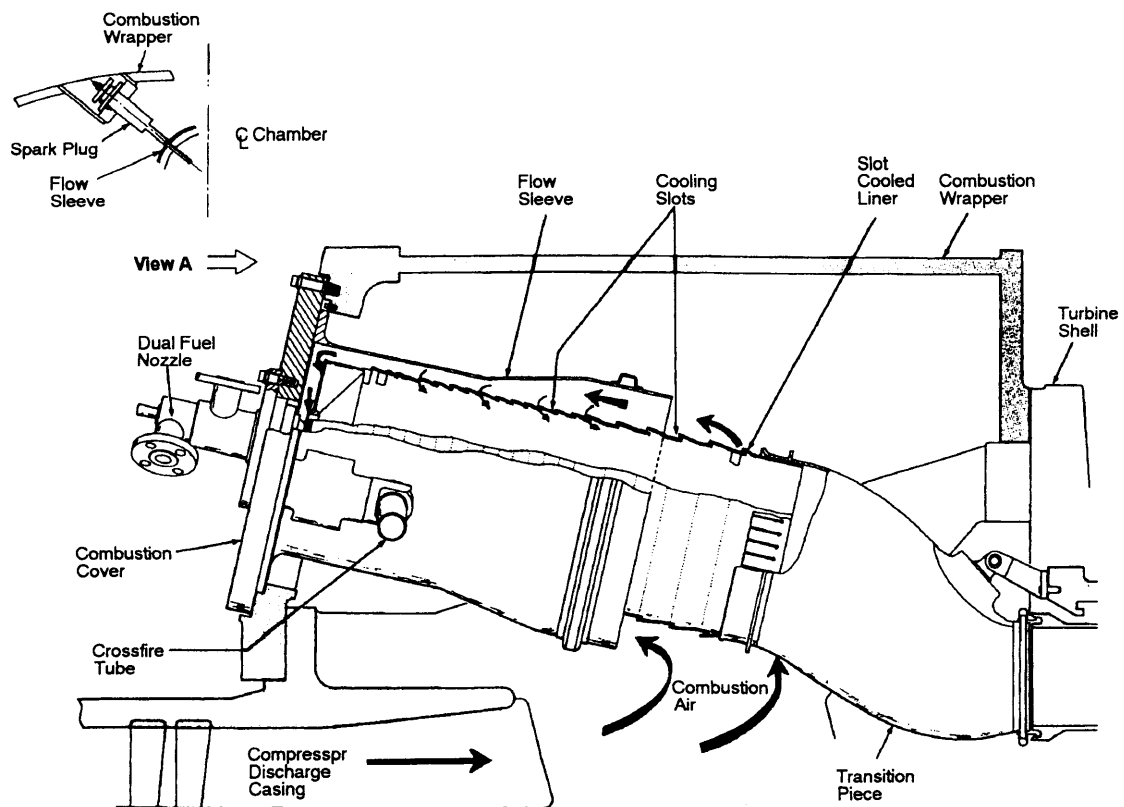


Figure 7 Combustion Chamber Details

d. Spark Plugs

Combustion is initiated by means of the discharge from two high voltage retractable electrode spark plugs installed in adjacent combustion chambers. These spring injected,



pressure retracted plugs receive their energy from ignition transformers. At firing, a spark at one or both of these plugs ignites the fuel in a chamber, the remaining chambers are ignited by crossfire through the tubes that interconnect the reaction zone of the remaining chambers. As rotor speed increases, chamber pressure causes the spark plugs to retract and the electrodes are removed from the combustion zone.

e. Ultraviolet Flame Detectors

During the starting sequence it is essential that an indication of the presence or absence of flame be transmitted to the control system. For this reason, a flame monitoring system is used consisting of sensors which are installed on adjacent combustion chambers and an electronic amplifier mounted in the turbine control panel.

The ultraviolet flame sensor contains a gas filled detector. The gas within this detector is sensitive to the presence of ultraviolet radiation emitted by a hydrocarbon flame. A dc voltage, supplied by the amplifier, is impressed across the detector terminals. If flame is present the ionization of the gas in the detector allows conduction in the circuit which gives an output defining "flame". Conversely, the absence of flame will generate an opposite output defining "no flame".

After the establishment of flame, if voltage is re-established to both sensors defining the loss (or lack) of flame a signal is sent to a relay panel in the turbine control circuitry where auxiliary relays in the turbine firing trip circuit, starting means circuit, etc. shut down the turbine. "FAILURE TO FIRE" or "LOSS OF FLAME" is also indicated on the annunciator. If a loss of flame is sensed by only one flame detector sensor the control circuitry will cause an annunciation of only this condition.

f. Fuel Nozzles

Each combustion chamber is equipped with a fuel nozzle that emits a metered amount of fuel into the combustion liner. Gaseous fuel is admitted directly into each chamber through metering holes located in the outer wall of the gas swirl tip. When liquid fuel is used, it is atomized in the nozzle swirl chamber by means of high pressure air. The atomized fuel/air mixture is then sprayed into the combustion zone. Action of the tip imparts a swirl to the combustion air with the result of more complete combustion and essentially smoke free operation of the unit. See figure 8 for fuel nozzle details.

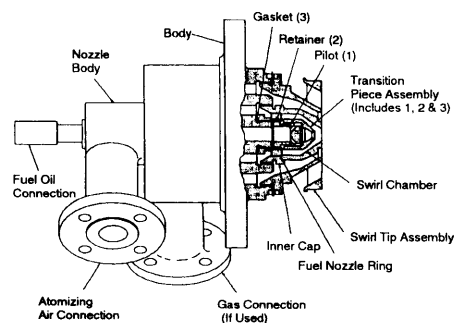


Figure 8 Fuel Nozzle Assembly (Dual Fuel, Air Atomised)



g. Crossfire Tubes

All fourteen combustion chambers are interconnected by means of crossfire tubes. These tubes allow flame from the fired chambers to propagate to the unfired chambers.

V. TURBINE SECTION

a. General

The three stage turbine section is the area where energy, in the form of high temperature pressurized gas produced by the compressor and combustion sections, is converted to mechanical energy.

MS9001E gas turbine hardware includes the turbine rotor, turbine casing, exhaust frame, exhaust diffuser, nozzles and shrouds.

b. Turbine Rotor

1. Structure

The turbine rotor assembly consists of two wheel shafts; the first, second, and third stage turbine wheels with buckets, and two turbine spacers. Concentricity control is achieved with mating rabbets on the turbine wheels, wheel shafts, and spacers. The wheels are held together with through bolts. Selective positioning of rotor members is performed to minimize balance corrections.

The forward wheel shaft extends from the first stage turbine wheel to the aft flange of the compressor rotor assembly. The journal for the No. 2 bearing is a part of the wheel shaft.

The aft wheel shaft connects the third stage turbine wheel to the load coupling. It includes the No. 3 bearing journal.

Spacers between the first and second, and between the second and third stage turbine wheels determine the axial position of the individual wheels. These spacers carry the diaphragm sealing lands. The forward faces of the spacer include radial slots for cooling air passages. The first and second stage spacer also has radial slots for cooling air passages on the aft face.

2. Buckets

The turbine buckets increase in size from the first to the third stage. Because of the pressure reduction resulting from energy conversion in each stage an increased annulus area is required to accommodate the gas flow; thus necessitating increasing the size of the buckets. The first stage buckets are the first rotating surfaces encountered by the extremely hot gases



leaving the first stage nozzle. Each first stage bucket contains a series of longitudinal air passages for bucket cooling. Air is introduced into each first stage bucket through a plenum at the base of the bucket dovetail. It flows through cooling holes extending the length of the bucket and exits at the recessed bucket tip. The holes are spaced and sized to obtain optimum cooling of the airfoil with minimum compressor extraction air.

Like the first stage buckets, the second stage buckets are cooled by span-wise air passages running the length of the airfoil. Since the lower temperatures surrounding the bucket shanks do not require shank cooling the second stage cooling holes are fed by a plenum cast into the bucket shank. Span-wise holes provide cooling air to the airfoil at a higher pressure than shank holes. This increases the cooling effectiveness in the airfoil with minimum penalty to the thermodynamic cycle.

The third stage buckets are not internally air cooled; the tips of these buckets, like the second stage buckets, are enclosed by a shroud which is a part of the tip seal. These shrouds interlock from bucket to bucket to provide vibration damping.

Turbine buckets for each stage are attached to their wheels by straight, axial entry, multiple tang dovetails that fit into matching cutouts in the turbine wheel rims. Bucket vanes are connected to their dovetails by means of shanks. These shanks locate the bucket to wheel attachment at a significant distance from the hot gases, reducing the temperature at the dovetail. The turbine rotor assembly is arranged so that the buckets can be replaced without unstacking the wheels, spacers and wheel shaft assemblies.

3. Cooling

The turbine rotor must be cooled to maintain reasonable operating temperatures and therefore assure a longer turbine service life. Cooling is accomplished by a positive flow of cool air radially outward through a space between the turbine wheel with buckets and the stator into the main gas stream. This area is called the wheel-space.

4. First Stage Wheelspaces

The first stage forward wheel-space is cooled by compressor discharge air. High pressure packing is installed at the aft end of the compressor rotor between the rotor and the inner barrel of the compressor discharge casing. Part of the leakage through this labyrinth furnishes the air flow through the first stage forward wheel-space. This cooling air flow discharges into the main as stream aft of the first stage nozzle.

In addition, a small amount of air is supplied by a single hole at the forward end of the inner barrel. This air provides adequate cooling during all transient operation conditions.

The first stage aft wheel-space is cooled by compressor discharge air supplied through the second stage nozzle. Some of this first stage aft wheel-space cooling air flows through the second stage inner seal while the remainder returns to the gas path forward of the second stage nozzle.



5. Second Stage Wheelspaces

The second stage forward wheelspace is cooled by leakage from the first stage aft wheelspace through the interstage labyrinth. This air returns to the gas path at the entrance of the second stage buckets.

The second stage aft wheelspace is cooled by air from the internal extraction system. This air enters the wheelspace through slots in the forward face of the spacer. Some of this second stage aft cooling airflows through the third stage inner seal while the remainder returns to the gas path at the third stage nozzle entrance.

6. Third Stage Wheelspaces

The third stage forward wheelspace is cooled by leakage from the second stage aft wheelspace through the interstage labyrinth. This air re-enters the gas path at the third stage bucket entrance.

The third stage aft wheelspace obtains its cooling air from the exhaust frame cooling system. This air enters the wheelspace at the rear of the third stage turbine wheel and then flows into the gas path at the entrance to the exhaust diffuser.

c. Turbine Stator

1. Structure

The turbine shell and the exhaust frame constitute the major portion of the MS9001E gas turbine stator structure. The turbine nozzles, shrouds, No. 3 bearing and turbine exhaust diffuser are internally supported from these components.

2. Turbine Casing (Shell)

The turbine shell controls the axial and radial positions of the shrouds and nozzles. It determines turbine clearances and the relative positions of the nozzles to the turbine buckets. This positioning is critical to as turbine performance. See figure 9 for positions of these components.

Hot gases contained by the turbine shell are a source of heat flow into the shell. To control the shell diameter it is important that the shell design reduces the heat flow into the shell and limits its temperature. Heat flow limitations incorporate insulation, cooling and multi layered structures. The external surface of the shell incorporates cooling air passages. Flow through these passages is generated by an off base cooling fan.

Structurally, the shell forward flange is bolted to flanges at the aft end of the compressor discharge casing and combustion wrapper. The shell aft flange is bolted to the forward flange of the exhaust frame. Trunnions cast onto the sides of the shell are used with similar



trunnions on the forward compressor casing to lift the gas turbine when it is separated from its base.

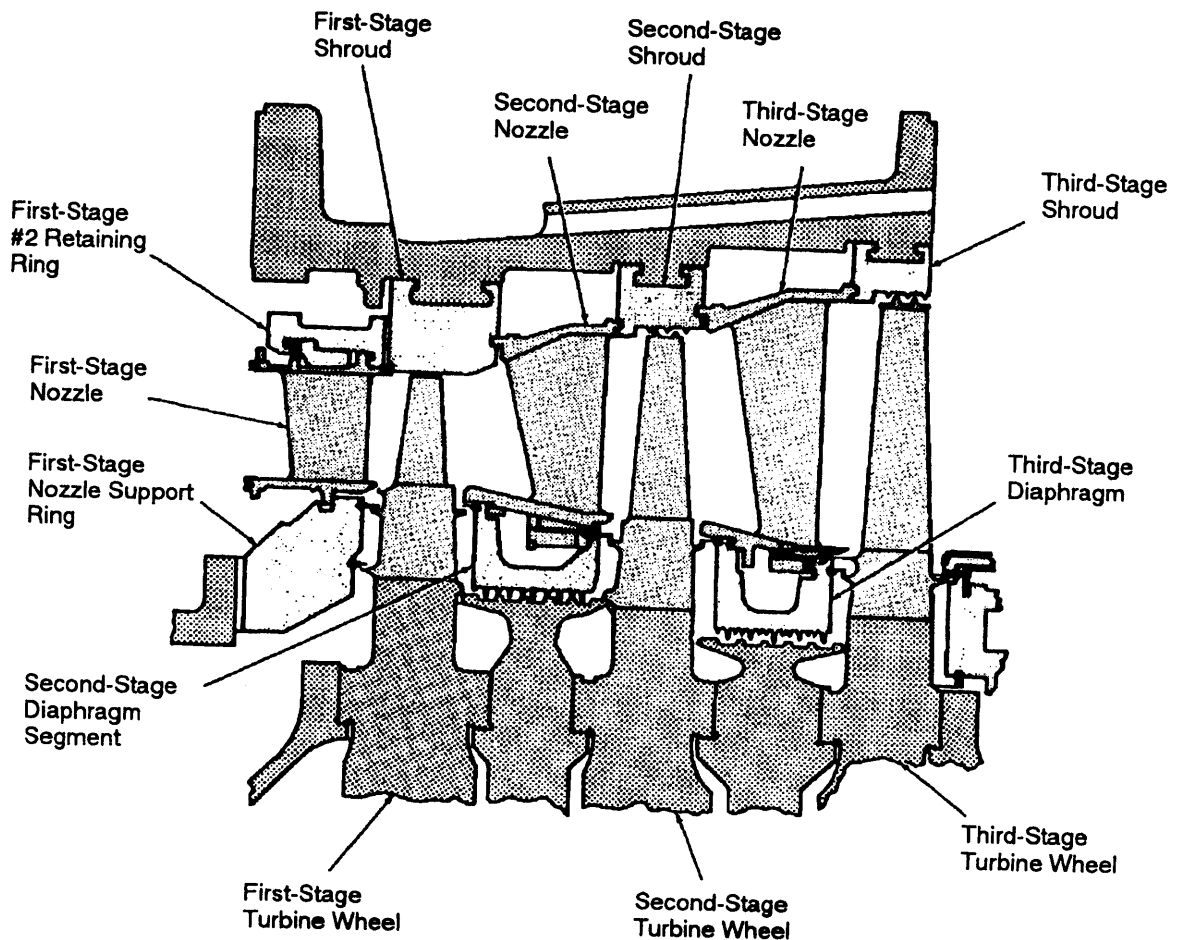


Figure 9 Turbine Section

3. Nozzles

In the turbine section there are three stages of stationary nozzles (figure 9) which direct the high velocity flow of the expanded hot combustion gas against the turbine buckets causing the turbine rotor to rotate. Because of the high pressure drop across these nozzles there are seals at both the inside and outside diameters to prevent loss of system energy by leakage. Since these nozzles operate in the hot combustion gas flow they are subjected to thermal stresses in addition to gas pressure loadings.



4. First Stage Nozzles

The first stage nozzle receives the hot combustion gases from the combustion system via the transition pieces. The transition pieces are sealed to both the outer and inner sidewalls on the entrance side of the nozzle. This minimizes leakage of compressor discharge air into the nozzles. The 18 cast nozzle segments, each with two partitions, or airfoils, are contained by a horizontally split retaining ring which is centerline supported to the turbine shell on lugs at the sides and guided by pins at the top and bottom vertical centerlines. This permits radial growth of the retaining ring resulting from changes in temperature while the ring remains centred in the shell.

The aft outer diameter of the retaining ring is loaded against the forward face of the first stage turbine shroud and acts as the air seal to prevent leakage of compressor discharge air between the nozzle and shell.

On the inner sidewall the nozzle is sealed by direct bearing of the nozzle inner load rail against the first stage nozzle support ring bolted to the compressor discharge casing.

The nozzle is prevented from moving forward by the lugs welded to the aft outside diameter of the retaining ring at 45° from vertical and horizontal centerlines. These lugs fit in a groove machined in the turbine shell just forward of the first stage shroud T-hook. By moving the horizontal joint support block and the bottom centerline guide pin the lower half of the nozzle can be rolled out with the turbine rotor in place.

5. Second Stage Nozzle

Combustion air exiting from the first stage buckets is again expanded and redirected against the second stage turbine buckets by the second stage nozzle. This nozzle is made of 16 cast segments, each with three partitions, or airfoils. The male hooks on the entrance and exit sides of the outer sidewall fit into female grooves on the aft side of the first stage shrouds and on the forward side of the second stage shroud to maintain the nozzle concentric with the turbine shell and rotor. This close tongue and groove fit between nozzle and shrouds acts as an outside diameter air seal. The nozzle segments are held in a circumferential position by radial pins from the shell into axial slots in the nozzle outer sidewall.

The second stage nozzle is cooled by compressor discharge air.

6. Third Stage Nozzles

The third stage nozzle receives the hot gas as it leaves the second stage buckets, increases its velocity by pressure drop, and directs this flow against the third stage buckets. The nozzle consists of 16 cast segments, each with four partitions or airfoils. It is held at the outer sidewall forward and aft sides in grooves in the turbine shrouds in a manner identical to that used on the second stage nozzle. The third stage nozzle is circumferentially positioned by radial pins from the shell.



7. Diaphragms

Attached to the inside diameters of both the second and third stage nozzle segments are the nozzle diaphragms. These prevent air leakage past the inner sidewall of the nozzles and the turbine rotor. High/low labyrinth seal teeth are machined into the inside diameter of the diaphragm. They mate with opposing sealing lands on the turbine rotor. Minimal radial clearance between stationary parts (diaphragm and nozzles) and the moving rotor are essential for maintaining low interstage leakage. This results in higher turbine efficiency.

8. Shrouds

Unlike the compressor blading, the turbine bucket tips do not run directly against an integral machined surface of the casing but against annular curved segments called turbine shrouds. The shrouds' primary function is to provide a cylindrical surface for minimizing bucket tip clearance leakage.

The turbine shrouds' secondary function is to provide a high thermal resistance between the hot gases and the comparatively cool shell. In doing this shell cooling load is drastically reduced, the shell diameter is controlled, the shell roundness is maintained and important turbine clearances are assured.

The shroud segments are maintained in the circumferential position by radial pins from the shell. Joints between shroud segments are sealed by interconnecting tongues and grooves.

9. Exhaust Frame Assembly

The exhaust frame assembly (figure 10) consists of the exhaust frame and the exhaust diffuser. The exhaust frame is bolted to the aft flange of the turbine shell. Structurally, the frame consists of an outer cylinder and inner cylinder interconnected by ten radial struts. On the inner gas path surfaces of the two cylinders are attached the inner and outer diffusers. The No. 3 bearing is supported from the inner cylinder.

The exhaust diffuser, located at the extreme aft end of the as turbine, bolts to, and is supported by, the exhaust frame. The exhaust diffuser is a fabricated assembly consisting of an inner cylinder and an outer divergent cylinder that flairs at the exit end at a right angle to the turbine centerline. At the exit end of the diffuser, between the two cylinders, are five turning vanes mounted at the bend. Gases exhausted from the third turbine stage enter the diffuser where velocity is reduced by diffusion and pressure is recovered. At the exit of the diffuser turning vanes direct the gases into the exhaust plenum.

Exhaust frame radial struts cross the exhaust gas stream. These struts position the inner cylinder and No. 3 bearing in relation to the outer casing of the gas turbine. The struts must be maintained at a uniform temperature to control the centre position of the rotor in relation to the stator. This temperature stabilization is accomplished by protecting the struts from exhaust gases with a metal fairing fabricated into the diffuser and then forcing cooling air into this space around the struts.



Turbine shell cooling air enters the space between the exhaust frame and the diffuser and flows in two directions, into the turbine shell cooling annulus and also down through the space between the struts and the airfoil fairings surrounding the struts and subsequently into the load shaft tunnel and turbine third stage aft wheelspace.

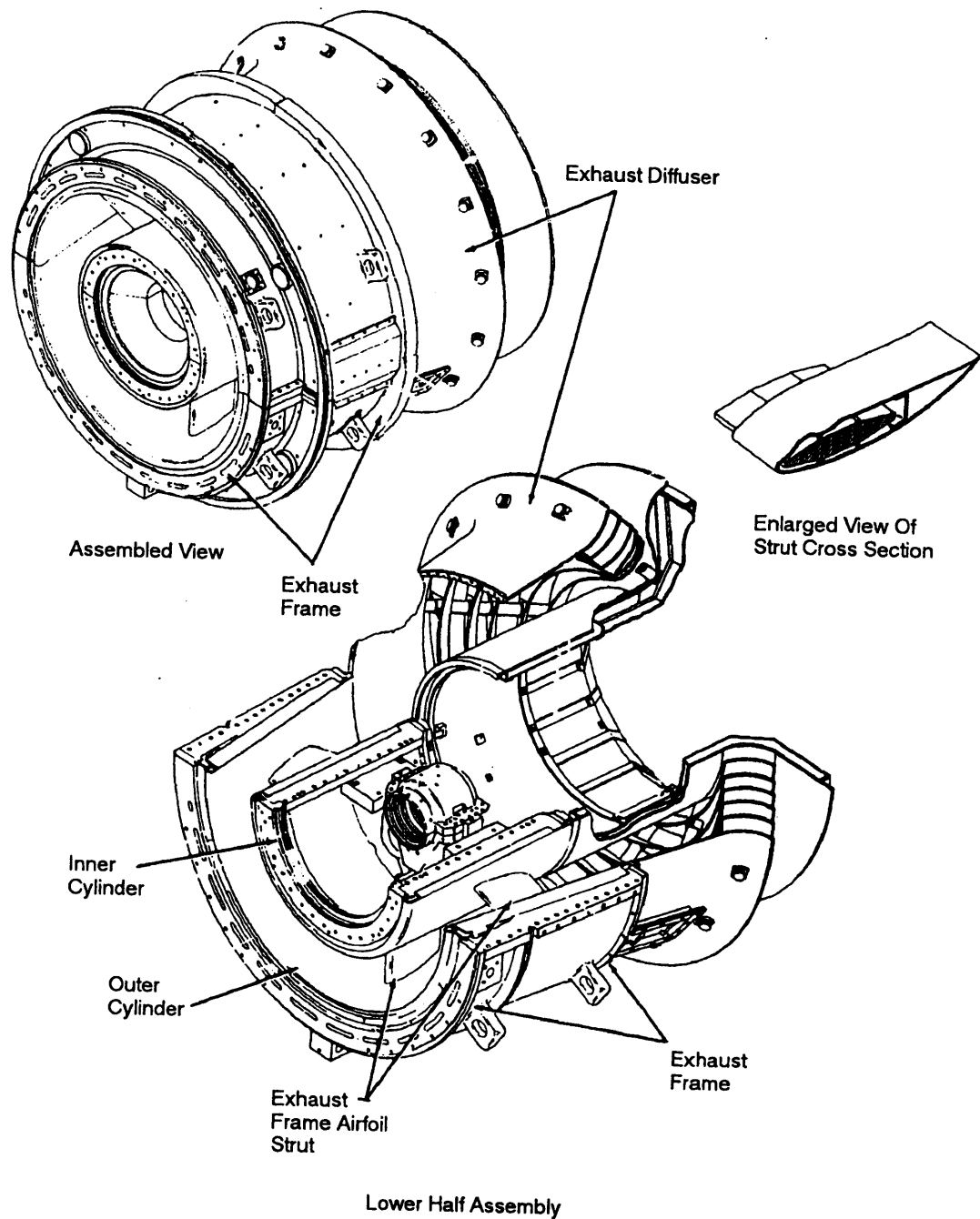


Figure 10 **Exhaust Frame Assembly**



VI. BEARINGS

a. General

The MS9001E gas turbine unit contains three main journal bearings used to support the gas turbine rotor. The unit also includes thrust bearings to maintain the rotor to stator axial position and support the thrust loads developed on the rotor. These bearings and seals are incorporated in three housings: one at the inlet casing, one in the discharge casing, and one in the exhaust frame. These bearings are pressure lubricated by oil supplied from the main lubricating oil system. The oil flows through branch lines to an inlet in each bearing housing.

The bearings used in this gas turbine are classified as follows:-

1	Loaded Thrust	Tilting Pad Thrust Equalizing
	Unloaded Thrust	Tilting Pad Non Thrust Equalizing
1	Journal	Elliptical
2	Journal	Elliptical
3	Journal	Tilting Pad

b. Elliptical Journal Bearings

1. General

Elliptical bearings are the predominant type of journal bearings used in gas turbines. These are characterized by their non cylindrical bores and are designed to improve the stability of the shafts at high speeds.

In the design of these bearings convergent clearance regions exist even at a concentric shaft position. The convergence increases with an increase in shaft eccentricity. This convergency creates high pressure regions which in effect puts an additional load on the bearing; a factor which tends to improve the shaft stability. The extra clearance space, as compared with a cylindrical bearing of a diameter equal to the inscribed circle in these bearings, increases the oil flow and also often reduces power losses resulting in lower temperature rises in the bearing.

2. Description

The elliptical bearing is made up of two cylindrical halves brought together so that their centres are displaced several millimetres from the bearing centre. It is manufactured by placing shims at the horizontal split and then machining a cylindrical bore. The shims are then removed and the two halves are brought together to form the elliptical bearing.



c. Tilting Pad Journal Bearings

1. General

In those gas turbine applications where a shaft may exhibit susceptibility to whirl or misalignment, tilting pad bearings are frequently employed. These bearings are distinguished by their movable segments or pads, which give them very stable dynamic properties.

Tilting pad bearings operate in the hydrodynamic mode just like elliptical types which are more commonly employed in gas turbines. The pads are assembled creating converging passages between each pad and the journal surface. These converging passages generate a high pressure oil film beneath each pad which produces a symmetric loading or "clamping" effect on the journal. This is a stabilizing influence which is very effective in resisting shaft whirl particularly in bearings that are lightly loaded and operating at high speed. Because the pads are point pivoted, they are free to move in two dimensions which makes them capable of tolerating both offset and angular shaft misalignment. Another very desirable characteristic of this bearing is its ability to run cool when supporting heavy loads, due to the relatively short arc length of the individual pads.

2. Description

A tilting pad journal bearing is comprised of pads and a retainer ring. The pads are made from a cylindrical steel shell which is babbitted, cut into sectors, and then finish bored. In their final assembled configuration the pads are displaced inward toward the bearing centre to produce converging clearances when assembled around the bearing journal. The inscribed clearance circle formed by the pads is located high relative to the outside diameter of the retaining ring. This allows the rotor to run concentric with respect to the stator under full speed operating conditions. In most designs the pad pivots are offset toward the trailing edges of the pads. This is done deliberately to improve the hydrodynamic operation of the bearing.

The retainer ring serves to locate and support the pads. It is a horizontally split member which contains the pad support pins, adjusting shims, oil feed orifices and oil discharge seals. The outside diameter of the retainer ring is carefully machined to produce a good fit when inserted into the bearing housing. The oil discharge seals have babbitted surfaces and float on the shaft. The support pins and shims transmit the loads generated at the pad surfaces and are used to set the bearing clearance. An anti rotation pin extends from one edge of the lower half of the retainer ring. This pin locates the bearing within its housing and prevents the bearing from rotating with the journal. The anti rotation pin also provides the correct installation of the bearing liner in the bearing housing which is essential. The offset of individual pads on their supporting pins makes the bearing non symmetrical with respect to shaft rotation.

Oil is fed from the lower half of the bearing housing into the annulus which surrounds the retainer ring. Orifice holes are drilled radially through the ring into the gaps that exist



between the individual pads. These orifices serve to control the flow entering the bearing. The oil is then drawn by the shaft into the gap between shaft and pads. Floating ring seals with babbitted surfaces restrict the outgoing oil flow thereby maintaining an adequate oil supply within the pad region. Excess oil drains from the liner through slots in the bottom area of the lower half of the liner.

d. Bearing Lubrication

1. General

The three gas turbine bearing housings are pressure lubricated with oil supplied from the lubricating oil reservoir and interconnected tanks and piping. Oil feed piping, where practical, is run within the lube oil reservoir drain line, or drain channels, as a protective measure. This construction is referred to as double piping. In the event of a supply line leak, oil will not be sprayed on nearby equipment, thus eliminating a potential safety hazard.

When the oil enters the housing inlet it flows into an annulus around the bearing. From the annulus the oil flows through machined holes or slots to the bearing to rotor interface.

2. Lubricant Sealing

Oil on the surface of the turbine shaft is prevented from being spun along the shaft by oil seals in each of the three bearing housings. These labyrinth seals are assembled at the extremities of the bearing assemblies where oil control is required. A smooth surface is machined on the shaft and the seals are assembled so that only a small clearance exists between the oil seal and the shaft. The oil seals are designed with tandem rows of teeth and an annular space between them. Pressurized sealing air is admitted into this space and prevents lubricating oil from spreading along the shaft. Some of this air returns with the oil to the main lubricating oil reservoir and is vented through a lube oil vent. The remainder of the air passes into adjoining turbine spaces or is vented into atmosphere.

e. Number 1 Bearing

The No. 1 bearing subassembly is located in the centre of the inlet casing assembly and contains three bearings: the active (or loaded) thrust bearing, the inactive (or unloaded) thrust bearing and the journal bearing. Additionally, it contains a "running type" ring seal, four labyrinth seals and a two part housing in which the components are installed. The components are keyed to the housing to prevent rotation. The No. 1 bearing housing is supported from the inner cylinder of the compressor inlet casing. The top of the housing is removable, being flanged and bolted to the bottom half.

The outer labyrinth seals at each end of the housing are pressurized with air extracted from the compressor fifth stage. Inboard of the pressurized labyrinth seals, are two additional labyrinth back-up seals for positive sealing of the bearing oil cavity. The "running type" ring seal at the forward end of the thrust bearing cavity contains the oil within the bearing and limits entrance of air into the cavity. The No. 1 journal bearing liner has an integral,



non contacting ring seal which contains the oil in a circumferential drain groove. The oil drains from this groove through a vertical slot into the bearing drain cavity.

f. Number 2 Bearing

The No. 2 bearing subassembly is located in the centre of the inner cylinder of the compressor discharge casing. The casing support consists of ledges at the horizontal plane and an axial key at the bottom centerline. This arrangement permits relative growth resulting from temperature differences while the bearing remains centred in the discharge casing.

The assembly includes a bearing liner, labyrinth seals and a bearing housing. This assembly is located in a pressurized space (the inner barrel) between the turbine and compressor.

The No. 2 bearing liner is prevented from rotating with the shaft by an anti rotation pin located in the lower bearing liner.

g. Number 3 Bearing

The No. 3 bearing subassembly is located at the aft end of the turbine shaft in the centre of the exhaust frame assembly. It consists of a tilting pad bearing, three labyrinth seals, two floating ring seals and a bearing housing. The individual pads are designed and assembled so that a high pressure oil film is generated between each pad and the bearing surface. This produces a symmetrical loading or "clamping" effect on the bearing surface that helps maintain shaft stability. Because the pads are free to move in two dimensions they are capable of tolerating a certain amount of shaft misalignment.

h. Thrust Bearings -Tilting Pad Equalizing and Non Equalizing Types

1. General

A thrust bearing unit is made up of a shaft member called the "thrust runner" and a stationary member called the "bearing". Thrust bearings support the thrust loads developed on the rotor surfaces of a gas turbine unit. The thrust load imposed on such a bearing is the sum of the forces that act on the rotor assembly in a direction along the rotor axis. For example, the thrust forces of an axial flow compressor, such as those used in General Electric gas turbines, are only partially compensated for by the anti-thrust forces of the turbine that drives it. The resultant thrust load will tend to move the rotor assembly in a direction opposite to that of the air flow through the compressor. During normal operation of a gas turbine unit, the thrust load of a rotor assembly is unidirectional, however, during a startup and shutdown of the unit, the direction of the thrust load will generally reverse. Thus, two thrust bearings are provided on a rotor shaft assembly in order to support the thrust loads imposed in either direction. The bearing which takes the thrust load during normal operation is called the "active" or "loaded" thrust bearing. That which takes the thrust load during start up or shut down of the unit is called the "inactive" or "unloaded" thrust bearing.



Tilting pad, equalizing type thrust bearings are commonly employed as "loaded" thrust bearings in General Electric gas turbines. This type of bearing will sustain high loads and is tolerant of shaft and housing misalignment.

Tilting pad, non equalizing type thrust bearings are used for the "inactive" or "unloaded" application. This type of bearing is capable of carrying high thrust loads but is less tolerant of misalignment than the tilting pad, equalizing type.

2. Description

The principal parts of the tilting pad equalizing thrust bearing include the stationary pivoted segments or "pads", two rows of hardened steel equalizing levers called "levelling plates" and the supporting member called the "base ring".

The tilting pad, non equalizing types of thrust bearing is similar to the equalizing types, except for the "levelling plates" which are not a part of the design.

The pads and the levelling plates are assembled in the base ring. The complete assembly is supported in a bearing housing which is secured to the main turbine structure. The thrust bearings are keyed in place to prevent rotation.

The bearing pad is shaped like the sector of a ring. Its bearing surface is faced with babbitt and each pad has a hardened steel button, called a "pad support", set into its back which allows the pad to tilt slightly in any direction on its levelling plate.

The levelling plates are in effect short levers with centre fulcrums. Their function is to align the bearing pads with the thrust runner and equalize the load among the pads despite possible slight misalignment of the shaft axis from the normal, a condition that might result from small deflections in the turbine structure during operation.

The levelling plates are located in the base ring by dowels or screws such that the plates are free to tilt on their fulcrums. The load transmitted by the thrust runner to any one pad causes that pad to press against the upper levelling plate immediately behind it. Each levelling plate, in turn, is supported upon one edge of each of the two adjacent lower levelling plates, the other edges of which take part in supporting the next upper levelling plates on either side. As a result of this arrangement, any incipient excess of thrust on one pad is shared through the interaction of the levelling plates by the adjacent pads. This interaction and load sharing is distributed all around the circle so that all the pads receive equal loading.

The tilting pad, non equalizing type thrust bearing does not contain levelling plates and, as a result, is thinner in the axial dimension.

The base ring provides support for all the parts of the bearing assembly and keeps the parts in their proper location. In some bearing applications, the base ring is specially designed to



contain the oil flow around the pads and thrust runner to prevent flooding of adjacent compartments. Such a base ring incorporates a tooth which surrounds the thrust runner on the shaft to contain the oil flow within the bearing. A thrust bearing with this type of base ring would be installed in a bearing housing which would incorporate the necessary oil baffles or other devices to allow proper oil flow around the bearing and prevent excessive leakage along the shaft where such leakage would be objectionable.

Oil control plates are used on some tilting pad thrust bearings to direct the flow of lubricating oil to the pads and prevent excessive leakage of oil outward away from the pads.

The oil control plates are bronze segments which are placed between the pads and attached at both ends to the base ring.

The tilting pad thrust bearing is classified as a hydrodynamically lubricated bearing which means that the bearing surfaces are separated from the thrust runner by a thin film of lubricating oil which is formed and maintained by the relative motion of the bearing surfaces. This oil film supports the thrust load and prevents metal to metal contact of the bearing surfaces. In addition to acting as a load supporting medium, the oil also carries away the heat generated by the shearing action in the oil film.

The pads of a tilting pad thrust bearing are free to assume the position which will provide for the optimum wedge shaped oil film required by different combination of load, speed, oil viscosity and temperature to which the bearing is subjected.

The tilting pad thrust bearing is lubricated by oil which is admitted under pressure through ports in the bearing housing to an annulus behind the base ring. The lube oil then flows through ports in the base ring to the thrust bearing cavity where it is picked up by the rotating thrust runner and carried around the entire bearing surface. Oil circulation through the tilting pad thrust bearing is assisted by the natural pumping action of the rotating thrust collar.

Oil leaves the bearing at the outer periphery of the pads and thrust collar where it is gathered in a large annular cavity and drained. The drain annulus and exit ports are cast or machined into the bearing housing.

VII. GEAR ASSEMBLIES

a. General

Gear assemblies are used to increase, or decrease, shaft rpm as required by driven equipment such as load and accessories.



b. Accessory Drive

The accessory drive gear, located at the compressor end of the gas turbine, is a gearing assembly coupled directly through a flexible coupling to the turbine rotor. Its function is to drive each gas turbine accessory at its proper speed and to connect the turbine to its starting device. In addition, it contains the system main lube oil pump and the turbine overspeed bolt and trip mechanism.

Contained within the gear casing there are the gear trains which provide the proper gear reductions to drive the accessory devices at the required speed with the correct torque values.

Accessories driven by the gear may include the main lube oil pump, the main hydraulic supply pump, the liquid fuel pump, the water pump and the main atomizing air compressor. Lubrication of the gear is from the turbine's pressurized bearing header supply.

A turbine overspeed trip, capable of mechanically dumping the oil in the trip circuits, is mounted on the exterior casing of the gear. This device can shut the turbine down when the speed exceeds the design speed. The overspeed bolt which actuates the trip upon overspeed is installed in the main shaft.

1. Description

For ease of maintenance and inspection, the gear casing is split at the horizontal plane into an upper and lower section. Interconnected shafts are arranged in a parallel axis in the lower casing. Three of the shafts are located on the same horizontal plane as the casing joint.

The gear consists of four parallel axis, interconnected shafts arranged in a casing which provides mounting pads for the various driven accessories. With the exception of the lube oil pump and hydraulic supply pump shaft all the shaft centre lines are located on the horizontal joint of the accessory drive casing.

The gear casing is made of cast iron and split at the horizontal joint to facilitate assembly. The lower half casing has a closed bottom with openings for lube oil pump suction and discharge lines and casing drain line.

All of the shafts are connected together by single helical gears which are shrunk to the shafts after the teeth are cut. It is possible, in some instances, to remove individual gears which may have been damaged in service and to replace them with new gears. This operation, however, should be performed at the factory so that the required precision may be maintained.

All of the shafts located on the horizontal joint are contained in babbitt lined, steel-backed journal bearings with integral thrust faces which are split on the horizontal joint of the casing. The thrust faces of the bearings maintain the shafts in their proper axial location. The necessary thrust clearance is preset at the factory. The shaft which is not on the



horizontal joint are contained in babbitt lined, steel backed, non split bushings with integral thrust faces. Their thrust clearance is preset at the factory.

The main lubricating oil pump is located on the inboard wall of the lower-half casing of the accessory drive gear.



GAS TURBINE FUNDAMENTALS

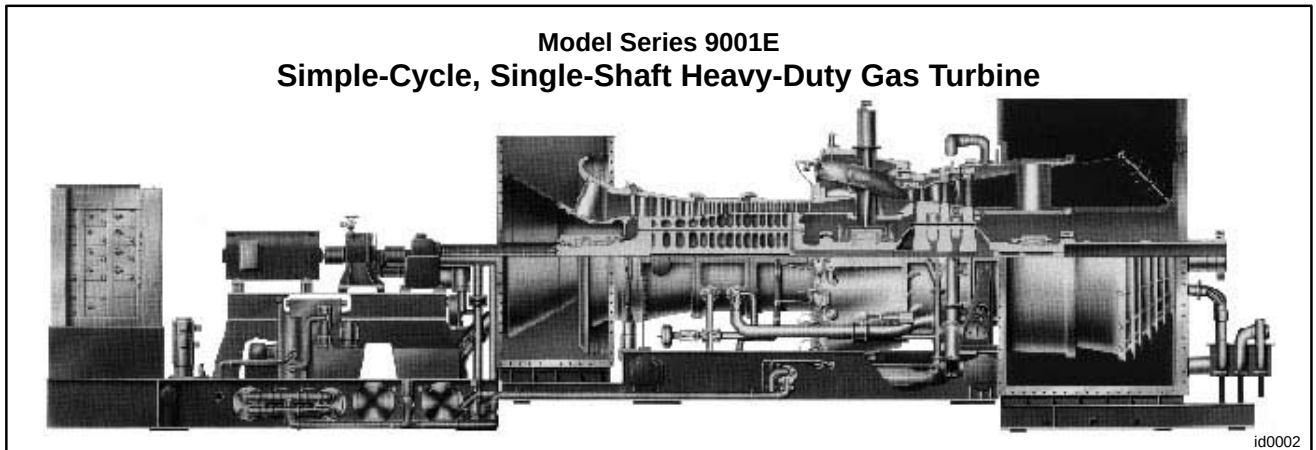


Figure 1

GENERAL

Figure 1 depicts a General Electric simple-cycle single-shaft, heavy-duty gas turbine. It is an internal combustion engine which produces energy through a cycle similar to the Otto or Diesel cycles in that the three cycles consist of the same four stages: compression, combustion, expansion, and exhaust. There are, however, differences in the details of the three cycles which are worth examining.

The Otto Cycle

In the Otto Cycle, Figure 2, the compression stroke (from 1 to 2) is followed by combustion of constant volume (2 to 3) resulting in increased pressure. The pressure causes expansion (3 to 4) with exhaust taking place between points 4 and 1.

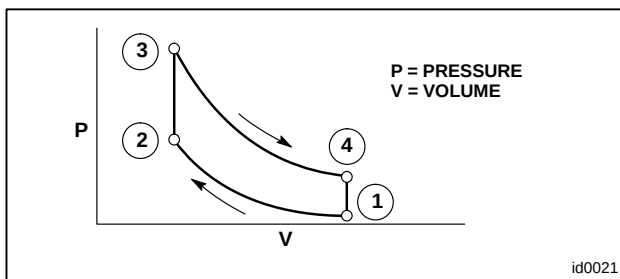


Figure 2 Otto Cycle

The Diesel Cycle

The Diesel Cycle, Figure 3, is similar, except that combustion takes place at a constant pressure (2–3). This is accomplished by injecting fuel at a rate sufficient to compensate for the volume change. Expansion and exhaust then take place as it does in the Otto Cycle.

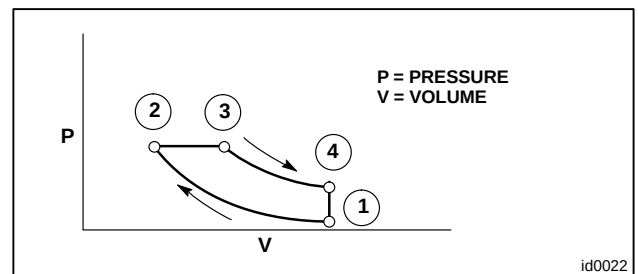


Figure 3 Diesel Cycle

The Brayton Cycle

In both the Otto and Diesel cycles a loss occurs due to the pressure drop involved in the exhaust stroke. This loss is avoided by creating a cycle in which the exhaust stroke is longer than the compression stroke, thus allowing the working fluid to be expanded to atmospheric pressure. Such a cycle has been devised, and is called a Brayton Cycle (Figure 4). It is also called a Constant Pressure Cycle since combustion and exhaust both take place at constant



pressure. When the Brayton Cycle is worked out for a steady-flow process, we have the simple gas turbine cycle.

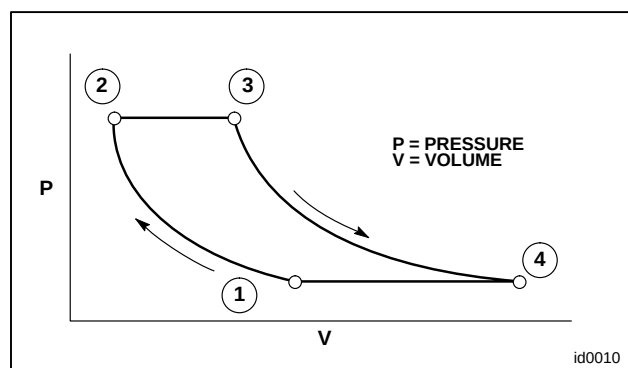


Figure 4 Brayton Cycle

In the simple gas turbine cycle, combustion and exhaust occur at constant pressure and compression and expansion occur continuously, rather than intermittently as in the Otto or Diesel cycles. This means that gas turbine power is continuously available, whereas in a reciprocating engine power takeoff is available only on the expansion stroke. Figure 5 schematically represents the hardware necessary for the cycle. The points on Figures 4 and 5 are consistent. At point 1, air enters the compressor (c). The high pressure compressor discharge air at point 2 is mixed with fuel in the burner (b). The product of this continuous combustion at point 3 enters the turbine (t), and is expanded to atmospheric pressure (point 4). The turbine provides the horsepower to drive the compressor and load (in this case, a generator).

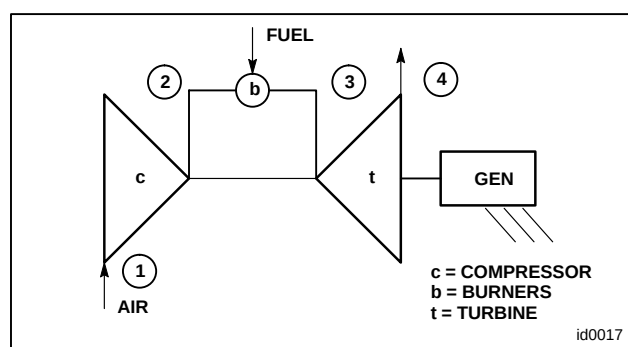


Figure 5 Fundamental Gas Turbine

GENERAL DESCRIPTION

The Model Series 9001E gas turbine is a 3000-rpm, single-shaft, simple-cycle power package that basically requires only fuel and fuel connections, generator breaker connections, and an AC-power source for turbine start-up. The MS9001E is also available in a combined-cycle configuration for applications utilizing a Heat Recovery Steam Generator or similar device.

GAS TURBINE UNIT

The gas turbine unit consists of a 17-stage axial-flow compressor and a 3-stage power turbine. Each section, compressor rotor and turbine rotor, is assembled separately and then joined together. Through-bolts connect the compressor rotor wheels to the forward and aft stubshafts. The turbine rotor also utilizes through-bolt construction with spacer wheels between the first- and second-stage and the second- and third-stage wheels.

The assembled rotor is a three-bearing design utilizing pressure-feed elliptical and tilt-pad journal bearings. The three-bearing design assures that rotor-critical speeds are above the operating speed and allows for optimum turbine bucket/turbine shell clearances.

TURBINE COMPONENTS – OVERVIEW

The major components of the gas turbine are the rotor components, primarily the axial flow compressor and the turbine wheels; the stationary components, primarily the compressor casings, turbine shell, and nozzles; and the combustion components.

Casings

The casings make up the structural backbone of the gas turbine. This structure supports the rotating ele-



ments through its bearing housings, functions as a pressure vessel to contain the turbine's working fluids of compressed air and combustion gases, and provides a surface of revolution for the blading to operate while maintaining minimum radial and axial clearance and, therefore, optimum performance.

Compressor

The function of the axial flow compressor is to furnish high pressure air to the combustion chambers for the production of the hot gases necessary to operate the turbine. Since only a portion of its output is used for combustion the compressor also serves as a source of cooling air for the turbine nozzles, turbine wheels, transition pieces, and other portions of the hot-gas path.

Air enters the inlet of the multistage compressor where it is compressed from atmospheric pressure to approximately 8.95 to 12.92 bar (130 to 185 psig), depending on frame size. This gives a Compressor Pressure Ratio of approximately 10:1 to 13.5:1,

$$C.R. = \frac{\text{Atmos Press} + \text{Compressor Disch Pressure}}{(\text{Atmospheric Pressure})}$$

again dependent on frame size. The air which continuously discharges from the compressor will occupy a smaller volume at the compressor discharge than at the inlet and, due to heating during compression, will have a temperature of 315°C to 360°C (600°F to 680°F).

Turbine

The turbine wheels are an area of primary importance because they are the point at which the kinetic energy of the hot gases is converted into useful rotational, mechanical energy by the turbine buckets. This produces the power necessary to meet the load requirements and drive the axial-flow compressor.

Nozzles

General Electric turbines are of the impulse or high-energy stage design (i.e., pressure and heat conversion in the nozzle). The high pressure drop across the nozzle imparts a high velocity (kinetic energy) to the combustion gases. This energy is directed to the buckets which use this energy to rotate the shaft, driving the axial compressor and load.

Combustion System

The overall function of the combustion system is to supply the heat energy to the gas turbine cycle. This is accomplished by burning fuel mixed with compressor discharge air. The combustion gases are then diluted with excess air to achieve the desired gas temperature at the inlet of the first-stage turbine nozzle.

The combustion system consists of a number of similar combustion chambers. Compressor discharge air is distributed to these chambers where it is bled into a cylindrical combustion liner. Fuel is injected into the forward end of the liners where it mixes with the compressor discharge air and combustion takes place, thereby creating hot gases with temperatures in excess of 1650°C (3000°F) in the flame zone. As well as being used for combustion, the relatively cool compressor discharge air acts as a blanket to protect the liners from the heat of combustion. In addition to cooling the combustion liners, compressor discharge air mixes with the combustion gases downstream of the combustion reaction zone, cooling and diluting the gases which now pass through transition pieces to the turbine first-stage nozzle. The amount of air necessary to cool the liner wall and dilute the hot gas to the temperature desired at the first-stage nozzle is about four times that required for complete combustion; this "excess air" in the turbine exhaust makes it possible to install auxiliary burners in a Heat Recovery Steam Generator if so desired.

The schematic operation of the single-shaft simple-cycle gas turbine may be seen in Figure 6.

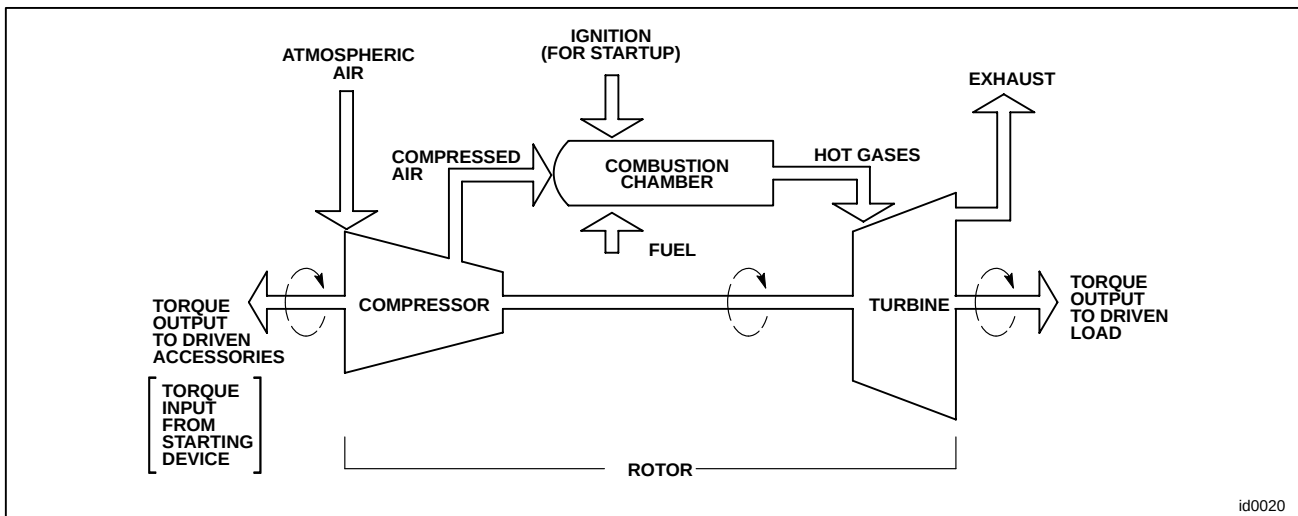
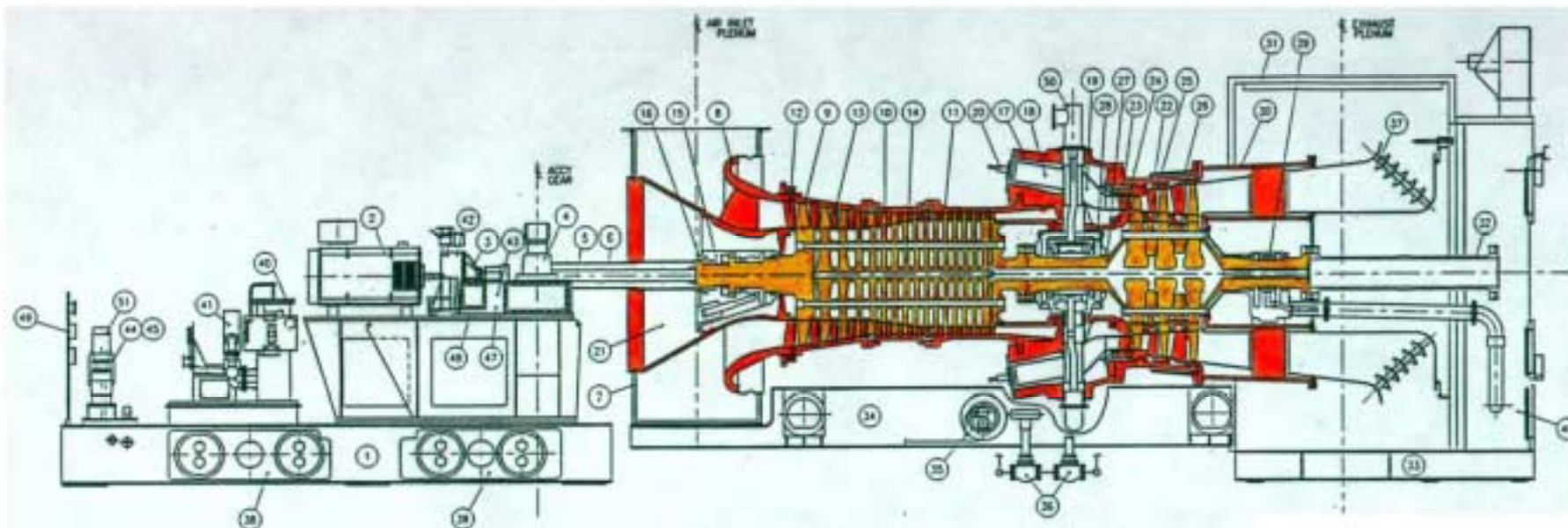


Figure 6 Simple-Cycle Gas Turbine Operation

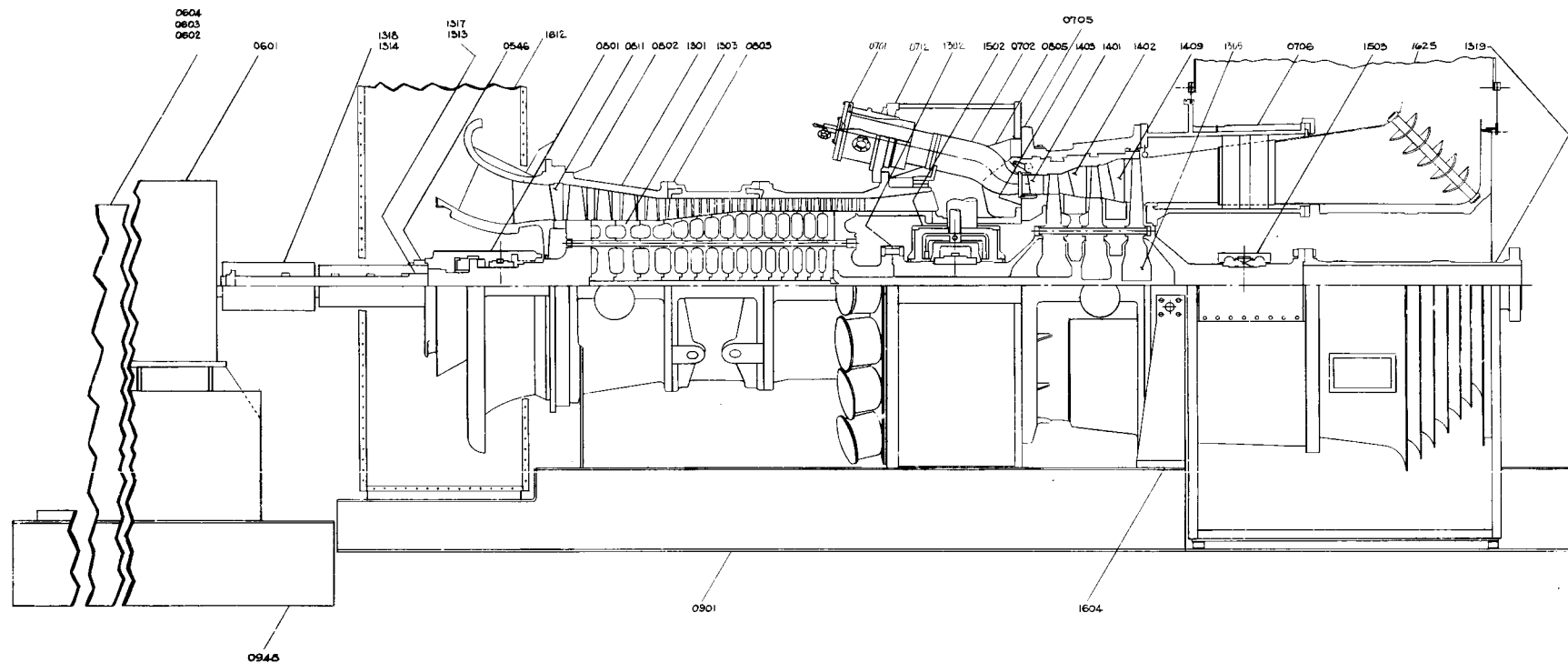




1 ACCESSORY BASE	14 COMPRESSOR ROTOR - ASSEMBLY	27 TURBINE ROTOR - ASSEMBLY	40 FUEL OIL FILTERS
2 STARTING MOTOR	15 BEARING No.1 - ASSEMBLY	28 BEARING No.2 - ASSEMBLY	41 FUEL OIL STOP VALVE
3 TORQUE CONVERTER	16 PICK-UP AIRGHT. HP MAGNET	29 BEARING No.3 - ASSEMBLY	42 AUX. HYDRAULIC PUMP
4 ACCESSORY GEAR	17 CASING - COMBUSTION WHIMPER	30 FRAME ASSEMBLY - EXHAUST	43 MAIN HYDRAULIC PUMP
5 ACCESSORY GEAR COUPLING	18 COMBUSTION LINER	31 EXHAUST PLENUM	44 AUX. LUBE OIL PUMP
6 ACCESSORY GEAR COUPLING CLAMP	19 COMBUSTION TRANSITION PIECE	32 LOAD COUPLING	45 EMERGENCY LUBE OIL PUMP
7 INLET PLENUM	20 FUEL NOZZLES	33 EXHAUST PLENUM BASE	46 LOAD DRIVE COMPARTMENT
8 CASING - COMPRESSOR, INLET	21 INLET CONE	34 TURBINE BASE	47 HYDRAULIC MODULE
9 CASING - COMPRESSOR, FORWARD	22 CASING - TURBINE	35 ATMOSPHERIC AIR PRE-COOLER	48 STARTING WEIR PLATFORM
10 CASING - COMPRESSOR, AFT	23 RING ASSEMBLY SUPPORT	36 CONTR. VALVES - FUEL NOZZLE PURGE	49 GAUGE PANEL
11 CASING - COMPRESSOR, DISCHARGE	24 1st STAGE NOZZLES - TURBINE	37 EXHAUST DIFFUSER	50 No.2 BEARING VENT PIPE
12 INLET GUIDE VANE VARIABLE	25 2nd STAGE NOZZLES - TURBINE	38 LUBE OIL HEAT EXCHANGERS ASSEMBLY	51 SEAL OIL PUMP
13 COMPRESSOR STATOR BLADES	26 3rd STAGE NOZZLES - TURBINE	39 LUBE OIL FILTERS ASSEMBLY	

MS9001E Single Shaft Heavy Duty Gas Turbine

Tab 2



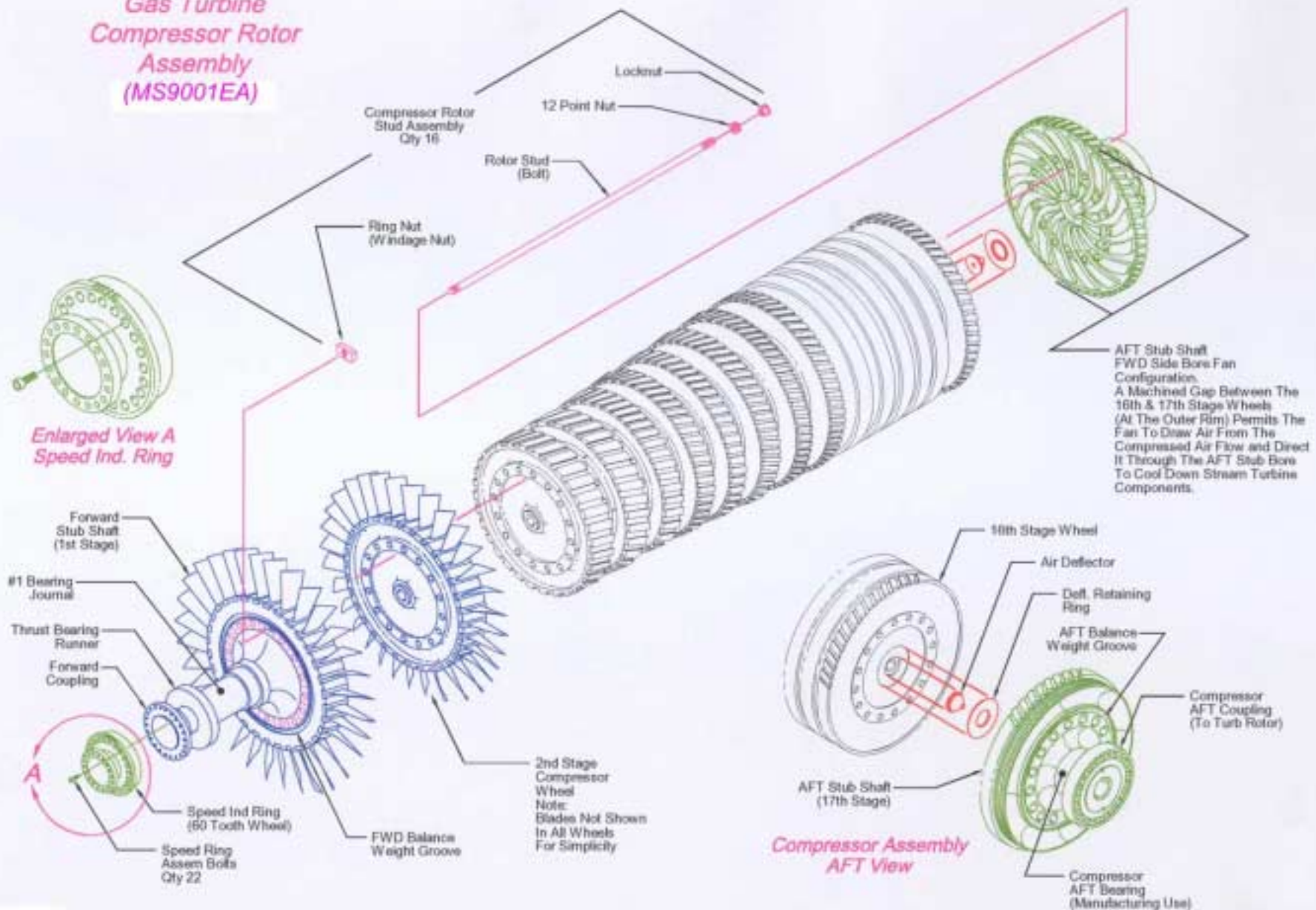
Traduction GE Energy Products-Europe

④ CONVERSION 123 GENERAL ELEMENT REPORT

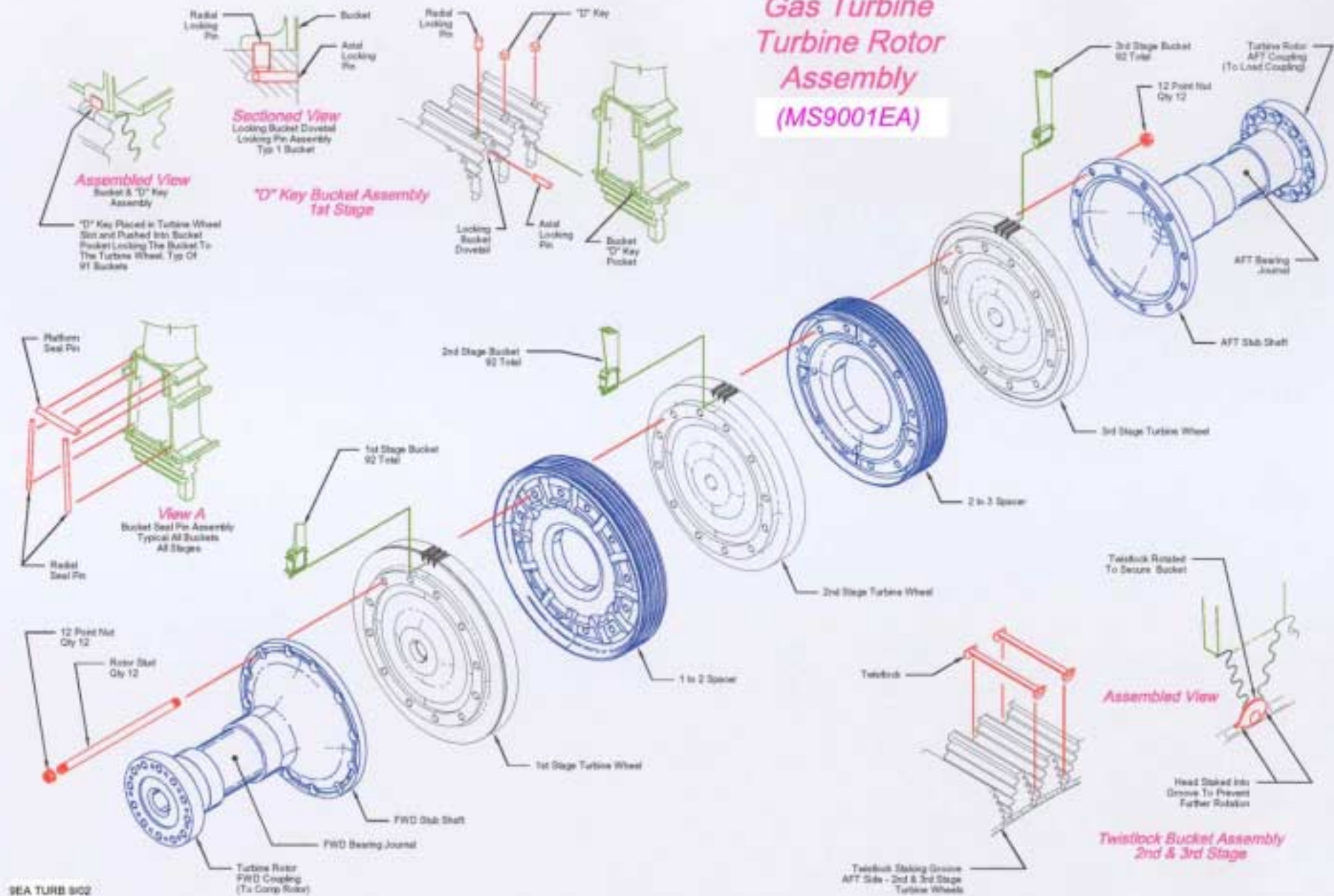
REVISIONS

REV	DATE	DESCRIPTION	BY	CHKD
1	APR 10 1991	INITIAL DESIGN	W. J. DUNN	W. J. DUNN
2	MAY 10 1991	REVISION	W. J. DUNN	W. J. DUNN
3	JUN 10 1991	REVISION	W. J. DUNN	W. J. DUNN
4	JUL 10 1991	REVISION	W. J. DUNN	W. J. DUNN
5	AUG 10 1991	REVISION	W. J. DUNN	W. J. DUNN
6	SEP 10 1991	REVISION	W. J. DUNN	W. J. DUNN
7	OCT 10 1991	REVISION	W. J. DUNN	W. J. DUNN
8	NOV 10 1991	REVISION	W. J. DUNN	W. J. DUNN
9	DEC 10 1991	REVISION	W. J. DUNN	W. J. DUNN
10	JAN 10 1992	REVISION	W. J. DUNN	W. J. DUNN
11	FEB 10 1992	REVISION	W. J. DUNN	W. J. DUNN
12	MAR 10 1992	REVISION	W. J. DUNN	W. J. DUNN
13	APR 10 1992	REVISION	W. J. DUNN	W. J. DUNN
14	MAY 10 1992	REVISION	W. J. DUNN	W. J. DUNN
15	JUN 10 1992	REVISION	W. J. DUNN	W. J. DUNN
16	JUL 10 1992	REVISION	W. J. DUNN	W. J. DUNN
17	AUG 10 1992	REVISION	W. J. DUNN	W. J. DUNN
18	SEP 10 1992	REVISION	W. J. DUNN	W. J. DUNN
19	OCT 10 1992	REVISION	W. J. DUNN	W. J. DUNN
20	NOV 10 1992	REVISION	W. J. DUNN	W. J. DUNN
21	DEC 10 1992	REVISION	W. J. DUNN	W. J. DUNN
22	JAN 10 1993	REVISION	W. J. DUNN	W. J. DUNN
23	FEB 10 1993	REVISION	W. J. DUNN	W. J. DUNN
24	MAR 10 1993	REVISION	W. J. DUNN	W. J. DUNN
25	APR 10 1993	REVISION	W. J. DUNN	W. J. DUNN
26	MAY 10 1993	REVISION	W. J. DUNN	W. J. DUNN
27	JUN 10 1993	REVISION	W. J. DUNN	W. J. DUNN
28	JUL 10 1993	REVISION	W. J. DUNN	W. J. DUNN
29	AUG 10 1993	REVISION	W. J. DUNN	W. J. DUNN
30	SEP 10 1993	REVISION	W. J. DUNN	W. J. DUNN
31	OCT 10 1993	REVISION	W. J. DUNN	W. J. DUNN
32	NOV 10 1993	REVISION	W. J. DUNN	W. J. DUNN
33	DEC 10 1993	REVISION	W. J. DUNN	W. J. DUNN
34	JAN 10 1994	REVISION	W. J. DUNN	W. J. DUNN
35	FEB 10 1994	REVISION	W. J. DUNN	W. J. DUNN
36	MAR 10 1994	REVISION	W. J. DUNN	W. J. DUNN
37	APR 10 1994	REVISION	W. J. DUNN	W. J. DUNN
38	MAY 10 1994	REVISION	W. J. DUNN	W. J. DUNN
39	JUN 10 1994	REVISION	W. J. DUNN	W. J. DUNN
40	JUL 10 1994	REVISION	W. J. DUNN	W. J. DUNN
41	AUG 10 1994	REVISION	W. J. DUNN	W. J. DUNN
42	SEP 10 1994	REVISION	W. J. DUNN	W. J. DUNN
43	OCT 10 1994	REVISION	W. J. DUNN	W. J. DUNN
44	NOV 10 1994	REVISION	W. J. DUNN	W. J. DUNN
45	DEC 10 1994	REVISION	W. J. DUNN	W. J. DUNN
46	JAN 10 1995	REVISION	W. J. DUNN	W. J. DUNN
47	FEB 10 1995	REVISION	W. J. DUNN	W. J. DUNN
48	MAR 10 1995	REVISION	W. J. DUNN	W. J. DUNN
49	APR 10 1995	REVISION	W. J. DUNN	W. J. DUNN
50	MAY 10 1995	REVISION	W. J. DUNN	W. J. DUNN
51	JUN 10 1995	REVISION	W. J. DUNN	W. J. DUNN
52	JUL 10 1995	REVISION	W. J. DUNN	W. J. DUNN
53	AUG 10 1995	REVISION	W. J. DUNN	W. J. DUNN
54	SEP 10 1995	REVISION	W. J. DUNN	W. J. DUNN
55	OCT 10 1995	REVISION	W. J. DUNN	W. J. DUNN
56	NOV 10 1995	REVISION	W. J. DUNN	W. J. DUNN
57	DEC 10 1995	REVISION	W. J. DUNN	W. J. DUNN
58	JAN 10 1996	REVISION	W. J. DUNN	W. J. DUNN
59	FEB 10 1996	REVISION	W. J. DUNN	W. J. DUNN
60	MAR 10 1996	REVISION	W. J. DUNN	W. J. DUNN
61	APR 10 1996	REVISION	W. J. DUNN	W. J. DUNN
62	MAY 10 1996	REVISION	W. J. DUNN	W. J. DUNN
63	JUN 10 1996	REVISION	W. J. DUNN	W. J. DUNN
64	JUL 10 1996	REVISION	W. J. DUNN	W. J. DUNN
65	AUG 10 1996	REVISION	W. J. DUNN	W. J. DUNN
66	SEP 10 1996	REVISION	W. J. DUNN	W. J. DUNN
67	OCT 10 1996	REVISION	W. J. DUNN	W. J. DUNN
68	NOV 10 1996	REVISION	W. J. DUNN	W. J. DUNN
69	DEC 10 1996	REVISION	W. J. DUNN	W. J. DUNN
70	JAN 10 1997	REVISION	W. J. DUNN	W. J. DUNN
71	FEB 10 1997	REVISION	W. J. DUNN	W. J. DUNN
72	MAR 10 1997	REVISION	W. J. DUNN	W. J. DUNN
73	APR 10 1997	REVISION	W. J. DUNN	W. J. DUNN
74	MAY 10 1997	REVISION	W. J. DUNN	W. J. DUNN
75	JUN 10 1997	REVISION	W. J. DUNN	W. J. DUNN
76	JUL 10 1997	REVISION	W. J. DUNN	W. J. DUNN
77	AUG 10 1997	REVISION	W. J. DUNN	W. J. DUNN
78	SEP 10 1997	REVISION	W. J. DUNN	W. J. DUNN
79	OCT 10 1997	REVISION	W. J. DUNN	W. J. DUNN
80	NOV 10 1997	REVISION	W. J. DUNN	W. J. DUNN
81	DEC 10 1997	REVISION	W. J. DUNN	W. J. DUNN
82	JAN 10 1998	REVISION	W. J. DUNN	W. J. DUNN
83	FEB 10 1998	REVISION	W. J. DUNN	W. J. DUNN
84	MAR 10 1998	REVISION	W. J. DUNN	W. J. DUNN
85	APR 10 1998	REVISION	W. J. DUNN	W. J. DUNN
86	MAY 10 1998	REVISION	W. J. DUNN	W. J. DUNN
87	JUN 10 1998	REVISION	W. J. DUNN	W. J. DUNN
88	JUL 10 1998	REVISION	W. J. DUNN	W. J. DUNN
89	AUG 10 1998	REVISION	W. J. DUNN	W. J. DUNN
90	SEP 10 1998	REVISION	W. J. DUNN	W. J. DUNN
91	OCT 10 1998	REVISION	W. J. DUNN	W. J. DUNN
92	NOV 10 1998	REVISION	W. J. DUNN	W. J. DUNN
93	DEC 10 1998	REVISION	W. J. DUNN	W. J. DUNN
94	JAN 10 1999	REVISION	W. J. DUNN	W. J. DUNN
95	FEB 10 1999	REVISION	W. J. DUNN	W. J. DUNN
96	MAR 10 1999	REVISION	W. J. DUNN	W. J. DUNN
97	APR 10 1999	REVISION	W. J. DUNN	W. J. DUNN
98	MAY 10 1999	REVISION	W. J. DUNN	W. J. DUNN
99	JUN 10 1999	REVISION	W. J. DUNN	W. J. DUNN
100	JUL 10 1999	REVISION	W. J. DUNN	W. J. DUNN

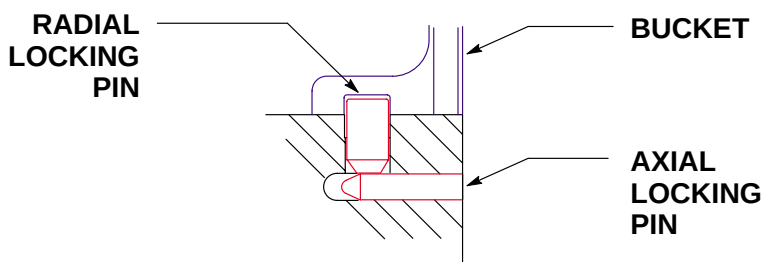
Gas Turbine Compressor Rotor Assembly (MS9001EA)



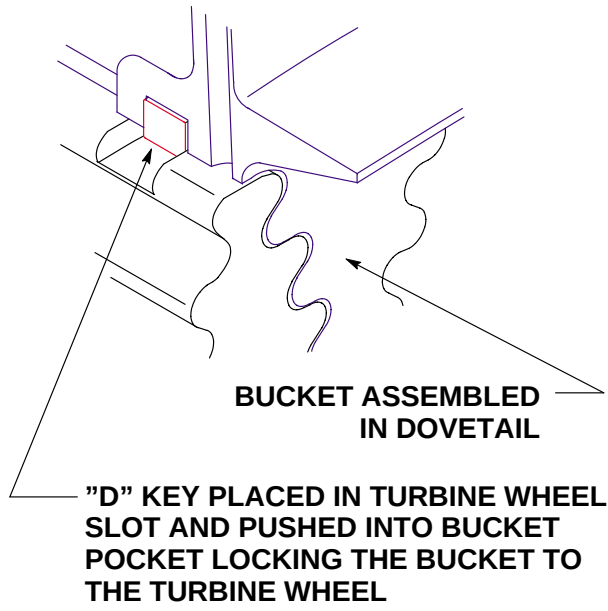
Gas Turbine Turbine Rotor Assembly (MS9001EA)



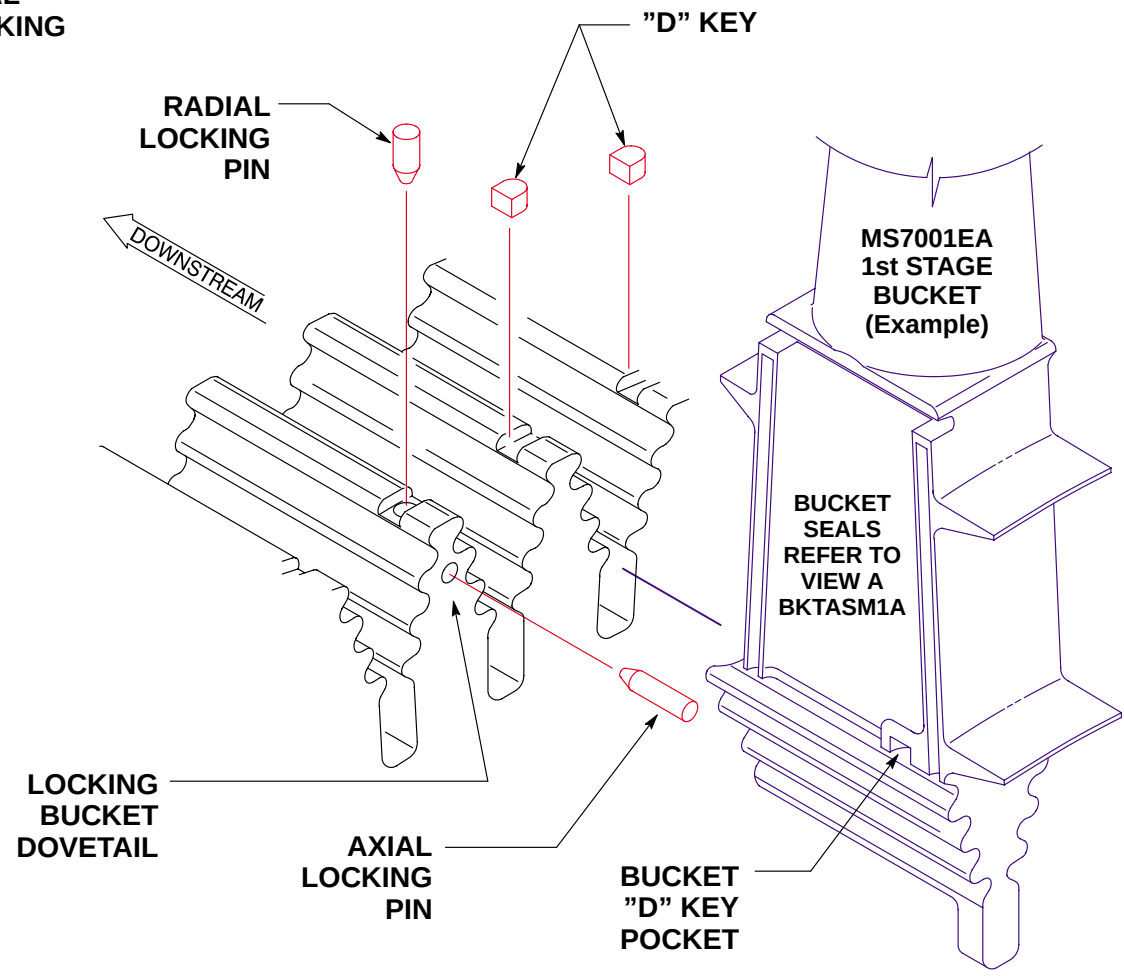
**GAS TURBINE
BUCKET TO TURBINE WHEEL
ASSEMBLY METHODS**



**SECTION VIEW
LOCKING BUCKET DOVETAIL
LOCKING PIN ASSEMBLY**

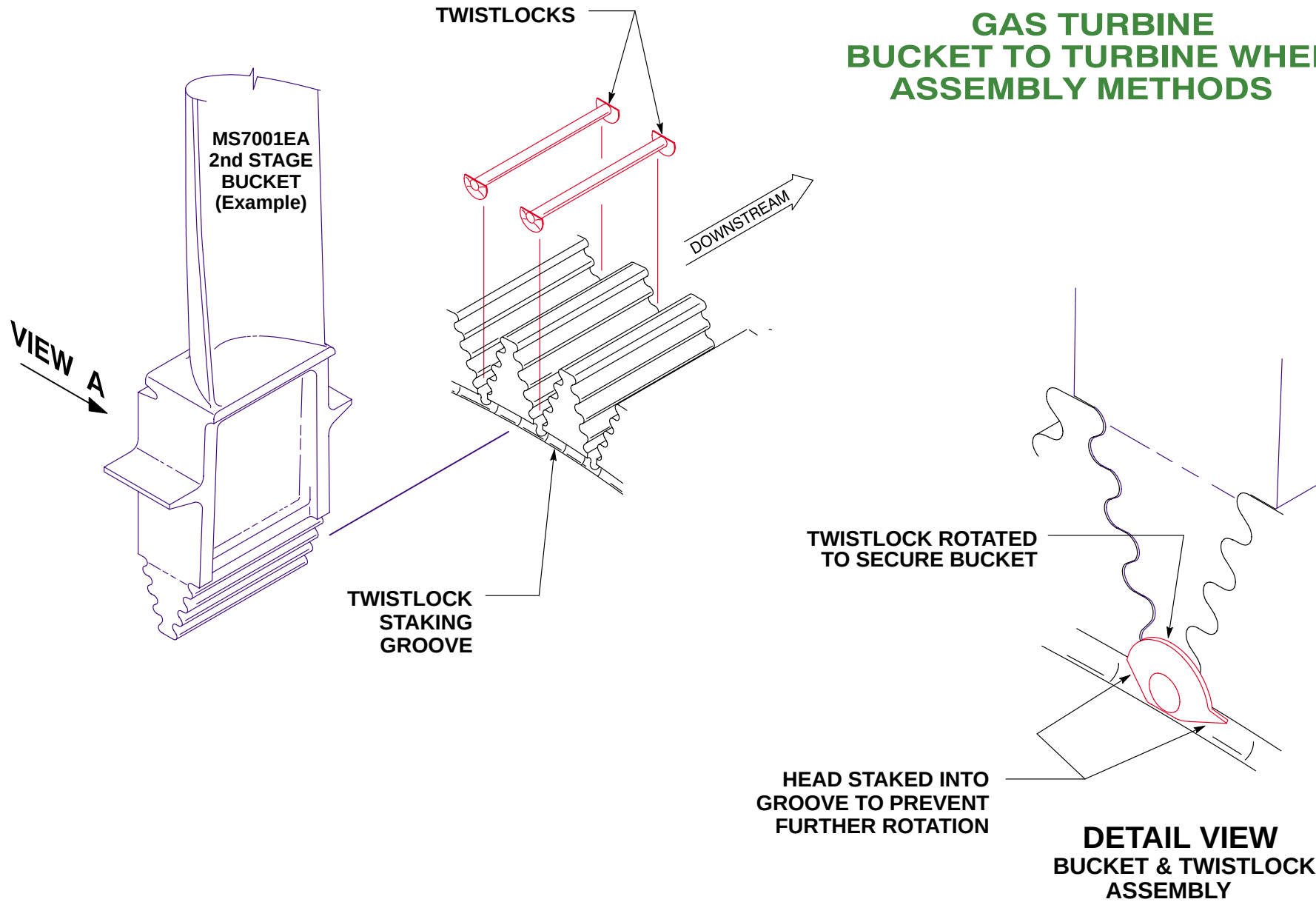


**ENLARGED VIEW C
BUCKET & "D" KEY
ASSEMBLY**

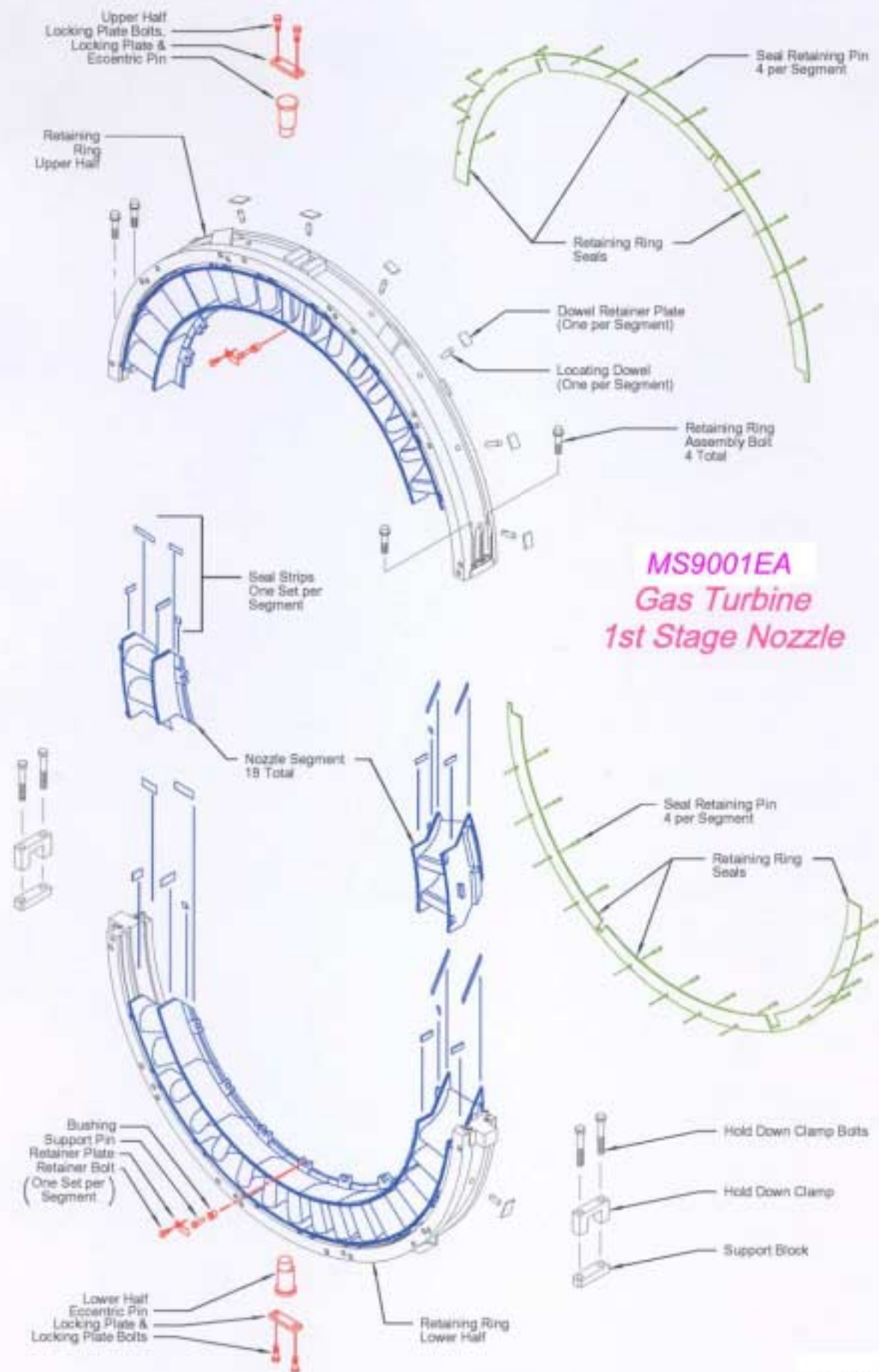


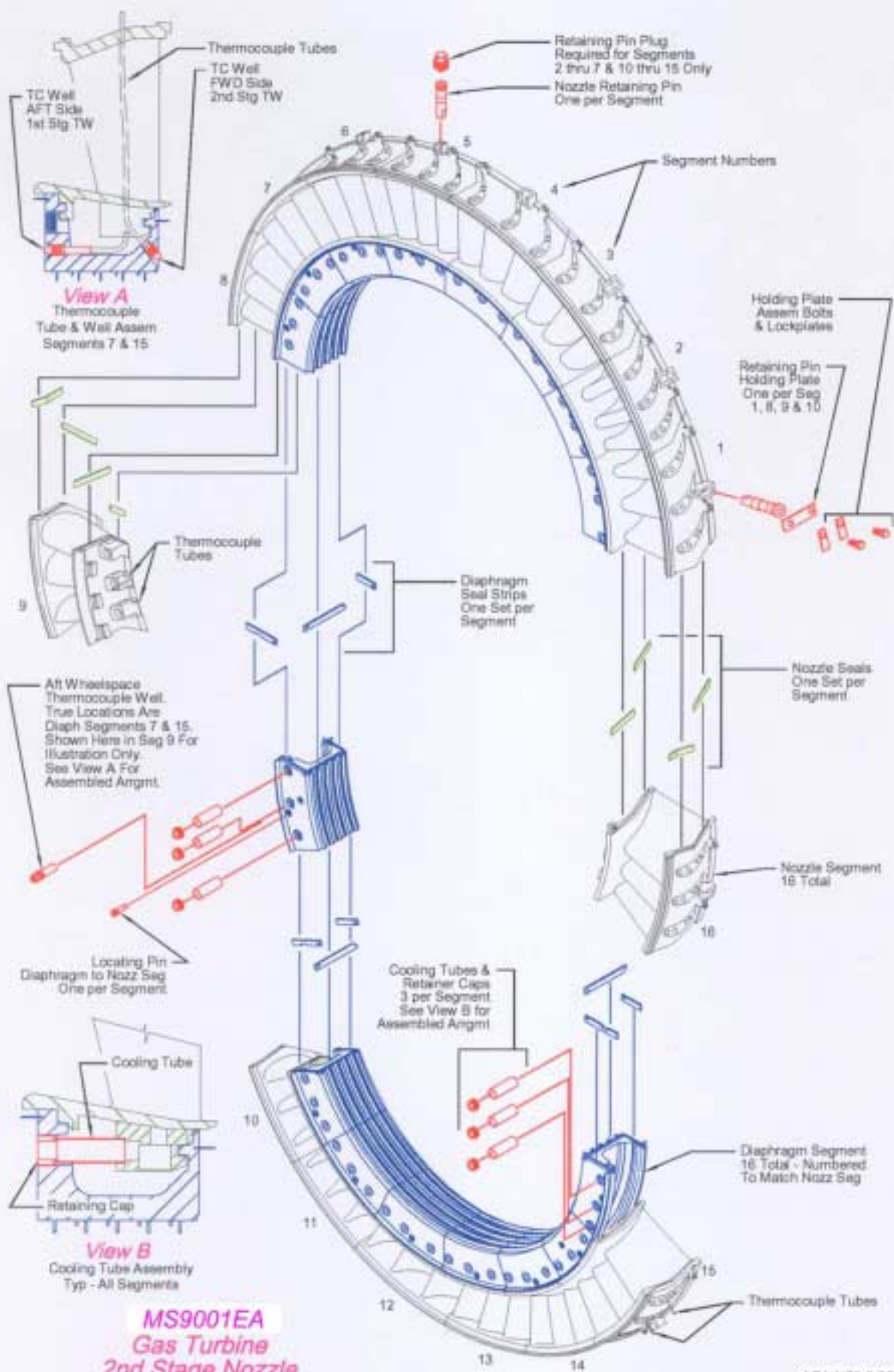
"D" KEY ASSEMBLY

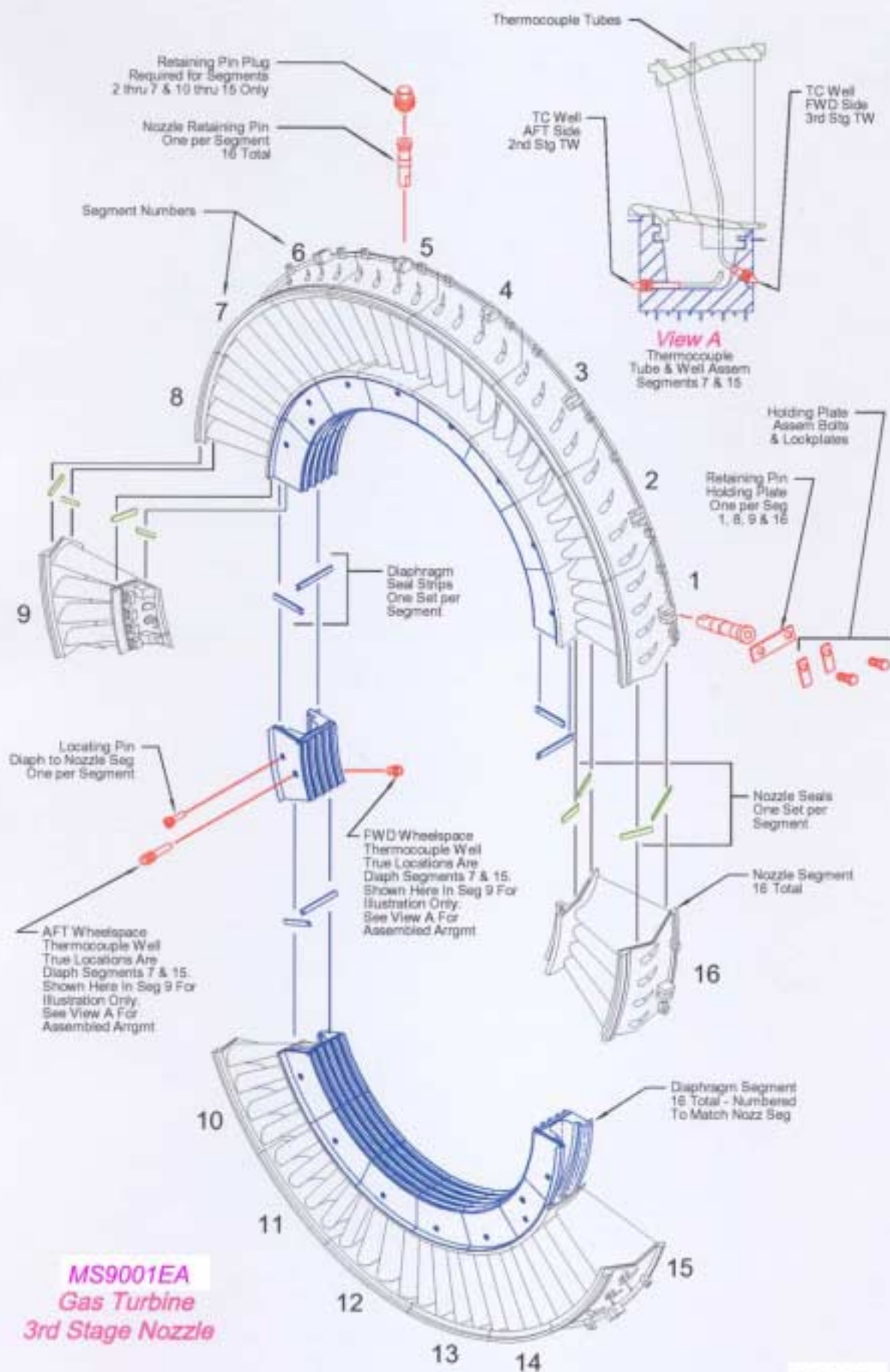
GAS TURBINE BUCKET TO TURBINE WHEEL ASSEMBLY METHODS

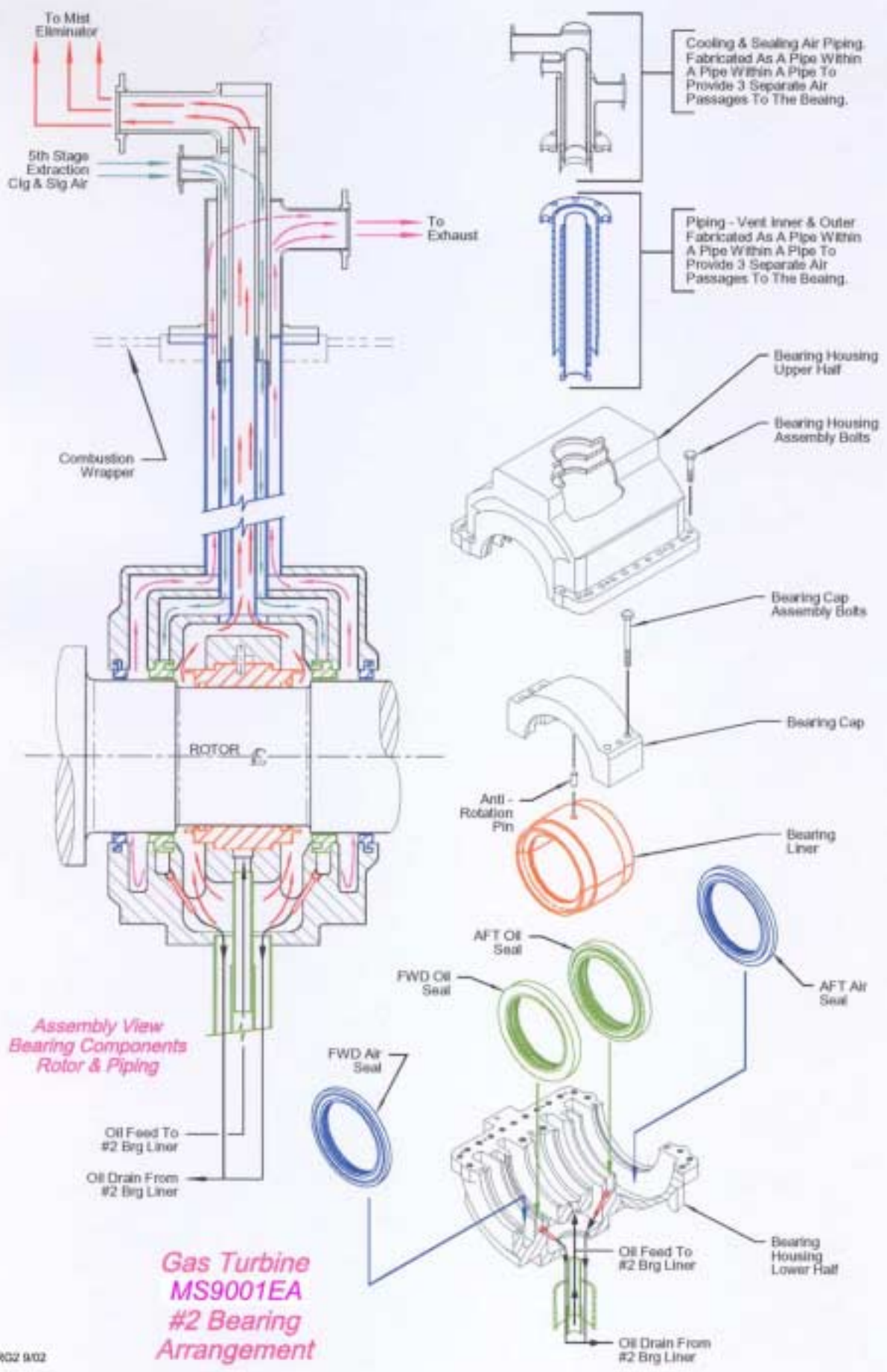


TWISTLOCK ASSEMBLY









Assembly View
Bearing Components
Rotor & Piping

**Gas Turbine
MS9001EA
#2 Bearing
Arrangement**



TURBINE CONTROL DEVICES

MS7001EA

GENERAL DESCRIPTION

The turbine control devices are all of the control components, sensors, and transducers used to monitor and control the operation of the flange-to-flange gas turbine. The devices are located in the inlet and exhaust plenums and mounted on the gas turbine unit, with functions including the following:

- a. temperature measurement
- b. vibration detection
- c. speed measurement
- d. flame detection
- e. combustion ignition

FUNCTIONAL DESCRIPTION

Inlet Plenum

The devices mounted in the forward wall of the inlet plenum are the compressor inlet temperature thermocouples (CT-IF-1, 2), and are used as an indication of the ambient temperature to the compressor inlet.

Exhaust Plenum

The devices mounted in the exhaust plenum are the turbine exhaust control and protection thermocouples (TT-XD-1 thru 18), and the primary function is to provide turbine exhaust temperature measurements 360° around all ten (10) combustors. Selected groupings of six (6) thermocouples are wired

to the three (3) <RST> controllers in the Speedtronic control panel to provide temperature inputs to the combustion monitor and exhaust temperature control, alarm, and trip functions.

Flange-to-Flange Gas Turbine

The remaining devices mounted on the turbine itself are grouped in the following categories:

Bearing Vibration Detection – using velocity (seismic) type sensors:

#1 Bearing Housing – (39V-1A, 1B)

#2 Bearing Housing – (39V-2A)

#3 Bearing Housing – (39V-3A, 3B)

These devices function are to monitor and protect the turbine rotor and bearings from excessive vibration and damage.

Turbine Shaft Speed Detection – using magnetic type pickups:

Forward Compressor Stub Shaft – (77NH-1, 2, 3)

This function is to provide a speed signal reference for the Speedtronic controls during start-up, loading, and shutdown of the turbine unit.

Temperature Detection – using precision thermocouples:

Compressor discharge – (CT-DA-1, 2)

This function provides a compressor discharge temperature corrected reference for Pcd bias control during IGV operation and speed control.



Turbine Wheelspaces as:

First stage aft outer (TT-WS1AO-1, 2)
First stage forward inner (TT-WS1FI-1, 2)
First stage forward outer (TT-WS1FO-1, 2)
Second stage aft outer (TT-WS2AO-1, 2)
Second stage forward outer (TT-WS2FO-1, 2)
Third stage aft outer (TT-WS3AO-1, 2)
Third stage forward outer (TT-WS3FO-1, 2)
Turbine inner barrel (TT-IB-1)

This function is to protect the turbine hot section parts such as nozzles, buckets, and wheels from damage due to excessive temperatures during start-up, normal operation, and shutdown.

Flame Detection—using ultraviolet radiation type sensors:

flame detectors (28FD-2, 3, 7, 8) in combustors # 2, 3, 7, 8

This function is to indicate the presence of flame in the combustors during turbine start-up and normal operation.

Combustion Ignition—using devices as:

spark plugs (95SP-1, 10) in combustors # 1 & 10

ignition transformers (95TR-1, 10) mounted on turbine base

This function is to light-off the combustors and establish combustion during turbine start-up.

SPECIAL CUSTOMER OPTIONS

Bearing Vibration Monitoring—using proximity (non-contacting) type position sensors:

#1 Bearing Housing – (39VS-11, 12) [radial] & (96VC-11, 12) [axial]; (77RP-11) [key phasor]

#2 Bearing Housing – (39VS-21, 22, 23, 24) [radial]

#3 Bearing Housing – (39VS-31, 32) [radial]

Bearing Metal Thermocouples

The turbine unit journal and thrust bearings are equipped with bearing metal thermocouples embedded into the bearing babbitt metal with the function to monitor the “actual” bearing temperatures during operation and give an alarm indication if the metal temperature is too high. This function is to protect the turbine bearings and rotor journal surfaces from overheating and failure (i.e. “wiped”). The thermocouples are placed in the following locations:

#1 main journal bearing – (BT-J1-1A, 1B, 2A, 2B)

#2 main journal bearing – (BT-J2-1A, 1B, 2A, 2B)

#3 main journal bearing – (BT-J3-1A, 1B, 2A, 2B)

Thrust Bearing – Active Lands – (BT-TA1-1A, 1B, 2A, 2B)

Thrust Bearing – Inactive Lands – (BT-TI1-1A, 1B, 2A, 2B)

Turbine Performance Monitor

The compressor inlet bellmouth area has total pressure probes included as well as an RTD mounted to monitor the compressor performance during turbine unit operation. The compressor inlet pressure and temperature values must be measured in order to perform this function. The system includes the following equipment:

a. Inlet plenum RTD (CT-IF-3/RTD)



-
b. Total and static pressure probes	compressor discharge pressure (96CD-2)
c. Performance monitor manifold with valving & condensate drain traps	exhaust pressure (96EP) inlet filter differential pressure (96TF)
d. Pressure transducers to measure:	
inlet air total pressure (96CS)	
bellmouth differential pressure (96BD)	
barometric pressure (96AP)	
- The above pressure transducers are mounted on the performance monitor manifold, that is located off-base in close proximity to the turbine compartment inlet and exhaust plenums. The pressure sensing lines are run from the plenums to the monitor manifold connections for the transducers.

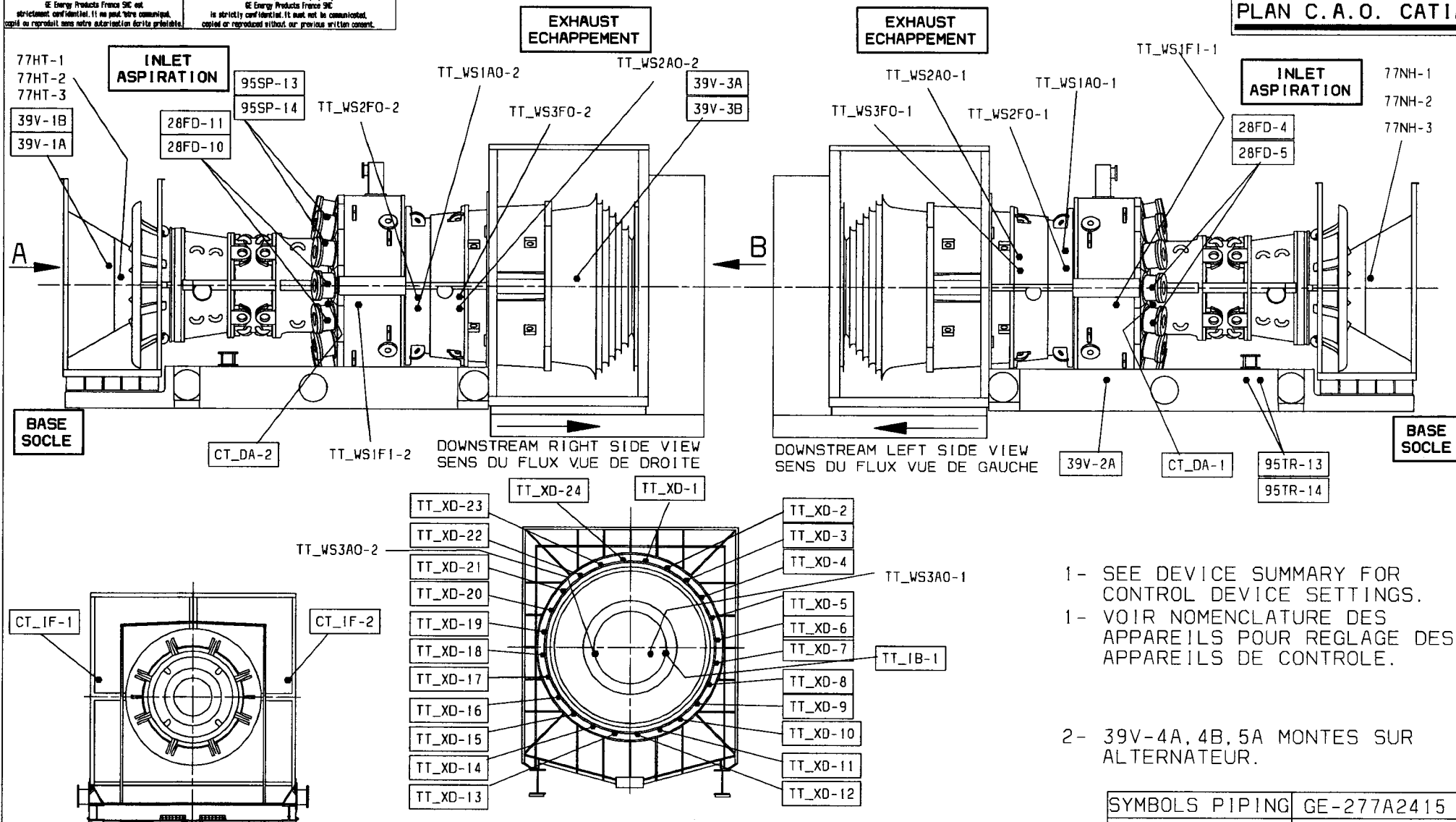


GE Power Systems



GE Power Systems Training

*General Electric Company
One River Road
Schenectady, NY 12345*



- 1- SEE DEVICE SUMMARY FOR CONTROL DEVICE SETTINGS.
1- VOIR NOMENCLATURE DES APPAREILS POUR REGLAGE DES APPAREILS DE CONTROLE.

- 2- 39V-4A, 4B, 5A MONTES SUR ALTERNATEUR.

SYMBOLS PIPING	GE-277A2415
COMPL. DOC.	DOC. N°

VUE A; VIEW A
FORWARD WALL, INLET PLENUM
PAROI AVANT, CAISSON ASPIR.

VUE B; VIEW B
AFT. WALL, EXH PLENUM
PAROI ARRIERE, CAISSON ECHAPP.

SIMILAIRE A: SIMILAR TO:	91-311684	PREM. EXECUTION: FIRST MADE FOR:	MS 9107	O	M	K
OPTION: STD	B	IM-2000002932	23 OCT 00	THIRION F.	THIRION F.	BITSCH JM.
	A	IM-1999001726	12 AOU 99	COURTOT JF	COURTOT JF	HANNON P.
ITEM: 0415	Indice	N° Instruction Modif	Date	Nom	Visa	Visa
		MODIFICATIONS		MODIFIE	VERIFIE	APPROUVE

APPROUVE	15/07/96	LE TRIVIDIC	TITRE	SCHEMA APP. DE PROTECTION TG
VERIFIE	15/07/96	BITSCH JM.	TITLE	DIAGRAM, CON DEVICES-TURBINE
DES./RED	15/07/96	GILLET B.		
QA : C	Date	Nom	Visa	
LANGUE	E-F	BELFORT	☒	SECT. DOC
DIFFU	2	NATURE	SH	91 A
EMETTEUR	FORMAT	A3	CONT. PAGE	PAGE
			F	1

GE Energy Products - Europe

91-313 097

Tab 3



GE Power Systems Gas Turbine

Air Inlet and Exhaust System

I. GENERAL

Gas turbine performance and reliability are a function of the quality and the cleanliness of the inlet air entering the turbine. Therefore, for most efficient operation, it is necessary to treat the atmospheric air entering the turbine to filter out the contaminants. It is the function of the air inlet system with its specially designed equipment and ducting to modify the quality of the air under various temperature, humidity and contamination situations and make it more suitable for use in the unit. Additionally, the intake noise generated during gas turbine operation is attenuated by absorptive silencing material built into the inlet duct, which dissipates or reduces the acoustical energy to an acceptable level.

II. AIR INLET SYSTEM

A. General

The air inlet system consists of an automatic self cleaning filter house with high efficiency Duratek Spiderweb moisture resistant filter media, with provisions for a chiller coil, and an inlet ducting system all mounted on support structures and leading to the inlet plenum and compressor section of the turbine. Inlet air enters the inlet compartment, continues through the acoustical silencer and the trash screen to the inlet plenum and then to the turbine compressor. The elevated ducting arrangement provides a compact system and minimizes the pickup of dust concentrated in the air near the ground.

The inlet system makes use of materials and coatings in its construction which are designed to make it maintenance-free. All external and internal surface areas of the filter house and ductwork are coated with a protective corrosion-preventive primer. The trash screen is fabricated of stainless steel and inlet silencing perforated sheet 304L stainless steel. All support steel is galvanized. The general arrangement of the inlet compartment with respect to the gas turbine inlet plenum is shown on the mechanical outline drawing in the Reference Drawings section.

B. Inlet Compartment

1. Description

The filter house (inlet filter system), with its integrated support structure, sits on a (separate) foundation forward of the Accessory Base. The filter system consists of high efficiency self cleaning filter stage. The self-cleaning filter elements are mounted on grid plates and contained within a light gauge steel sheet metal enclosure which has been specially designed for proper air flow manage-

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes the matter should be referred to the GE Company.

ment and weather protection. The filter elements are connected to a common clean air plenum which has an aft outlet flange where it connects to the inlet ducting system. The filter house has been designed to provide provisions for a chiller coil system designed and installed by the customer.

The filter system is equipped with a reverse-pulse type self-cleaning system which is initiated when the pressure drop across the filter media reaches a predetermined value. The pulsed dirt from the filters falls into a screw auger dust collection system.

Details of the theory, operation, and maintenance of the inlet filtration system are contained in the maintenance manual in this section.

Access for maintenance and inspection of the filter elements is by use of caged ladder and platform.

C. Inlet Ducting And Silencing

The air inlet ductwork directs the inlet air flow from the filter house exit to the entrance of the gas turbine compressor. It is supported above the accessory compartment and consists of transition section just downstream of the inlet house, 8 feet of parallel baffle silencing, a 90 down elbow at the centerline of the inlet plenum, transition duct, lined expansion joint, and plenum side extensions.

The inlet silencer consists of an acoustically lined duct containing silencing baffles constructed of a low density insulating material which is encapsulated by 304L stainless steel sheet steel. The acoustic lining in the walls of the silencer duct and the walls of the ducting downstream of the silencer have a similar construction. The vertical-parallel baffle configuration was specially designed to eliminate the fundamental compressor tone, and to attenuate the noise at other frequencies also.

There is stationary 2 piece trash screen within the 90 down elbow which can be accessed for cleaning and inspection through a removable access panel on the side of the down elbow.

The acoustically lined expansion joint is provided for two main purposes: 1) to isolate the loads associated with the inlet system from the gas turbine, and 2) to aid in turbine rotor maintenance.

III. EXHAUST SYSTEM

A. General

The exhaust system is that portion of the turbine in which the gas used to power the turbine wheels is redirected before being released either to atmosphere or to the exhaust heat recovery equipment. The exhaust system directs the hot exhaust gas from the the exhaust plenum laterally into the exhaust ducting (provided by others) prior to entering the purchaser's exhaust heat recovery equipment. This exhaust system includes the exhaust plenum, exhaust wraparound and expansion joint. Exhaust temperature thermocouples are mounted in the aft wall of the exhaust plenum to sense exhaust temperatures and input these values to the SPEEDTRONIC™ control system.

B. Exhaust Plenum

The exhaust plenum is the beginning of the exhaust duct, receiving the gas flow from the exhaust diffuser. It consists of a box, open at each side and at the top, which is welded to an extension of the turbine base. The exhaust plenum is connected to the exhaust frame assembly with flex-plate expansion joints. The open sides and top of the plenum are covered with a wrapper whose purpose is to enlarge the plenum

volume and force the exhaust gases to one side and into the exhaust ducting. The wrapper is supported by the foundation mounted pedestals.

C. Exhaust Expansion Joint

The exhaust system includes an expansion joint which bolts to the exhaust plenum and panel assembly at one side and attaches to the exhaust duct flange at the other side. This joint compensates for the thermal expansion of the plenum and the exhaust system.

D. Purchaser Interface

The exhaust ducting connects with the purchaser's equipment at the other side of the expansion joint. The remainder of the exhaust system ducting, which includes the exhaust stack, is the responsibility of others and is, therefore, not covered in this publication.

THIS PAGE INTENTIONALLY LEFT BLANK.

SIZE B DWG NO 351B7195 SH 1 REV C

NOTE(S):

1. SEE DEVICE SUMMARY (MLI 0414) FOR CONTROL DEVICE SETTINGS.
2. CONVENIENCE OUTLETS, LIGHTS, LIGHT SWITCHES, AND INDICATOR LIGHTS ARE NOT SHOWN.
3. SEE DIAGRAM SCHEM PP-TURB & CPRSR WSHG (MLI 0442)
4. SEE OUTLINE, FDN, INTFC. - OFF-BASE MECH. (MLI 0326), PL, FOUNDATION INTERFACE OTLN (MLI 0323), OUTLINE, GT PACKAGE CONN-PIPING (MLI 0313) & NOTES, GT PKG CONN OUTLINE-PP FOR P.C. LOCATIONS (MLI 0314).
5. SEE DIAGRAM SCHEM PP-CONTROL AIR (MLI 0419).
6. SEE PIPING PP-LIQUID FUEL (MLI 0424) FOR DRAIN LOCATION.

REVISIONS			
REV	DESCRIPTION	DATE	APPROVED
A	UPDATED REV STATUS OF SHEETS TO REV A FOR SHEETS 1 AND 2. CHG'D TO 5.517 BARS WAS 552 KPS, 6.885 BARS WAS 689 KPA, 7.831 BARS WAS 783 KPA. CD41650 RICHARD P. WEINHEIMER	R.P.W. 98-06-14	D.A.W.
B	UPDATED REV STATUS OF SHEETS TO REV B FOR SHEETS 1 AND 2. CHG'D TO 70 SCFM (2.0 SCMM) WAS 50 & 91.4 SCMM. CD42800 RICHARD P. WEINHEIMER	R.P.W. 98-07-06	D.A.W.
C	UPDATED REV STATUS OF SHEETS TO REV C FOR SHEETS 1 AND 2. CD44387 RICHARD P. WEINHEIMER	R.P.W. 98-08-24	D.A.W.

REVISE ON CAD ONLY
UG PART: 351B7195P001

PC	TEMPERATURE			PRESSURE			FLOW		
	MIN	NOMINAL	MAX	MIN	NOMINAL	MAX	MIN	NOMINAL	MAX
1E2	N/A	80°F (27°C)	150°F (66°C)	80 PSIG (5.517 BARS)	100 PSIG (6.896 BARS)	115 PSIG (7.931 BARS)	N/A	70 SCFM (2.0 SCMM)	100 SCFM (2.8 SCMM)

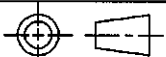
1	PIPING SYMBOLS	277A2415
1T.	NOMENCLATURE	IDENT
LIST OF COMPLEMENTARY DOCUMENTS		

C	C	REV	REV STATUS
2	1	SH	OF SHEETS

© COPYRIGHT 1998 GENERAL ELECTRIC COMPANY

PROPRIETARY INFORMATION-THIS DOCUMENT CONTAINS PROPRIETARY INFORMATION OF GENERAL ELECTRIC COMPANY AND MAY NOT BE USED OR DISCLOSED TO OTHERS, EXCEPT WITH THE WRITTEN PERMISSION OF GENERAL ELECTRIC COMPANY.

THIRD ANGLE PROJECTION



UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON:
2 PL DECIMALS ±
3 PL DECIMALS ±
ANGLES ±
FRACTIONS ±

APPLIED
PRACTICES
348A9200

SIGNATURES	DATE
R.P. WEINHEIMER	98-04-23
R.P. WEINHEIMER	98-04-23
D.A. WAYMAN	98-04-23
R.P. WEINHEIMER	98-04-23



GE Power Generation

GENERAL ELECTRIC COMPANY
GAS TURBINE
Schenectady, NY

DIAGRAM, FLOW-INLET & EXHAUST

FIRST MADE FOR : ML-7A1PEA143-1T6 0471

SIZE B	CAGE CODE	DWG NO 351B7195
SIN TO1	NONE	SCALE NONE
		SHEET 1

DISTR TO

DT-IN

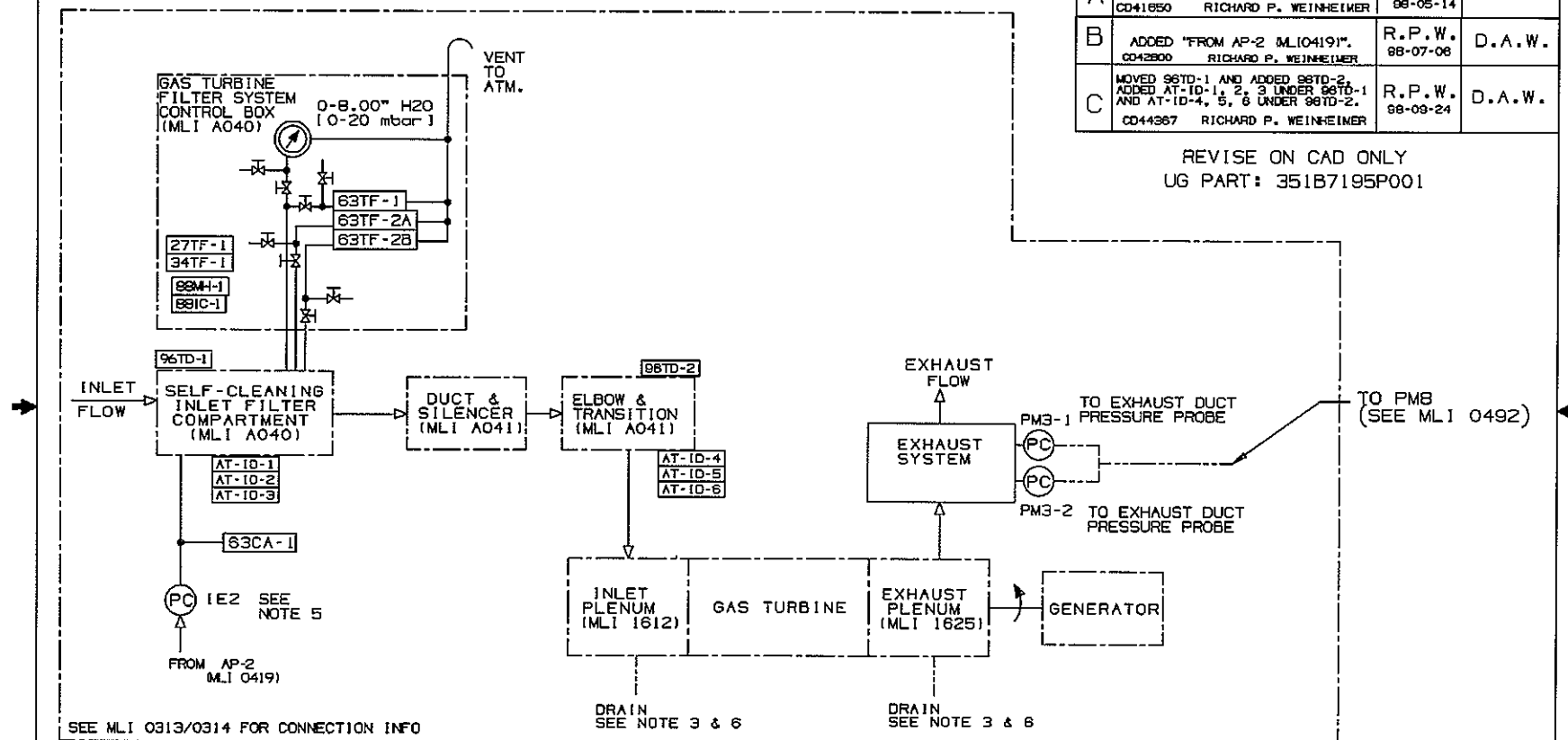
GRO418

AF2D

SIZE B DWG NO 351B7195

REVISIONS			
REV	DESCRIPTION	DATE	APPROVED
A	CHANGED TO 0-20 mbar WAS 0-2 KPA TO GAUGE IN GAS TURBINE FILTER SYS CONTROL BOX. CD41850 RICHARD P. WEINHEIMER	R.P.W. 98-05-14	D.A.W.
B	ADDED "FROM AP-2 MLI0419". CD42800 RICHARD P. WEINHEIMER	R.P.W. 98-07-08	D.A.W.
C	MOVED 98TD-1 AND ADDED 98TD-2 ADDED AT-ID-1, 2, 3 UNDER 98TD-1 AND AT-ID-4, 5, 6 UNDER 98TD-2. CD44367 RICHARD P. WEINHEIMER	R.P.W. 98-09-24	D.A.W.

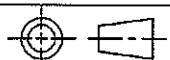
REVISE ON CAD ONLY
UG PART: 351B7195P001



© COPYRIGHT 1998 GENERAL ELECTRIC COMPANY

PROPRIETARY INFORMATION-THIS DOCUMENT CONTAINS PROPRIETARY INFORMATION OF GENERAL ELECTRIC COMPANY AND MAY NOT BE USED OR DISCLOSED TO OTHERS, EXCEPT WITH THE WRITTEN PERMISSION OF GENERAL ELECTRIC COMPANY.

THIRD ANGLE PROJECTION



GENERAL ELECTRIC COMPANY GE Power Generation Schenectady, NY		SIZE	CAGE CODE	DWG NO
B				351B7195
DRAWN R.P.WEINHEIMER	98-04-23			
ISSUED R.P.WEINHEIMER	98-04-23	SCALE NONE	SHEET	2

DISTR TO

GR0418

Tab 4

DESCRIPTIVE GUIDE

3.4. LUBRICATION SYSTEM**3.4.1. DESCRIPTION AND SIMPLIFIED SCHEMATIC**

NOTE : Lubricating oil recommendations are included in the Gas turbine equipment publications volumes.

The lubricating requirements for the gas turbine power plant are furnished by a common forced-feed lubrication system. This lubrication system, complete with tank, pumps, coolers, filters, valves and various control and protection devices, furnishes normal lubrication and absorption of heat rejection load of the gas turbine. Lubricating fluid is circulated to the three main turbine bearings, generator bearings, and to the turbine accessory gear and fuel pump. Also, lubricating fluid is supplied to the starting means torque converter for use as hydraulic fluid as well as for lubrication. Additionally, a portion of the pressurized fluid is diverted and filtered again for use by hydraulic control devices as control fluid. The lubrication system including all major components is shown in Figure LS-1.

Major system components include :

- Lube reservoir in the accessory base ;
- Main lube pump (shaft driven from the accessory gear) ;
- Auxiliary lube pump and emergency lube pump ;
- Pressure relief valve VR-1 in the main pump discharge ;
- Lube fluid heat exchangers ;
- Lube filters ;
- Bearing header pressure regulator VPR-2-1.

Lube fluid temperatures are indicated on the thermocouples which may be located in the bearing header, bearing drains, and the oil tank.

For turbine starting, a maximum of 800 SSU is specified for reliable operation of the control system and for bearing lubrication. A thermocouple, LT_OT-1A, prevents turbine start-up if the temperature of the lubricant is lower than the switch setting (only if applicable).

Lubricating fluid for the main, auxiliary and emergency pumps is supplied from the reservoir, while lubricating fluid used for control is supplied from the bearing header. This lubricant must be regulated to the proper, predetermined pressure to meet the requirements of the main bearings and the accessory lube system, as well as the hydraulic control and trip circuits. Regulating devices are shown on the Lube System Schematic Diagram Figure LS-1. All lubricating fluid is filtered and cooled before being piped to the bearing header.

The reservoir for the lubrication system is the 3300 gallon (i.e. 12 491 l) tank which is fabricated as an integral part of the accessory base. Lubricating fluid is pumped from the reservoir by the main shaft driven pump (part of the accessory gear) or auxiliary or emergency pumps at a pressure of 25 psig (i.e. 1.75 bar) to the bearing header, the accessory gear and the hydraulic supply system. After lubricating the bearings the lubricant flows back through various drain lines to the lube reservoir.

DESCRIPTIVE GUIDE

All lubricant pumped from the lube reservoir to the bearing header flows through the lube fluid heat exchanger(s) to remove excess heat and then through the cartridge type filters providing five micron filtration. The dual heat exchangers are connected in parallel.

Filtration of all lube oil is accomplished by a 5 micron, pleated paper filter installed in the lube system just after the lube oil heat exchanger.

Two filters are used with a transfer valve installed between the filters to direct oil flow through either filter and into the lube oil header.

The lube filters have removable resin-impregnated paper-pleated filter elements and a differential pressure gauge indicates when the filter element should be changed differential pressure switch 63 QQ-1 will cause an alarm if differential pressure across the oil filters becomes too high. A quick connection with check valve allows reading of the pressure with a differential pressure gauge.

Lubricant from the n° 1 turbine bearing assembly is piped through an internal drain line to the lube tank. Drain from the other turbine bearing assemblies and the generator bearings is piped to a surge tank and then to an externally routed drain header that interconnects the accessory base, turbine base. The lube fluid drain flows forward through this common drain header to the lube reservoir. The main oil reservoir is under slight pressure from sealing air that flows into the bearing seals and then into the reservoir.

A lube level gauge and alarm system, a hermetically sealed, float arm operated device, is mounted to the side of the lube reservoir above the maximum expected level of the lube supply. The float mechanism operates a dial gauge and two device switches 71 QH-1 and 71 QL-1. The switches are connected into the alarm circuit of the turbine control panel to initiate an alarm display message on the turbine panel scope and sounds an audible alarm if the liquid level rises above, or falls below a predetermined level.

Temperature readings of the lube oil feed header are available from the thermocouples LT_TH-1A, -1B, -2A, -2B, -3A, -3B installed in the header. Diaphragm operated regulating valve VPR 2, installed downstream from the lube fluid heat exchanger maintains designed pressure. It will open to dump fluid to the tank when the pressure exceeds the control setting.

Standby heaters

During standby periods, the lubricating fluid is maintained at a viscosity proper for turbine start-up operation by immersion heaters 23 QT-1 and 23 QT-2 installed in the lube reservoir. Thermocouples LT_OT-1A and LT_OT-2A sense reservoir fluid temperature, and control the heaters to maintain fluid temperature to achieve allowable viscosity. Also thermocouple LT_OT-1A will not permit the turbine to be started if the fluid temperature drops below that required for start-up.

The ac motor driven auxiliary lube oil pump operates during standby heating periods to circulate the oil in the system.

Start-up

During start-up, lube oil is pumped from the lube oil tank by auxiliary pump 88 QA-1 to feed the starting means line to torque converter (refer to Starting System).

88 QA-1 motor is equipped with a heater 23 QA-1 to prevent condensation when the motor is not operating.

The basket filter has a differential pressure switch 63 QQ-8 which will cause an alarm if differential pressure across the oil filters becomes too high indicating when the filter element

DESCRIPTIVE GUIDE

should be changed. A quick connection with check valve allows reading of the pressure with a differential pressure gauge.

Mist eliminator

The system is ventilated through a mist eliminator mounted on top of the lube oil reservoir. A slight negative pressure is maintained in the system by the motor driven fan 88 QV-1 (with space heater 23 QV) pulling air through the mist eliminator. The separation of oil droplets shall be made by one coalescing filter. This negative pressure draws sealing air through the gas turbine bearing seals. A tap and a pressure switch 63 QV-1 are provided on the mist eliminator to permit monitoring tank pressure. A diaphragm is upstream of fan for the mist eliminator and is used to regulate tank pressure.

DESCRIPTIVE GUIDE

PART	NOMENCLATURE
23 QA-1	Space heater auxiliary lube oil pump motor.
23 QT-1,-2	Immersion heater. Lube oil tank.
23 QV-1	Fan motor heater for 88 QV-1.
63 QA-2	Low lube oil pressure auxiliary pump start.
63 QQ-1	Main lube oil filter differential pressure alarm.
63 QQ-8	Torque adjuster filter differential pressure switch.
63 QT-2A	Low lube oil pressure trip. Pressure switch (on the generator).
63 QV-1	Fouling coalescer filter differential pressure.
71 QH-1	High lube oil level alarm.
71 QL-1	Low lube oil level alarm.
88 QA-1	Auxiliary lube oil pump motor.
88 QE-1	Emergency lube oil pump motor.
88 QV-1	Mist eliminator fan motor.
96 QA-2	Lube oil pressure transmitter VPR2-1 outlet.
96 QT-2A	Low lube oil pressure transmitter generator side.
LT_OT-1A	Lube oil tank low temperature resistance thermometer detector.
LT-OT-2A	Lube oil tank normal temperature resistance thermometer detector.
LT_TH-1A,-1B	Lube oil system turbine header thermocouple.
LT_TH-2A,-2B	Lube oil system turbine header thermocouple.
LT_TH-3A,-3B	Lube oil system turbine header thermocouple.
LT_BT1D-1A,-1B	Lube system temperature turbine n° thrust bearing drain.
LT_B1D-1A,-1B	Lube system temperature - turbine n° 1 (sump) drain.
LT_B2D-1A,-1B	Lube system temperature - turbine n° 2 (sump) drain.
LT_B3D-1A,-1B	Lube system temperature - turbine n° 3 (sump) drain.
LT_G1D	Lube oil system temperature - generator n° 4 bearing.
LT_G2D	Lube oil system temperature - generator n° 5 bearing.
VPR2-1	Bearing header pressure regulator valve.
VR 1	Main lube pump pressure relief valve.

DESCRIPTIVE GUIDE**3.4.2. LUBRICATING OIL PUMPS**

Lubrication to the bearing header is supplied by three lube pumps :

- 1 The main lube supply pump is a positive displacement type pump mounted in and driven by the accessory gear.
- 2 The auxiliary lube supply pump is a submerged centrifugal pump driven by an A.C. motor.
- 3 The emergency lube supply pump is a submerged centrifugal pump driven by a D.C. motor.

- Main lube pump

The main lube pump is built into the inboard wall of the lower half casing of the accessory gear. It is driven by a splined quill shaft from the lower drive gear. The output pressure to the lubrication system is limited by a back-pressure valve to maintain system pressure.

- Auxiliary lube pump

The auxiliary lube pump is a submerged centrifugal type pump driven by an A.C. motor. It provides lubricant pressure during start-up and shut-down of the gas turbine when the main pump cannot supply sufficient pressure for safe operation. Operation of this pump is as follows :

The auxiliary lube pump is controlled by a low lube oil pressure alarm switch (63 QA-2). This low pressure level alarm causes the auxiliary pump to run under low lube oil pressure conditions as is the case during start-up or shut down of the gas turbine when the main pump, driven by the accessory drive device, does not supply sufficient pressure. At turbine start-up, the A.C. pump starts automatically when the master control switch on the turbine control panel is turned to the START position.

The auxiliary pump continues to operate until the turbine reaches approximately 95 per cent of operational speed.

At this point, the auxiliary (cooldown) lube pump shuts down and system pressure is supplied by the shaft-driven, main lube pump.

During the turbine starting sequence, the pump starts when the start signal is given. The control circuit is through the pressure level of pressure switch 63 QA-2. The pump will run until the turbine operating speed is reached (operating speed relay 14 HS picks up), even though the lube oil header is at rated pressure and the discharge pressure level (63 QA-2) is above alarm level setting.

When the turbine is on the shut-down sequence, this pressure transmitter will signal for the auxiliary pump to start running when the lube oil header pressure falls to the point at which pressure level alarm setting is reached.

- Emergency lube pump

The emergency lube pump is a D.C., motor-driven pump, of the submerged centrifugal type. This pump supplies lube oil to the main bearing header during an emergency shut-down in the event the auxiliary pump has been forced out of service because of loss of A.C. power, or for other reasons. It operates as follows :

This pump is started automatically by the action of pressure transmitter 96 QA-2 whenever the lube pressure in the main bearing header falls below the pressure switch setting.

All right reserved Copyright – Droits de reproduction réservés

DESCRIPTIVE GUIDE

If the auxiliary lube oil pump should resume operation, the emergency pump will be stopped by a pressure transmitter (96 QA-2) when the header pressure exceeds the alarm setting in speedtronic.

Should the auxiliary pump fail during the shut-down sequence, because of an A.C. power failure or any other cause, the emergency lube pump will be started automatically by the action of low lube oil pressure transmitter 96 QA-2 and continue to run until the turbine shaft comes to rest.

- Test valve for low lube oil pressure. Auxiliary pump start.

A gauge mounted test valve is also used to provide the means of checking the automatic operation of the auxiliary lube pump and pressure switch 63 QA-2 while the unit is operating normally on the main lube pump.

The test valve is installed in the piping after the pressure switch and is normally closed holding the lube system pressure on the pressure switch. When performing a test, the test valve should be opened gradually to lower the lube oil system pressure in the pressure switch piping. A quick connection with check valve into the pressure line allows checking of the pressure with a pressure gauge. The gauge provides a means of checking the pressure point at which the pressure switch operates to start the pump. When the oil pressure falls to the speedtronic setting for switch 63 QA-2, trip pump is started.

- Test valve for low lube oil pressure. Emergency pump start.

A test valve, provides the means of checking automatic start-up of the emergency lube oil pump and pressure transmitter 96 QA-2. This can be done while the unit is operating normally on the main lube pump.

The test valve is normally closed and maintains lubricating system pressure on the transmitter. When performing a test, the test valve should be opened gradually to lower lubricating system pressure in the piping in which the transmitter is mounted. A quick connection with check valve into the pressure line allows checking of the pressure with a pressure gauge. The gauge provides a means of checking the pressure point at which the transmitter operates to start the pump. A low lubricating fluid pressure indication should occur before the pump begins operating.

Upon closing the test valve, lube pressure is returned to normal and the pump should stop as a result of the restoration of pressure on the 96 QA-2 transmitter.

DESCRIPTIVE GUIDE**3.4.3. PRESSURE AND TEMPERATURE REGULATION AND PROTECTION DEVICES**

- Pressure regulation

Two regulating valves are used to control lubrication system pressure. A back-pressure relief valve, VR 1, limits the positive displacement main pump discharge header pressure and relieves excess fluid to the lube reservoir. The lube pressure in the bearing header is maintained at approximately 25 psig (i.e. 1.75 bar) by the diaphragm operated regulating valve, VPR2-1. This valve has an orifice which permits 80 per cent flow. The diaphragm valve is operated by sensing fluid pressure in the bearing header.

- Pressure and temperature protective devices

The condition of low lubricating fluid pressure is detected by a pressure switch and transmitters that open after a decrease of line pressure to a specified value and trips the unit. Pressure switch 63 QT-2A and transmitter 96 QT-2A which are installed in the lubricant feed piping on the generator side signal an alarm if the lubricant pressure drops to an unacceptable level. Likewise, thermocouples LT_TH-1A,-1B, LT_TH-2A,-2B and LT_TH-3A,-3B are installed in the lubricating fluid header piping and cause an alarm to sound and the unit to trip should the temperature of the lubricant to the bearings exceed a preset limit. The settings in speedtronic for the thermocouples are such that an alarm is actuated if any one of the thermocouples detects low temperature and the turbine is tripped if any two of the thermocouples detect low temperature.

This unit has a SPEEDTRONIC control system. Before the unit is tripped by either high temperature (LT_TH-1A,-1B, LT_TH-2A,-2B and LT_TH-3A,-3B), or low pressure (63 QA-2, 63 QT-2A and 96 QT-2A), the cause for the trip has to be sensed by two of the three measuring devices. This "voting logic" is to prevent a trip due to a malfunctioning sensor.

Provisions are made for checking lube flow to the main turbine and generator bearings by means of oil sights and thermocouples.

- Other temperature measuring and/or protective devices

There are thermocouples that can be checked by means of the T.C. selector on the gas turbine control panel : LT_TH-1A,-1B, LT_TH-2A,-2B and LT_TH-3A,-3B for the L.O. turbine header, LT_B1D for bearing n° 1 L.O. drain, LT_B2D for bearing n° 2 L.O. drain and LT_B3D for bearing n° 3 L.O. drain. LT_G1D for the L.O. system bearing n° 4 (generator), LT_G2D for the L.O. system bearing n° 5 (generator). LT_BT1D for the n° 1 thrust bearing drain.

DESCRIPTIVE GUIDE**3.4.4. HEAT EXCHANGERS AND FILTERS**

- Lube fluid heat exchangers :

The heat exchanger system is required to dissipate the heat absorbed by the lubricating fluid and to maintain the fluid at the proper bearing header temperature.

This is accomplished by circulating cooling water through the cooling tubes of the heat exchanger as the lubricant flows over the tubes. Cooling water flow through the heat exchanger is controlled by temperature sensitive flow regulator valve VTR 1, that maintains the correct bearing temperature.

(See Cooling water system for information on this regulator valve).

The lube fluid heat exchanger system uses a fluid-to-water cooler of the shell and tube bundle design. There is two heat exchangers, flange mounted in the lube reservoir in a horizontal position. A Utube bundle extends into the center of the shell through which the cooling water is passed. The lube fluid flows in and out of the shell ; passing over the cooling tubes of the tube bundle. Cooling water connections are made at the external steel bonnet that bolts to the shell mounting flange through the tube sheet that supports the tubes of the tube bundle.

- Filters :

Main lube filtering system

Filtration of all lube oil is accomplished by a 5 micron, pleated paper filter installed in the lube system just after the lube oil heat exchanger.

Two (duplex) filters are used with a transfer valve installed between the filters to direct oil flow through either filter and into the lube oil header.

The duplex filters arranged side by side, are installed on the tank and connected into the pump discharge header through a manual transfer valve. Only one filter will be in service at a time, thus cleaning, inspection, and maintenance of the second one can be performed without interrupting oil flow or shutting the gas turbine down. By means of the manually operated, worm-driven transfer valve, one filter can be put into service as the second is taken out, without interrupting the oil flow to the main tube oil header. The transfer of operation from one filter to the other should be accomplished as follows:

- 1 Open the filler valve and fill the standby filter until a solid oil flow can be seen in the flow sight in the filter vent pipe. This will indicate a "filled" condition.
- 2 Operate the transfer valve with a wrench to bring the standby filter into service.
- 3 Close the filler valve.

Filters should be changed when the differential pressure switch 63 QQ-1 indicates a differential pressure of 15 psig (i.e. about 1.03 bar). Refer to the Gas turbine maintenance guide volumes for inspection schedules. An alarm from 63 QQ-1 signals when the differential pressure exceeds 15 psig.

NOTE : For the detailed drawing of the lube oil system circuit and the settings, see Gas turbine operation guide volumes : Piping systems schematic.

NOTES

- 1- VALVE AND TRANSFER VALVE MUST BE LOCKED IN POSITION.
- 1- ROBINET ET VANNE TRANSFERT BLOQUEES EN POSITION
- 2- SEE DEVICE SUMMARY FOR CONTROL DEVICE SETTING AND TANK HEATING REQUIREMENTS.
- 2- VOIR NOMENCLATURE DES APPAREILS POUR REGLAGE DES APPAREILS DE CONTROLE ET CHAUFFAGE CUVES A HUILE.
- 3- TUYAUTERIE NECESSAIRE SUIVANT CONFIGURATION.
- 3- PIPING NEEDED FOLLOWING CONFIGURATION.

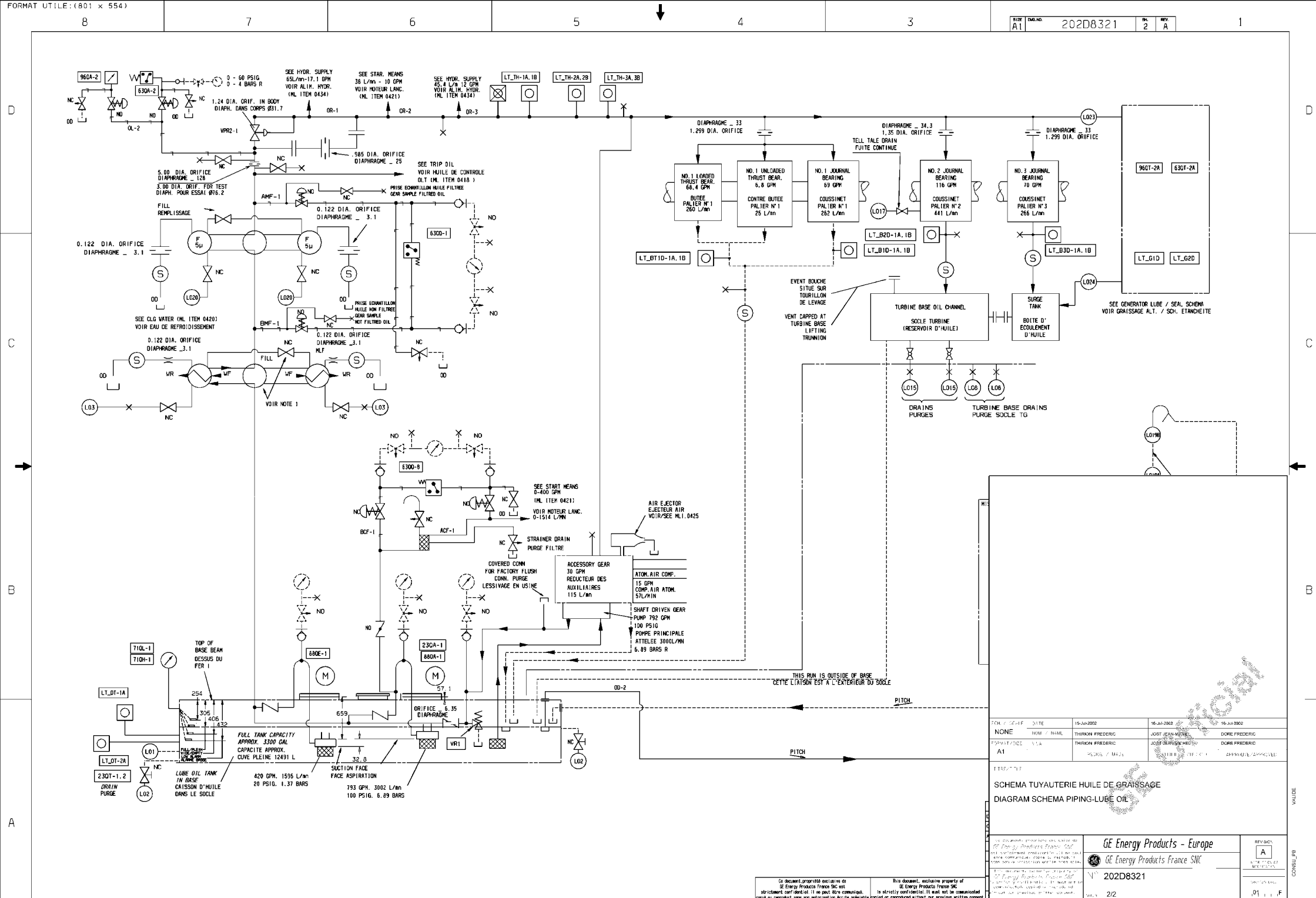
PARAMETERS AT CONNECTIONS

PC	TEMPERATURE			PRESSURE			FLOW			
	MINI	NOMINAL	MAXI	MINI	NOMINAL	MAXI	MINI	NOMINAL	MAXI	TRANSIENT
L017	10°C 50°F	71°C 160°F	86°C 186.8°F	—	1 BAR 14.5 PSIG	—	FUILE CONTINUE PAR GRAVITE TELL TALE DRAIN BY GRAVITY			
L023	10°C 50°F	71°C 160°F	86°C 186.8°F	—	1.8 BARS 26.1 PSIG	—	626 l/min 165.3 GPM	1014 l/min 267.8 GPM	—	—
L024	10°C 50°F	71°C 160°F	86°C 186.8°F	—	1.8 BARS 26.1 PSIG	—	626 l/min 165.3 GPM	1014 l/min 267.8 GPM	—	—
L017A	50°C 122°F	—	80°C 176°F	ATMOSPHERIC			—	—	2 l/h 0.53 GPM	—
L017B	50°C 122°F	—	80°C 176°F	ATMOSPHERIC			—	—	2 l/h 0.53 GPM	—
L018	50°C 122°F	—	80°C 176°F	ATMOSPHERIC			—	—	2 l/h 0.53 GPM	—
L019A	50°C 122°F	—	80°C 176°F	—	—	0.005 BARG 0.072 PSIG	—	2000 m³/h 8805 GPM	—	—
L019B	50°C 122°F	—	80°C 176°F	—	—	0.005 BARG 0.072 PSIG	—	2000 m³/h 8805 GPM	—	—

REV		DESCRIPTION	DATE
A	1	FIRST ISSUE	THIRION F. JUST J.M. DORE F.

DATE / DATE	15-JUN-2002	15-JUN-2002	15-JUN-2002
NONE	NONE / NONE	THIRION FREDERIC	DORE FREDERIC
THIRION FREDERIC	JUST JEAN-MARIE	DORE FREDERIC	DORE FREDERIC
A1	REVISED / REVISE	REVIEWED / REVISE	APPROVED / APPROUVE
SCHEMA TUYAUTERIE HUILE DE GRAISSAGE DIAGRAM SCHEMA PIPING-LUBE OIL			
GE Energy Products - Europe GE Energy Products France SNC 202D8321		REVISED / REVISE A 01	

GE Energy Products - Europe
GE Energy Products France SNC
202D8321



Tab 5

DESCRIPTIVE GUIDE

3.8. HYDRAULIC SUPPLY SYSTEM AND I.G.V.

3.8.1. HYDRAULIC SUPPLY SYSTEM

1 General and simplified schematic (see Figure HS-1)

The main hydraulic supply system utilizes turbine lube oil to supply the high pressure fluid for operating the fuel control valves, or other devices. A typical main hydraulic supply system is shown schematically in Figure HS-1. For the specific application refer to the schematic diagrams, in the Operation guide.

The hydraulic supply system regulates a supply pressure of approximately 1500 psi suitable to modulate oil fuel control valve. The system filters the oil for servovalve use, and includes : accumulators to provide transient flow and prevent hydraulic pressure spikes to devices to protect the turbine if hydraulic pressure becomes inadequate to support essential control functions.

On units where continuous turbine operation is essential, dual hydraulic filters with a transfer valve VM 4, and an auxiliary hydraulic pump are included in the system. A signal from hydraulic pressure switch 63 HQ-1 activates the auxiliary hydraulic pump when the system pressure drops below the control panel value. A quick connection with check valve allows reading of the pressure with a differential pressure gauge.

88 HQ-1 motor is equipped with an heater 23 HQ-1 to prevent condensation when the motor is not operating.

DESCRIPTIVE GUIDE

PART	NOMENCLATURE
23 HQ-1	Space heater - auxiliary hydraulic supply pump motor.
63 HF-1	Hydraulic oil filter differential pressure alarm.
63 HQ-1	Low hydraulic oil supply pressure, auxiliary hydraulic pump start - pressure switch.
88 HQ-1	Auxiliary hydraulic supply pump motor.
AH 1-1,-2	Control oil hydraulic accumulator.
FH 2-1,-2	Hydraulic supply filters.
PH 1	Main hydraulic supply pump.
PH 2	Auxiliary hydraulic supply pump.
VAB 1	Hydraulic system air bleed valve.
VAB 2	Hydraulic system air bleed valve (aux.).
VCK 3-1	Hydraulic pump check valve for main pump.
VCK 3-2	Hydraulic pump check valve for auxiliary pump.
VM 4	Hydraulic filter transfer valve.
VPR 3-1	Compensator - hydraulic supply pump (in pump).
VR 21	Main hydraulic supply pump pressure relief valve.
VR 22	Auxiliary hydraulic pump pressure relief valve.

DESCRIPTIVE GUIDE

2 Major devices and functional description**Main pump**

The primary source of high pressure oil is an accessory gear driven pressure compensated piston pump. The pump's pressure compensator is designed VPR 3-1.

Auxiliary pump

A motor driven 88 HQ-1 fixed displacement pump is provided as a back up to the main pump. While the main pump is at low speed, during the normal starting sequence, the auxiliary pump runs until the 14 HS speed sensor indicates minimum governing speed is reached. Any time the main pump fails to maintain adequate pressure, as sensed by 63 HQ-1 pressure switch, the auxiliary pump is started. When this pump is initiated by the 63 HQ-1 pressure switch, it will continue to run until shut down manually.

Dual filter and transfer valve

A 0.5 micron dual filter assembly FH 2-1 and FH 2-2 complete with fill valve, and transfer valve VM 4 is provided on continuous duty units to maintain clean oil for servovalve use. When dual filters are supplied the following procedure should be followed in transferring from one filter to the other.

- Open the air bleed valve on the unused filter.
- Open the fill valve.
- When oil with air comes out of the air bleed, operate the transfer valve.
- Close the fill valve.
- When no air is contained in oil coming from the air bleed close the bleed valve.

Delta P gauges

A differential pressure gauge 63 HF-1 are provided on each filter to show the amount of pressure drop through it. When one of these gauges indicates a pressure drop of 60 psi, the filter cartridge should be changed. A quick connection with check valve allows reading of the pressure with a differential pressure gauge.

Relief valves

Relief valve VR 22 controls the auxiliary hydraulic pump outlet pressure. Another valve, VR 21, is provided to protect the main hydraulic pump circuit from damage in the event of failure of the main pump pressure compensator.

Check valve

Each hydraulic pump circuit includes a check valve downstream of its relief valve to keep the hydraulic lines full when the turbine is shut-down. These are designated VCK3-1 and VCK3-2.

Air bleed

In each pump circuit, ahead of the check valve, are automatic air bleed valves VAB 1 and VAB 2. These valves close whenever oil is supplied to them at more than 150 psig.

DESCRIPTIVE GUIDE

Manifold

A brazed laminated hydraulic manifold provides a convenient mounting device for relief valves, the air bleed valves, and the check valves. It also includes the connecting network for these devices.

Supply pressure switch.

Pressure switch 63 HQ-1 causes the auxiliary hydraulic pump to start if the hydraulic supply circuit pressure falls below an acceptable running level. Low hydraulic supply pressure is sensed by pressure switch 63 HQ-1, which sounds an alarm. A quick connection with check valve allows reading of the pressure with a differential pressure gauge.

Filter differential pressure gauge

Differential pressure gauges located on the gauge panel indicate the hydraulic supply pressure drop across the filters of the dual filter system, one per filter. When the HP filter is dirty, one pressostat 63 HF-1 give an alarm to the CRT.

Hydraulic accumulator

The accumulator manifold assembly (AH 1-1 and AH 1-2) stabilizes the oil pressure going to the different systems.

DESCRIPTIVE GUIDE

3.8.2. MODULATED INLET GUIDE VANE SYSTEM**General**

Variable compressor inlet guide vanes are installed on the turbine to provide compressor pulsation protection during start-up and shut-down and also to be used during operation under partial load conditions. The variable inlet guide vane actuator is an hydraulically actuated assembly having a closed feedback control loop to control the guide vanes angle. The vanes are automatically positioned within their operating range in response either to the control system exhaust temperature limits for normal loaded operation, or to the control system pulsation protection limits during the start-up and shut-down sequences. Inlet guide vanes are modulated in order to maintain various stresses, pressures and flows within required limits. Their corrected speed control system is a portion of their control system, to accomplish this function.

Guide vane actuation

The modulated inlet guide vane actuating system includes the following components : servovalve 90TV-1, position sensors (LVTD) 96TV-1 and 96TV-2, solenoid valve 20TV and hydraulic dump valve VH3-1. These are shown on the piping diagram here after. When the trip oil OLT is pressurized the dump valve VH3-1 is operated. Actuation of the dump valve allows hydraulic oil to flow through servovalve 90 TV-1. Control of 90 TV-1 will port hydraulic oil through the dump valve to operate the variable inlet guide vane actuator.

For normal shutdown, inlet guide vane actuation is the reverse of the startup sequence ; the compressor bleed valves will open when the generator breaker is opened. The inlet guide vanes will ramp to the full closed position as a function of temperature corrected speed.

In the event of a turbine trip, the 11th stage bleed valves will open and the inlet guide vanes will ramp to the closed position as a function of temperature corrected speed.

Operation

I.G.V. operation is described in GEH 6195 in the "Gas turbine operation guide (MARK V)" volume. The various parameters entering the control and protection system (SPEEDTRONIC) are (Figure MGI-1) :

TA compressor inlet temperature signal (sometimes referred to as CTIM).

CPD compressor discharge pressure signal.

FSR electronic control signal of the fuel.

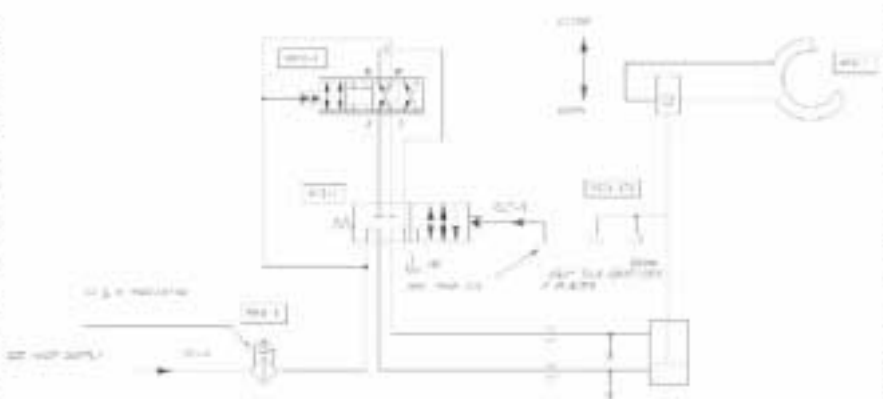
TNH turbine speed signal.

TTXM exhaust temperature signal.

DESCRIPTIVE GUIDE

PART	NOMENCLATURE
90 TV-1	Turbine inlet guide vane (I.G.V.) servo-valve.
96 TV-1,-2	Turbine inlet guide vane L.V.D.T.
FH 6-1	Servo-hydraulic supply filter for I.G.V. assembly.
HM 3-1	Variable inlet guide vane system.
VH 3-1	I.G.V. dump valve hydraulically operated.

FIGURE W04-1 : MODULATED INLET GUIDE VANE HYDRAULIC SYSTEM



NOTES

SEE DEVICE SUMMARY (0414) FOR
CONTROL DEVICE SETTINGS

VOIR NOMENCLATURE POUR CONTROLE
ET REGLAGE DES APPAREILS

REVISIONS				
REV	DESCRIPTION			
A	FIRST ISSUE	DATE	NAMES/NOMS	SIGNATURES
		12 DEC 00	THIRION F.	
		12 DEC 00	THIRION F.	
		12 DEC 00	BITSCH JN.	

SPECIFICATION P&ID	354A3215
NOMENCLATURE	IDENT
LIST OF COMPLEMENTARY DOCUMENTS	
FIRST MADE FOR : MS 9001E	ITEM : 0434

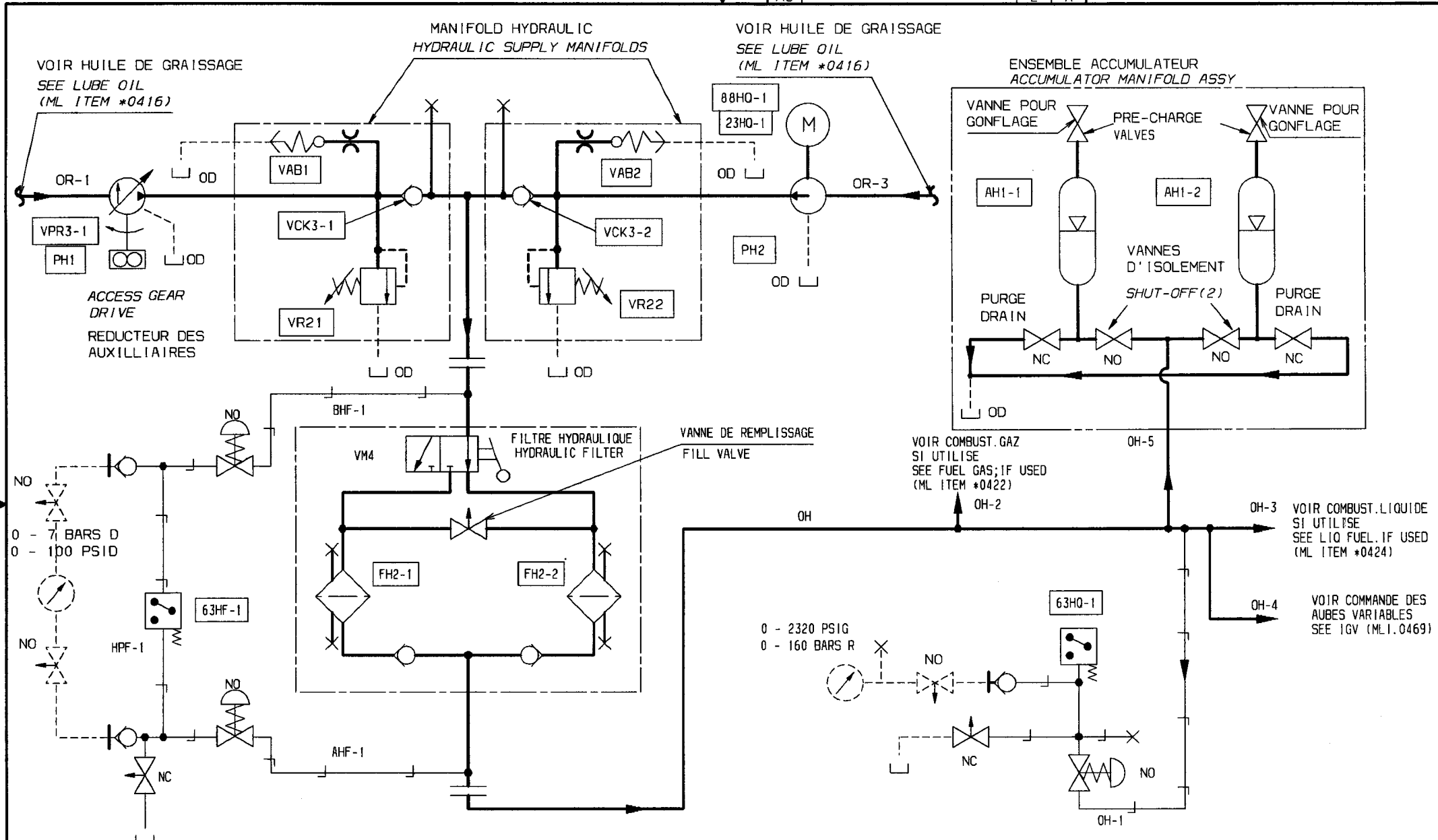
A	A	REV	REV STATUS OF SHEETS
2	1	SH	

OPTIONS BA11B & C

This document, exclusive property of
GE Energy Products France SNC
is strictly confidential. It must not be communicated
copied or reproduced without our previous written consent.

Ce document, propriété exclusive de
GE Energy Products France SNC est
strictement confidentiel. Il ne peut être communiqué,
copié ou reproduit sans son autorisation écrite préalable

SIGNATURES		DATE	 GE Energy Products - Europe GENERAL ELECTRIC COMPANY	
DRAWN	THIRION F.	12 DEC 00		
CHECKED	THIRION F.	12 DEC 00	SCH ALIM.HUILE HP DIAG. SCH. PP-HYD. SUPPLY	
APPROVED	BITSCH JN.	12 DEC 00		
			SIZE A3	CAGE CODE
			DWG. NO. 356B2697	
SIM TO : 356B2747		SCALE	REV. : A	SHEET 1



This document, exclusive property of
GE Energy Products France SNC
is strictly confidential. It must not be communicated
copied or reproduced without our previous written consent.

Ce document, propriété exclusive de
GE Energy Products France SNC est
strictement confidentiel. Il ne peut être communiqué,
copié ou reproduit sans son autorisation écrite préalable.

SIGNATURES		DATE	GE Energy Products - Europe	
DRAWN	THIRION F.	12 DEC 00		
CHECKED	THIRION F.	12 DEC 00		
APPROVED	BITSCH JM.	12 DEC 00		
			SCH ALIM. HUILE HP DIAG. SCH. PP-HYD. SUPPLY	
			SIZE A3	CAGE CODE
			DWG. NO. 356B2697	
SIM TO : 356B2747			SCALE	REV. : A
			SHEET 2	

Tab 6

DESCRIPTIVE GUIDE

3.9. TRIP OIL SYSTEM

3.9.1. GENERAL

The trip oil system is an hydraulic trip system. It is the primary protection interface between the turbine control and protection system and the components on the turbine which admit or shut-off fuel. The system contains devices which are electrically operated through the turbine control panel by SPEEDTRONIC signals as well as some totally mechanical devices. Besides the tripping functions, trip oil also provides a hydraulic signal to the fuel stop valves for normal start-up and shut-down sequences (see Figure TP OIL-1, hereafter).

DESCRIPTIVE GUIDE

3.9.2. PROTECTION COMPONENTS AND DEVICES

Significant protection components on the trip oil system are as follows : (See Figure TP OIL-1)

- Lube oil inlet orifice

An orifice, sized to limit lube oil flow into the trip oil system, is located in the pipe running from the bearing header supply to the trip oil system. It must ensure adequate capacity for all tripping device operation and prevent starvation of the lube oil system when the trip oil system is tripped.

- Dump valves

Solenoid valve 20 FG-1 is a spring biased spool valve which dumps trip oil pressure to drain causing the stop/ratio and gas control valves to trip shut. The valve is deenergized to trip and energized to reset from the SPEEDTRONIC control panel. It is spring biased to trip and, therefore, protects the turbine during all normal situations as well as for loss of dc power.

Solenoid valve 20 TV-1 is a spring return valve used in the I.G.V. (Inlet Guide Vane) system. The valve is energized when the turbine is running. Functionally it dumps lube oil pressure to I.G.V. trip relay valve VH 3-1 and stops the fuel flow.

- Orifice network

At the inlet of each individual fuel branch is an orifice network which limits flow into and out of the fuel branch. This network limits flow into each branch allowing individual fuel control without total system pressure decay.

- Pressure switches

Fuel branch contain three pressure switches 63 HG-1, -2, -3 which will insure tripping of the turbine if the trip pressure becomes too low for reliable operation while operating on that fuel. Trip is only valid if two pressure switches a low pressure (voting logic). A quick connection with check valve allows reading of the pressure with a differential pressure gauge.

DESCRIPTIVE GUIDE

3.9.3. OPERATION

The tripping devices which cause shut down through this system do so by dumping low pressure oil (OLT). See Figure TP OIL-1. This is done either directly or indirectly through electrohydraulic dump valves 20 FG-1 or 20 TV-1.

When oil in the trip oil line is dumped, fuel stop valves close by spring return action. At the proper point in the starting sequence, dump valves 20 FG-1 and 20 TV-1 are energized permitting oil pressure to open the fuel stop valves and inlet guide vanes. The fuel stop valves remain open until some trip action occurs or until the unit is shut down.

In the gas fuel circuit (see in 03.06.03, Figure GF-1), dump valve VH 5 ports the gas stop/ratio valve hydraulic actuation cylinder to drain to close stop/ratio valve VSR and to servovalve 90 SR hydraulic oil discharge port to permit stop/ratio valve control of gas fuel. VH 5 is pilot operated by trip oil.

Likewise, dump valve VH 12 ports the gas control valve hydraulic actuation cylinder to drain to close gas control valve VGC and to servovalve 65 GC hydraulic oil discharge port to permit gas control valve control of gas fuel. VH 12 is pilot operated by trip oil.

The tripping devices which cause selective fuel system shut-down, do so by dumping low pressure oil (OLT). The fuel stop valve may be selectively closed by dumping the flow pressure oil going to it. Dumping valve 20 FG-1 causes the trip relay on the gas fuel stop/ratio valve and the gas control valve to the trip state, which permit their spring returned closure.

The orifice and orifice network permits independent dumping of each branch of the trip oil system by its dump valve. Tripping all devices other than the individual dump valves, will result in dumping the total trip oil system which shut the unit down.

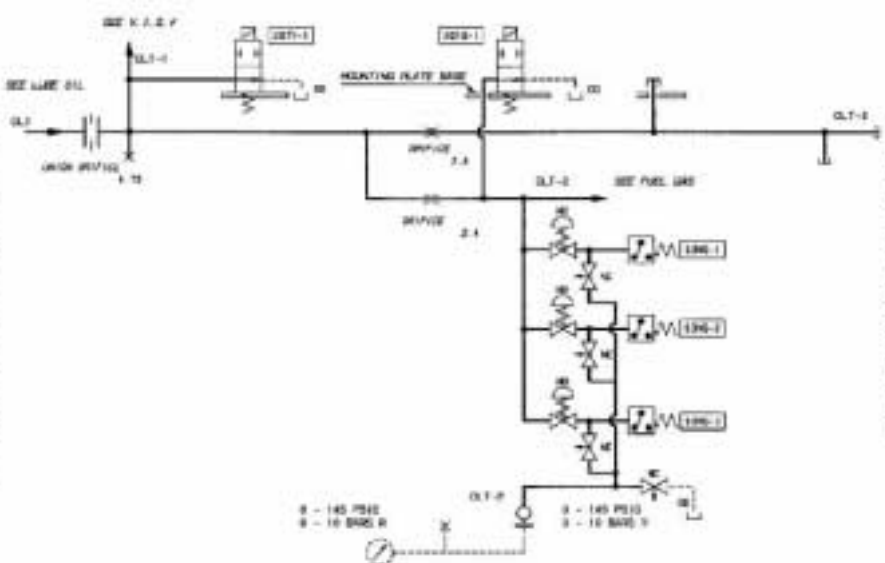
The orifice and orifice network permits independent dumping of the trip oil system by its dump valve. Tripping all devices other than the dump valve, will result in dumping the total trip oil system which shut the unit down.

DESCRIPTIVE GUIDE

PART	NOMENCLATURE
20 FG-1	Gas fuel stop valve, solenoid valve.
20 TV-1	I.G.V. hydraulic dump solenoid valve.
63 HG-1,-2,-3	Hydraulic trip pressure for gas fuel stop valve. Pressure switch.

DESCRIPTIVE GUIDE

FIGURE TO-1: TRIP OIL SYSTEM DIAGRAM



NOTES

VOIR NOMENCLATURE DES APPAREILS
POUR REGLAGE DES APPAREILS DE CONTROLE

SEE DEVICE SUMMARY FOR
CONTOL DEVICE SETTINGS

SYMBOLS PIPING	GE-277A2415
COMPL. DOC.	DOC. N°

SIMILAIRE A : 91-312423				PREM. EXECUTION : MS 9001E				O	M	K
SIMILAR TO :				FIRST MADE FOR :						
OPTION: STD	B	IM-2000002932	23 OCT 00	THIRION F.	~~THIRION F.~~	THIRION F.	~~THIRION F.~~	BITSCH JM.	~~BITSCH JM.~~	
	A	IM-1999001965	17 SEP 99	COURTOT JF	~~COURTOT JF~~	COURTOT JF	~~COURTOT JF~~	DUGUET P.	~~DUGUET P.~~	
ITEM: 0418	Indice	N° Instruction Modif	Date	Nom	Visa	Nom	Visa	Nom	Visa	
MODIFICATIONS				MODIFIE		VERIFIE		APPROUVE		

APPROUVE	02 SEP 98	REICHHART T.		TITRE	SCH. HUILE DE CONTROLE				
VERIFIE	02 SEP 98	GOEMINNE Y.		TITRE	DIA. SCH. PP-TRIP OIL				
DES. / RED.	02 SEP 98	HYSYS							
QA : C	Date	Nom	Visa						
INFO. INTERNE		LANGUE F/E	BELFORT	SECT. DOC.	GE Energy Products - Europe				
DIFFU	NATURE	EMETTEUR	FORMAT	CONT. PAGE	PAGE				
2	SH	91 A	A3	2	1	91-315584			

B
A

SIMILAIRE A: 91-312423				PREM. EXECUTION: MS 9001E				O	M	K	DES./RED.	CE	SE	NO	INSTR	QA : C	Dates	Noms	Visas	GE Energy Products - Europe		
OPTION: STD				B	IM-2000002932	23 OCT 00	THIRION F.	~~THIRION F.~~	THIRION F.	~~THIRION F.~~	BITSCH JM.	~~BITSCH JM.~~			LANGUE	F/E	BELFORT		SECT. DOC	01		
ITEM: 0418				A	IM-1999001965	17 SEP 99	COURTOT JF	~~COURTOT JF~~	COURTOT JF	~~COURTOT JF~~	DUGUET P.	~~DUGUET P.~~			DIFFU	NATURE	EMETTEUR	FORMAT	CONT. PAGE	PAGE	91-315584	
				Index	N°	Instruction	Modif	Date	Nom	Visa	Nom	Visa	Nom	Visa	2	SH	91 A	A3	F	2	A	
				MODIFICATIONS			MODIFIE			VERIFIE			APPROUVE									

Tab 7

DESCRIPTIVE GUIDE

3.6. FUEL SYSTEM(S)**3.6.1. DUAL FUEL SYSTEMS : GENERAL****1 General**

The fuel requirements of the gas turbine are satisfied by either of two fuel systems (dual fuel) that use both mechanical handling and electrical control components. Fuel nozzles, capable of burning either of the two type fuels, natural gas and distillate oil, are incorporated in the design.

A liquid fuel system that pumps and distributes fuel from the off-base fuel forwarding system is used to supply the distillate oil flow to the 14 combustion nozzles. When operating on natural gas, a system that includes gas strainers and flow control valves delivers a flow of gas fuel to these nozzles.

The text that follows describes the components and the operation of both fuel systems, in addition to the method of changeover from one type fuel to the other.

2 Dual fuel operation**Fuel changeover**

On dual fuel machines with automatic control, the fuel changeover is initiated manually through the fuel selector membrane switch 43 F or automatically by the fuel gas pressure transmitter 96 FG-3. Once initiated, the changeover proceeds automatically to operation on the other fuel system.

The manually initiated changeover is accomplished by depressing the desired (either gas or distillate) fuel selector membrane switch 43 F and the "EXECUTE" membrane switch. The automatically initiated changeover occurs only when the transfer is from gas to oil fuel operation. The signal for automatic changeover is given by the fuel gas pressure transmitter 96 FG-3, which operates when the fuel gas pressure drops below a preset value. In normal operation, the desired fuel is selected at startup by depressing either the GAS or DISTILLATE membrane switch (not MIXTURE). If startup was made on gas fuel, changeover to oil (or, distillate) fuel will occur automatically upon loss of the gas fuel pressure. Automatic changeover will only occur after the gas turbine has reached operating speed (14HS is picked up). Operation on oil (or, distillate) fuel will continue until gas fuel pressure is reestablished and changeover is initiated MANUALLY by pressing the DISTILLATE fuel selector membrane switch 43 F first, then the GAS fuel selector switch. Thus the transfer back to gas fuel is NOT automatically initiated.

A gradual transition (lasting 30-60 secs) is required to change from fuel gas to fuel oil system. Oil lines are purged of air and filled with oil to avoid delaying delivery of oil when, at the end of transition, oil requirements begin to increase.

DESCRIPTIVE GUIDE

3 NOTE :

- On dual fuel machines, equipped with an atomizing air system, some atomizing air is diverted to purge liquid fuel nozzles and prevent their coking during operation on gas fuel.
- Fuel oil and gas fuel RECOMMENDATIONS are included in the Gas turbine equipment publications volumes.
- For the detailed drawings of the liquid fuel system and its settings, and those of the gas fuel system and its settings, see the Gas turbine operation guide volumes), the Piping systems schematic, as well as for the Control specifications.

DESCRIPTIVE GUIDE

3.6.3. GAS FUEL SYSTEM**1 General**

The gas fuel system is designed to deliver gas fuel to the turbine combustion chambers at the proper pressure and flow rates to meet all of the starting, acceleration and loading requirements of gas turbine operation. A schematic diagram of the gas fuel system is provided in Figure GF-1.

The major components of a gas fuel system are the gas stop/ratio and gas control valves located in the gas fuel module. Associated with the two gas valves are the necessary inlet piping and strainer, fuel vent valve, control servovalves, pressure gauges and the distribution piping to the 14 combustion fuel nozzles.

The fuel gas stop ratio valve and the gas control valve, two independent valves, are located side by side in the gas fuel piping of the module. The gas fuel flows through the gas stop ratio valve and then into the gas control valve on its way to the gas manifold and individual combustion chambers. The position of each valve is servo controlled by electrical signals from the gas turbine SPEEDTRONIC control system. Both the gas stop ratio valve and the gas control valve are actuated by single-acting, hydraulic cylinders.

The following major components comprise the gas fuel system :

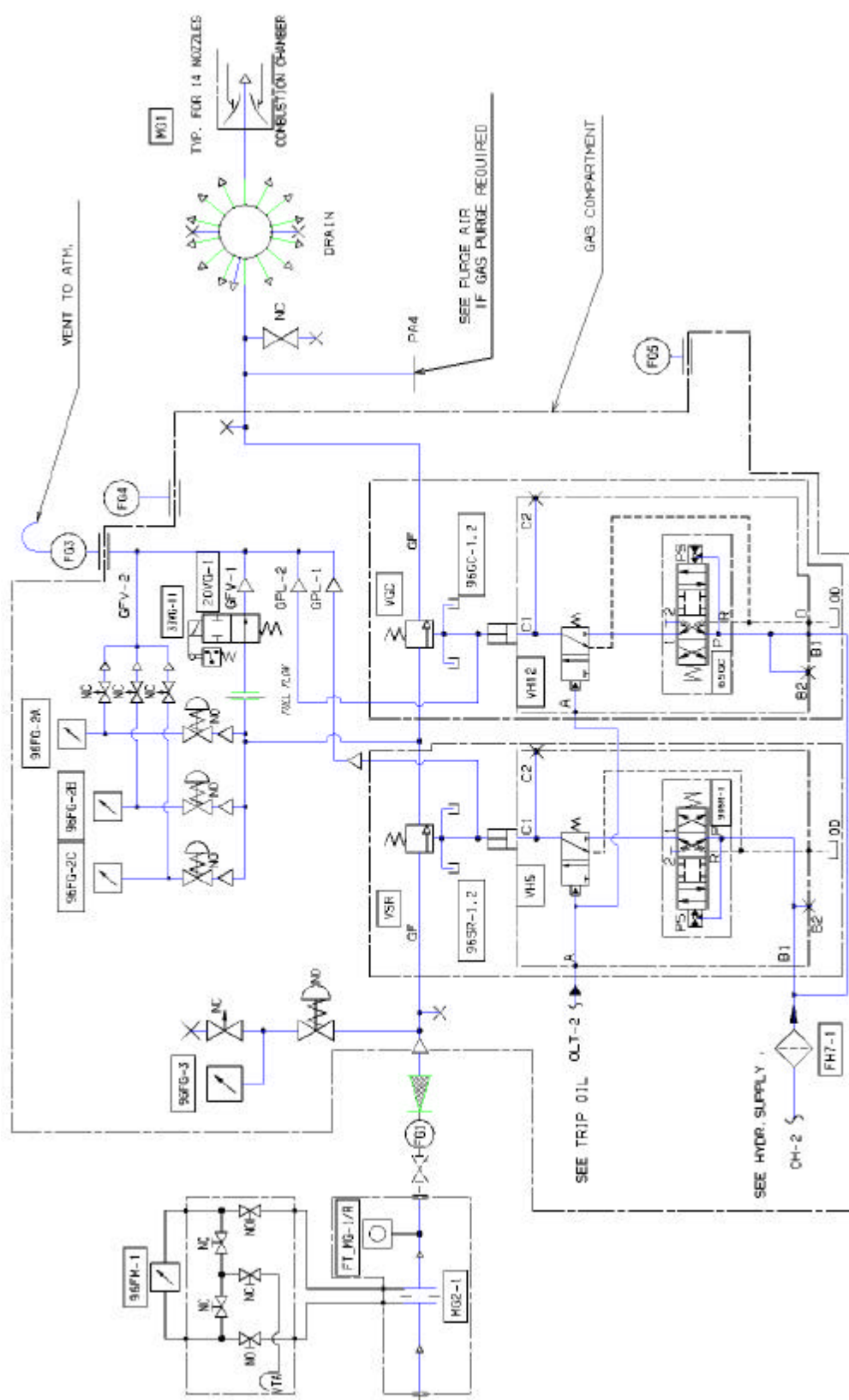
- Strainer
- Fuel gas supply pressure alarm switch
- Gas stop ratio valve VSR
- Gas control valve VGC
- Stop ratio LVDT 96 SR-1,-2
- Gas control valve LVDTs 96 GC-1, -2
- Stop ratio valve-control servovalve 90 SR-1
- Gas control valve-control servovalve 65 GC
- Gas fuel dump valves VH 5 and VH 12
- Gas fuel vent solenoid valves 20 VG-1 and -2
- Lines to the 14 combustion chambers

DESCRIPTIVE GUIDE

PART	NOMENCLATURE
20 VG-1	Gas fuel vent solenoid valve.
33 VG-11	Limit switch on solenoid valve 20 VG-1.
65 GC	Gas control valve (servo-valve).
90 SR-1	Stop/speed (pressure) ratio valve servo-valve.
96 FG-2A,-2B,-2C	Fuel gas pressure transmitter.
96 FG-3	Fuel gas supply pressure transmitter.
96 FM-1	Mass flow transmitter.
96 GC-1,-2	Gas control valve L.V.D.T. (Liner variable differential transformer).
96 SR-1,-2	Stop/speed (pressure) ratio valve L.V.D.T.
FH 7-1	Gas fuel hydraulic supply filter.
FT_MG-1R	Resistive temperature device connected to 96 FM-1.
MG 1	Gas fuel nozzle.
MG2-1	Gas fuel meter tube – orifice.
VGA	Gas valve assembly.
VGC	Gas control valve.
VH 5	Gas fuel dump valve - stop ratio valve.
VH 12	Gas fuel dump valve - gas control valve.
VSR	Fuel gas stop/ratio valve.
All right reserved Copyright – Droits de reproduction réservés 9e_m3_c6_p3 opt 1.13.doc	
Revision : A	
Date : 02/09	

DESCRIPTIVE GUIDE

FIGURE GF-1 : GAS FUEL SYSTEM SCHEMATIC



All right reserved Copyright – Droits de reproduction réservés

DESCRIPTIVE GUIDE

2 Functional description of the gas fuel system**General**

The gas control valve and the gas stop ratio valve, although similar, each perform separate functions. The fuel gas control valve meters fuel for use by the combustion chambers. It is activated by a SPEEDTRONIC control signal to admit the proper amount of fuel required by the turbine for a given load or speed. The fuel gas stop ratio valve is a dual function valve. It serves as a stop valve to shut off fuel flow to the turbine whenever required during either normal operation or in an emergency shut-down situation.

The stop ratio valve also serves as a pressure regulating valve to hold a known fuel gas pressure ahead of the gas control valve and enable the gas control valve to control fuel flow over the wide range required under turbine starting and operating conditions. Because of these dual functions the valve is sometimes called a stop/speed ratio valve.

Mass flow transmitter

On the purchaser's connection the electronic mass flow transmitter 96 FM-1 which provides a current output signal in direct proportion to a flow measurand when provided with DC voltage excitation. The transmitter uses two wire for power supply, output signal and digital communication.

The mass flow transmitter 96 FM-1 includes a capacitive type pressure transducer and signal amplifier. Pressure ports are isolated from the electronics by two outer isolating diaphragms and one internal sensing diaphragm.

Gas strainer

A gas strainer is located in the purchaser's gas fuel supply line ahead of the gas strainers. Foreign particles that may be in the incoming fuel gas are removed by the strainer. A blow-down connection on the bottom of the strainer body provides for periodic cleaning of the strainer screen. Frequency of cleaning will depend on the quality of the fuel gas being used. The strainer should be cleaned shortly after full turbine load has been attained for the first time and after any disassembly of the purchaser's fuel gas lines.

Gas stop/ratio and gas control valves

The gas control valve regulates the required control valve area and utilizes an hydraulic cylinder controlled by an electrohydraulic servovalve.

The gas control valve provides a fuel gas metering function to the turbine in accordance with its speed and load requirements. The position of the gas control valve (hence fuel gas flow to the turbine) is a linear function of a Fuel stroke reference voltage (FSR) generated by the SPEEDTRONIC control. The control voltage generated acts to shift the electrohydraulic servovalve to admit oil to, or release it from, the hydraulic cylinder to position the gas control valve so that the fuel gas flow is that which is required for a given turbine speed and load situation.

The gas control valve also provides a shut-off of the fuel gas flow when required by either normal operation or emergency conditions. A hydraulic trip relay (dump valve) VH12 is located between the electrohydraulic servovalve 65 GC and the hydraulic cylinders. The operation of this dump valve is the same as the trip relay (dump valve) VH5.

The gas stop/ratio valve is similar to the gas control valve. The ratio function of the stop ratio/valve provides a regulated inlet pressure for the control valve as a function of turbine

DESCRIPTIVE GUIDE

speed. The SPEEDTRONIC pressure control loop generates a position signal to position the stop ratio valve by means of a servovalve controlled hydraulic cylinder to provide required interval pressure.

The gas stop ratio valve functions as a stop valve in the fuel gas system to provide a positive fuel shut off when required by either normal or emergency conditions. Any emergency trip or normal shut-down will trip the valve to its closed position. This is done either by dumping hydraulic oil from the valve's hydraulic cylinder or driving the position control closed electrically. A dump valve VH 5 is operated by trip oil acting on the piston end of a spool. An hydraulic trip solenoid valve, 20 FG-1, is located in the trip oil line to the dump valve. When the trip oil pressure is normal and the 20 FG-1 solenoid valve is energized to reset, the spool of the dump valve is held in a position that allows hydraulic oil to flow between the control servovalve and the hydraulic cylinder. In this position, normal control of the stop ratio valve is allowed.

In event of a drop in trip oil below a predetermined limit, a spring in the dump valve shifts the spool to interrupt the flow path of oil between the control servovalve and the hydraulic cylinder. Hydraulic oil is dumped and the ratio valve closes, shutting off gas fuel flow to the turbine.

Gas fuel system protective devices

- Gas pressure transmitter

A low gas pressure transmitter 96 FG-3 is installed in the gas piping ahead of the gas stop/ratio valve assembly. This switch initiates a gas fuel pressure low alarm when gas supply pressure drops below the switch setting. It also initiates a transfer to liquid fuel if gas supply pressure drops below its setpoint.

- Gas fuel vent valves

Solenoid-operated valve 20 VG-1 is installed in the vent piping between the gas stop/speed ratio and gas control valve. When the turbine is shut down, any gas fuel that might accumulate in the compartment between the stop/speed ratio and gas control valves, vents to atmosphere through the piping. It also ensures that no gas fuel will leak past the closed gas control valve to collect in the combustors or exhaust.

Limit switch 33VG-11 controls the full opening of the 20 VG-1, if not it activates an alarm.

- Pressure transmitters

Pressure transmitters, 96 FG-2A, -2B, -2C are installed in the fuel system on the gas fuel discharge side of the stop/speed ratio valve, to provide the operational pressure feedback signal to the SPEEDTRONIC control system. The dc voltage output signal is the median of the 3 transmitters readings.

- Servo-hydraulic supply filters

A filter (FH 7-1) is installed in the hydraulic supply to the speed ratio and gas control valve servo-valves 90 SR and 65 GC to provide 15 microns filtration. A high filter differential pressure indicator is included.

DESCRIPTIVE GUIDE

- Fuel manifolds and nozzles

Fuel from the control valve is distributed through the manifold to the fuel nozzle assemblies mounted in each combustion chamber. Fuel from the nozzles is mixed with air in the combustion liner where combustion takes place.

NOTES:

- 1 -VOIR NOMENCLATURE POUR REGLAGE ET CONTROLE DES APPAREILS
- 2 -FG4: SORTIE AIR VERS EXTERIEUR PACKAGE ACOUSTIQUE
AVEC VENTILATEUR D'EXTRACTION
FG5: ENTREE AIR DEPUIS EXTERIEUR PACKAGE ACOUST.
- 3 -FILTRE TEMPORAIRE A DEMONTER APRES 500 HEURES DE FONCTIONNEMENT.
- 4 -LE CLIENT DOIT METTRE EN PLACE UNE VANNE D'ARRET
GAZ AVANT LA CABANE GAZ AINSI QU'UNE VANNE DE MISE
A L'EVEN T ENTRE LA VANNE D'ARRET ET LA CABANE GAZ.
- 5 -VOIR MLI.0302 POUR LES DETAILS DE L'INSTALLATION ET
DES CONNEXIONS PAR LE CLIENT DE LA MANCHETTE GAZ MG2-1.
- 6 -SUIVRE LES IMPOSITIONS DE ANSI/API 2530-1985
POUR LES LONGUEURS DE TUYAUTERIE EN AMONT ET EN AVAL
DE LA MANCHETTE GAZ MG2-1.
- 7 -INSTALLER LA MANCHETTE GAZ MG2-1 A L'EXTERIEUR.
- 8 -LE DIAMETRE DE L'ORIFICE SERA CALCULE PAR LE FOURNISSEUR ET DISPONIBLE DANS MLI 0639

9 - LE CLIENT DOIT RESPECTER EN FG3 LES CONDITIONS SUIVANTES: PRESSION MAX=0,5Bar eff POUR UN DEBIT MASSIQUE = 0,074KG/S

- 1 -SEE DEVICE SUMMARY FOR CONTROL DEVICE SETTINGS
- 2 -FG4: AIR OUTLET TO OUTSIDE ACOUSTIC ENCLOSURE WITH SUCTION FAN
FG5: AIR INLET FROM OUTSIDE ACOUSTIC ENCLOSURE
- 3 -TEMPORARY FILTER TO BE REMOVED AFTER APPROXIMATELY 500 HOURS.
- 4 -THE CUSTOMER HAS TO PUT A GAS STOP VALVE
UPSTREAM THE GAS COMPARTMENT AND A VENT VALVE
BETWEEN CUSTOMER STOP VALVE AND THE GAS COMPARTMENT.
- 5 -SEE MLI.0302 FOR PURCHASE CONNEXION AND INSTALLATION
DETAILS OF METER TUBE MG2-1.
- 6 -FOLLOW ANSI/API 2530-1985 REQUIERMENTS FOR PIPE LENGH
PRECEDING AND FOLLOWING METER TUBE MG2-1.
- 7 -LOCATE METER TUBE MG2-1 OUTSIDE OF BUILDING.
- 8 -THE DIAMETER OF THE ORIFICE WILL BE CALCULATED BY THE SUPPLIER AND AVAILABLE IN MLI 0639

9 - THE CUSTOMER WILL HAVE TO RESPECT THE FOLLOWING CONDITIONS:
PRESSURE MAX =0,5Bar eff FOR A FLOW = 0,074KG/S

REVISIONS		
REV	DESCRIPTION	
A	FIRST ISSUE	NAMES/NOMS
		THIRION F.
		JOST JM.
B	IM-2002005730	CAGNE S.
		TECHNICREA MZ
		JOST JM
		CAGNE S
C	IM-2002006634	THIRION F
		CAGNE S
		TECHNICREA JR

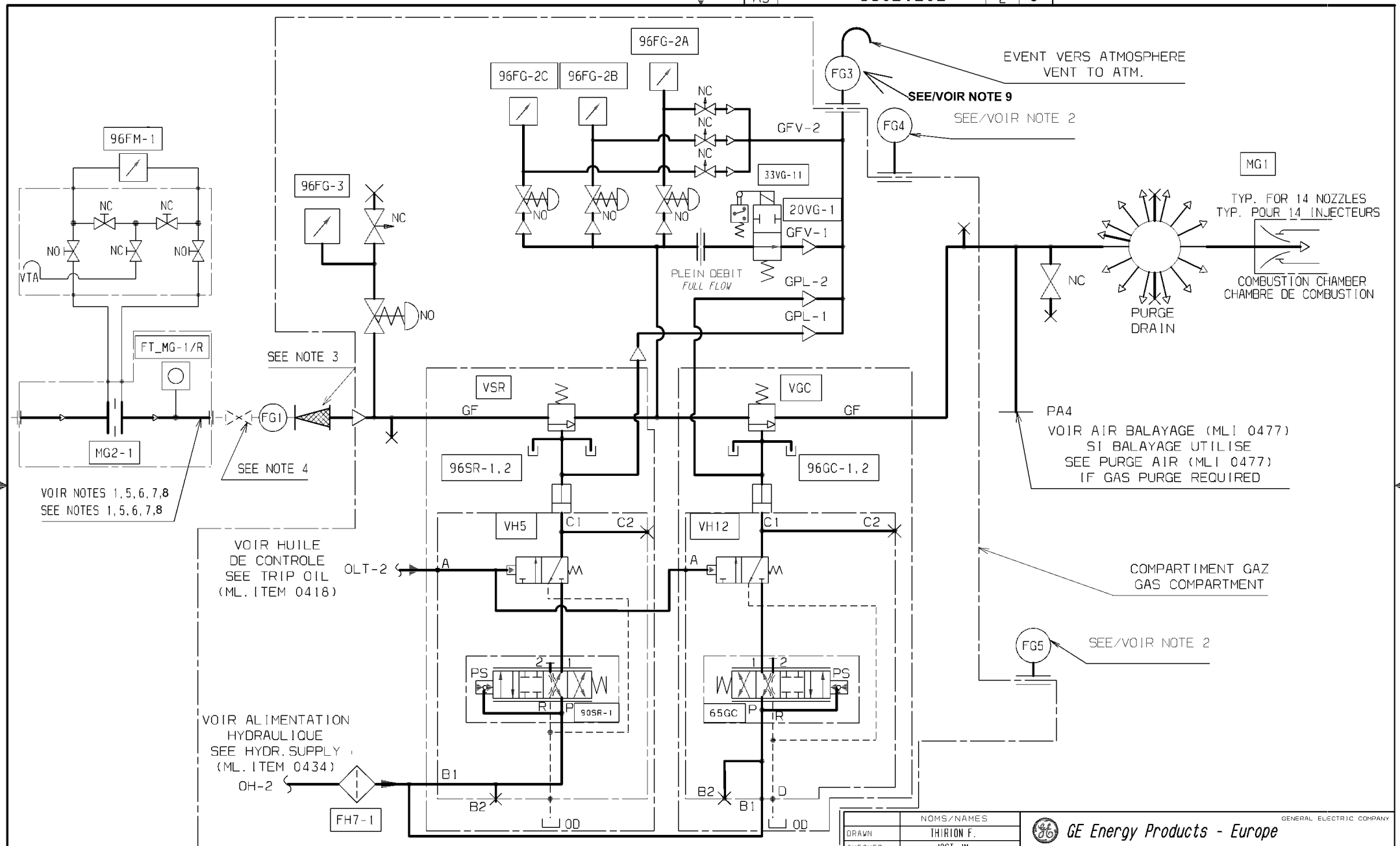
SYMBOLS PIPING	277A2415
NOMENCLATURE	IDENT
LIST OF COMPLEMENTARY DOCUMENTS	
FIRST MADE FOR : MS 9001E	ITEM : 0422

C	C	REV	REV STATUS
2	1	SH	OF SHEETS

This document, exclusive property of
GE Energy Products France SNC
is strictly confidential. It must not be communicated
copied or reproduced without our previous written consent.

Ce document, propriété exclusive de
GE Energy Products France SNC est
strictement confidentiel. il ne peut être communiqué,
copié ou reproduit sans son autorisation écrite préalable

		NOMS/NAMES		 <i>GE Energy Products - Europe</i>		GENERAL ELECTRIC COMPANY	
DRAWN		THIRION F.		SCHEMA TUYAUTERIE GAZ DIAG. SCH. PP-FUEL GAZ			
CHECKED		JOST JM.					
APPROVED		CAGNE S.					
				SIZE A3			
				CAGE CODE		DWG. NO.	
						360B1202	
SIM TO : 91-315585 REV:C				SCALE		REV. : C	
						SHEET 1	



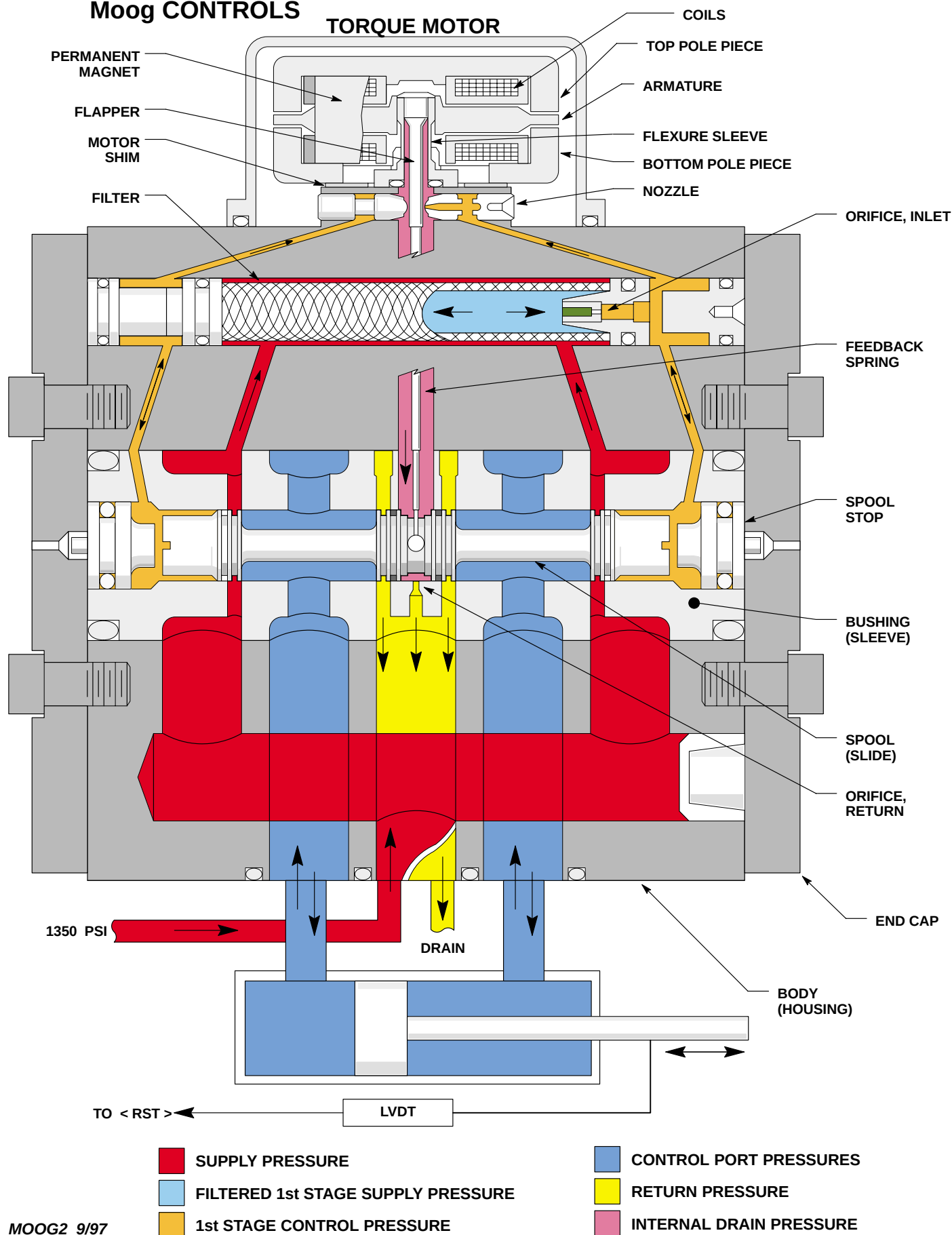
This document, exclusive property of
GE Energy Products France SNC
is strictly confidential. It must not be communicated
copied or reproduced without our previous written consent.

Ce document, propriété exclusive de
GE Energy Products France SNC est
strictement confidentiel. Il ne peut être communiqué,
copié ou reproduit sans son autorisation écrite préalable.

		NOMS/NAMES		GENERAL ELECTRIC COMPANY	
DRAWN		THURTON F.		 GE Energy Products - Europe	
CHECKED		JUST JM.			
APPROVED		CAGNE S.			
		SCHEMA TUYAUTERIE GAZ DIAG. SCH. PP-FUEL GAZ			
		SIZE	CAGE CODE	DWG. NO.	360B1202
		A3			
SIM TO : 91-315585 REV:C		SCALE	REV. : C	SHEET 2	

Servo Valve Overview

Moog CONTROLS



Tab 8

DESCRIPTIVE GUIDE

3.6.2. FUEL OIL SYSTEM

The liquid fuel (distillate oil) system pumps and distributes fuel as supplied from the fuel forwarding system, to the fourteen fuel nozzles of the combustion system. The fuel system filters the fuel and divides the fuel flow into 14 equal parts for distribution to the combustion chambers at the required pressure and flow rates.

Controlling the position of the fuel pump bypass valve VC3-1 regulates the amount of fuel input to the turbine combustion system by varying the amount of bypassed fuel. Information on control of the fuel system is provided in the "Control and protection systems" in this volume.

The fuel system shown in the schematic diagram, Figure LF-1 is comprised of the following major components plus several other control devices, switches and gauges.

- Fuel oil strainer
- Fuel oil stop valve VS1
- Liquid fuel pump PF1
- Fuel pump discharge relief valve VR-4
- Fuel bypass valve VC3-1
- High-pressure fuel filters FF2-1
- Flow divider or fuel distributor FD1-1
- Fuel line check valves
- Fuel nozzle assemblies
- False start drain valves

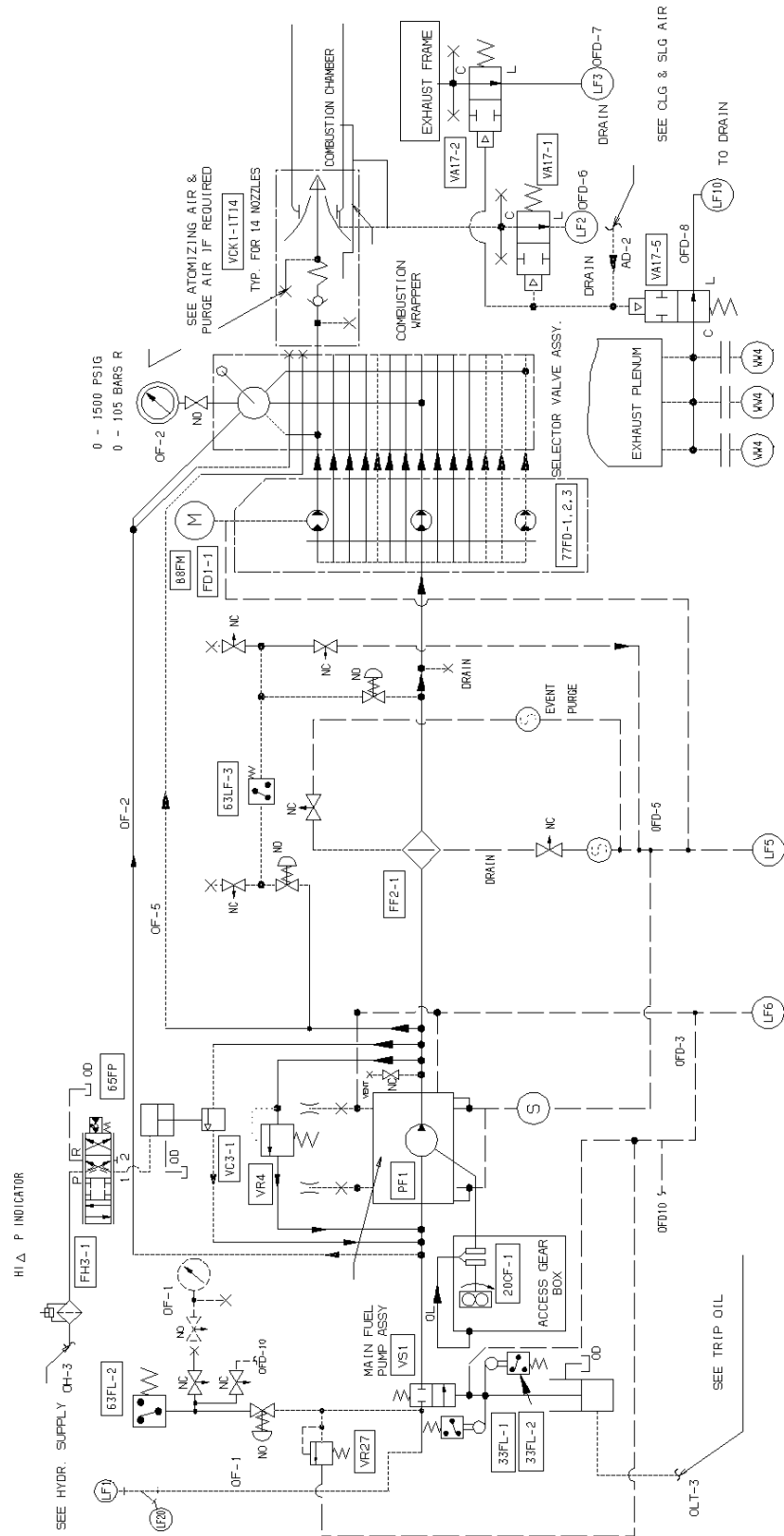
Control devices also associated with the fuel system include : the liquid fuel pressure switch 63 FL-2, servovalve 65 FP that controls the fuel bypass valve, fuel pump clutch solenoid 20 CF-1, and permissive limit switches 33 FL-1 and -2.

DESCRIPTIVE GUIDE

PART	NOMENCLATURE
20 CF-1	Fuel clutch solenoid.
33 FL-1,-2	Liquid fuel stop valve limit switch.
63 FL-2	Liquid fuel pressure upstream of stop valve.
63 LF-3	Liquid fuel pressure switch.
65 FP	Liquid fuel pump bypass valve servo-valve.
77 FD-1,-2,-3	Flow divider magnetic pickup speed.
88 FM	Flow divider starting motor.
FD 1-1	Flow divider.
FF 2-1	Secondary (high pressure) fuel filter.
FH 3	Hydraulic supply filter. Liquid fuel servo.
PF 1	Main fuel oil pump.
VA 17-1	False start drain valve. Combustion wrapper.
VA 17-2	False start drain valve. Exhaust frame.
VA 17-5	Exhaust plenum drain valve.
VC 3-1	Bypass control valve.
VCK 1-1(1 T 14)	Liquid fuel nozzle check valve.
VR 4	Main fuel pump pressure relief valve.
VR 27	Fuel oil pressure relief valve.
VS 1	Fuel oil stop valve.

DESCRIPTIVE GUIDE

FIGURE LF-1 : LIQUID FUEL SYSTEM DIAGRAM



All right reserved Copyright – Droits de reproduction réservés

DESCRIPTIVE GUIDE

- Functional description of the fuel oil system

- Low fuel oil strainer

Fuel oil at low pressure from the fuel forwarding system, flows through a low pressure oil filter (strainer) and fuel stop valve prior to entering the fuel pump. The type strainer housing contains a filter screen to remove any extraneous particulate residue left in the fuel lines after installation. The strainer screen is to be removed after the initial 600 hours of operation and the strainer housing must be cleaned and flushed upon removal of the screen prior to placing the turbine into service. Clean fuel is normally supplied to the turbine system ; however, during this initial period the low-pressure fuel strainer prevents contaminants from entering the fuel oil stop valve and the fuel pump, thereby preventing possible damage or improper functioning of these components.

- Fuel oil stop valve

Fuel oil stop valve VS 1 is an emergency valve, operated from the protection system, which shuts off the supply of fuel to the turbine during normal or emergency shutdowns. This valve is a special purpose, hydraulically operated, two positions (open and closed) valve with a venturi disc and valve seat. When the turbine is shut down in the normal sequence, or by an emergency, the fuel oil stop valve will fully close within a 0.5 second total elapsed time. During normal operation of the turbine the fuel trip valve is operated by electrical information issued from the SPEEDTRONIC in normal conditions, the fuel trip valve 20 FL is held in a position that allows hydraulic oil to flow between the control servovalve and the hydraulic cylinder. For normal start up and shutdown sequence operation and for electrical trips from the control panel, an electrohydraulic trip servo-valve shuts off the hydraulic oil flow to the fuel oil stop valve hydraulic cylinder. The spring in the fuel oil stop valve then overcomes the oil pressure and closes the valve.

- Fuel pump

The fuel pump PF1 is a positive displacement continuous output screw type pump with two sets of opposed screws. The integral shaft screws are end mounted in roller bearings that are oil lubricated. The bearings and timing gears are supplied with lube oil from the main lube oil header and are sealed off from the fuel oil pumping chamber by internal mechanical seals.

The pump is driven directly from the turbine driven accessory gear ; therefore, fuel pump speed is directly proportional to turbine speed. The fuel pump discharge flow at any given turbine speed is greater than the turbine combustion requirements at that speed.

Liquid fuel pressure switch 63 FL-2 indicates that inlet fuel pressure is established. It is used as a permissive to energize the fuel pump clutch solenoid 20 CF-1. In case of loss of pressure while the turbine is running, 63 FL-2 will trip the turbine.

- Fuel pump discharge relief valve

The fuel pump discharge relief valve, VR-4, is located in a loop between the discharge and inlet of the pump. The valve prevents the fuel oil pressure from getting high

DESCRIPTIVE GUIDE

enough to rupture any lines in the event of a flow divider malfunction or freeze up. This valve is set to operate in the range of 1200 to 1300 psi and relieves back into the inlet pipe.

- Fuel bypass valve

High pressure flow from the pump is modulated by the servocontrolled bypass valve assembly VC3-1. Components of this assembly include the bypass valve body, electrohydraulic servovalve 65 FP, and the hydraulic cylinder. This bypass valve is connected between the inlet and discharge sides of the fuel oil pump and meters the flow of fuel to the turbine by subtracting excess fuel delivered by the pump and bypassing it back to the pump inlet.

Servovalve 65 FP controls the bypass valve position according to the difference requirement and the sensed fuel flow. If the fuel requirement exceeds the actual oil flow, the bypass valve closes to increase the net oil flow to the turbine. The servovalve uses high pressure hydraulic oil (OH) (cleansed of contaminants by a metal filter FH3-1) to actuate the hydraulic cylinder and thus position the bypass valve.

- High pressure fuel filter

Fuel oil pump discharge pressure passes through the secondary (high pressure) fuel filter FF2-1 as it flows from the fuel pump to the flow divider. This full flow, high pressure filter helps to assure that contaminants and pipe scale are retained and prevented from entering the flow divider, thereby preventing possible damage or improper operation of this component.

There is one filters FF2-1, with a manuel transfer valve, equipped with isolating valves. A panel mouted differential manometer is connected to indicate directly the pressure drop through the filter.

There is one filter equipped with isolating valves. Filter differential pressure is controlled by 63 LF-3 pressure switch. Should the pressure increases above a preset value indicating fouling of the filter, pressure switch 63 LF-3 will cause an alarm to be annunciated.

- Flow divider

The flow divider FD1-1 equally distributes input fuel flow to the 14 combustion nozzles. The continuous flow, free-wheeling flow divider consists of 14 gear pump elements in a line arrangement having a common inlet with a single timing gear. This timing gear serves to maintain true synchronous speed of each pumping element with all other elements. As the fuel enters the flow divider, each pair of gear elements distributes one fourteenth of the fuel flow into each of the lines going to the fuel nozzles.

The speed of the flow divider pumping elements is directly proportional to the fuel flow through the flow divider. Three magnetic pickup assemblies 77 FD-1, 77 FD-2 and 77 FD-3, fitted to the flow divider, produce a flow feedback signal at a frequency proportional to fuel flow delivered to the combustion chambers. This signal is fed to the SPEEDTRONIC control panel where it is used in the fuel control system.

DESCRIPTIVE GUIDE

- Check valves

There is a check valve in each line between the flow divider and the fuel nozzles. The check valve is mounted in each discharge line from the flow divider near the input connection to each nozzle. These valves prevent fuel oil from continuing to flow when a stop signal is given resulting in a clean cut-off of fuel to the nozzle. These check valves are set at a pressure which is sufficient to prevent the fuel from the forwarding system from breaking through, should the stop valve not close.

- Selector valve indicator.

A 16-position selector valve and pressure gauge assembly is located at the flow divider to allow monitoring of selected fuel oil pressure in the nozzle inlet line. Positions 1 through 14 select the fuel nozzles, position 15 selects the fuel pump inlet pressure, and position 16 selects the fuel pump outlet pressure.

- False start drain valves (VA 17-1, -2, -5)

In the event of an unsuccessful start, the accumulation of combustible fuel oil is drained through false start drain valves provided at appropriate low points in the combustion/turbine area. The false start drain valve, normally open, closes as the turbine accelerates during start-up. Air pressure from the discharge of the unit's axial-flow compressor shut-down sequence, the valve opens as compressor speed drops (compressor discharge pressure is reduced).

SIZE	DWG. NO.	SH.	REV.
A2	239C7407	1	A

REVISIONS			
REV	DESCRIPTION	NAMES	SIGNATURES
A	FIRST ISSUE	THIRION F.	02 OCT 01
		JOST JM.	02 OCT 01
		ANCEL T.	02 OCT 01

NOTES

- 1 -NOTE SPECIALE : CONDITION D'ENTREE DU COMBUSTIBLE LIQUIDE
CONDITION D'ALIMENTATION DU COMBUSTIBLE LIQUIDE A L'ENTREE DE
LA VANNE D'ARRET FUEL
PRESSION : 2.75 à 5.17 BARS
DEBIT : 19 à 795 l/mn
TEMPERATURE MAXI : 121 °C
- SPECIAL NOTE : LIQUID FUEL INLET CONDITION
LIQUID FUEL SUPPLY CONDITION AT INLET TO FUEL
OIL STOP VALVE
PRESS REQ'D : 40 TO 75 PSIG
FLOW 5 TO 210 GPM
MAXI TEMPERATURE : 250 °F
- 2 -CE RACCORDMENT CLIENT DOIT ETRE RACCORDE A UN RESERVOIR SOUS PRESSION NORMALE
-THIS PURCHASER CONNECTION MUST BE CONNECTED TO AN UNPRESSURIZED SUMP.
- 3 -DEPOSER LE TAMIS DU FILTRE APRES 600 HEURES DE MARCHE PREVUE NETTOYER LE CORPS
DU FILTRE ET LE PASSER AU JET LORS DE LA DEPOSE DU TAMIS AVANT LA REMISE EN SERVICE
DE LA TURBINE
- STRAINER SCREEN IS TO BE REMOVED AFTER THE INITIAL 600 HOURS OF OPERATION. STRAINER
HOUSING IS TO BE CLEANED & FLUSHED UPON REMOVAL OF THE SCREEN PRIOR TO PUTTING
THE TURBINE INTO SERVICE.

SPECIFICATION P&ID	237A2415
NOMENCLATURE	IDENT
LIST OF COMPLEMENTARY DOCUMENTS	
FIRST MADE FOR : MS-90015	ITEM : 0424

A	A	REV	REV STATUS
2	1	SH	OF SHEETS

SIGNATURES		DATE	GENERAL ELECTRIC COMPANY	
DRAWN	THIRION F.	02 OCT 01	 <i>GE Energy Products - Europe</i>	
CHECKED	JOST JM.	02 OCT 01		
APPROVED	ANCEL T.	02 OCT 01		
			SCH. TUY. COMBUSTIBLE LIQUIDE	
			DIAG. SCH. PP-LIQUID FUEL	
SIZE	CAGE CODE	DWG. NO.		
A2		239C7407		
SIM TO : 356B2891		REV. : A	SHEET 1	

De document, propriété exclusive de
GE Energy Products France SNC est
strictement confidentiel. Il ne peut être communiqué,
copié ou reproduit sans son autorisation écrite préalable.

This document, exclusive property of
GE Energy Products France SNC
is strictly confidential. It must not be communicated
copied or reproduced without our previous written consent.

Tab 9

DESCRIPTIVE GUIDE

3.7. ATOMIZING AIR SYSTEM**3.7.1. GENERAL AND SIMPLIFIED SCHEMATIC**

The atomizing air system provides sufficient pressure in the air atomizing chamber of the fuel nozzle body to maintain the proper ratio of atomizing air pressure to compressor discharge pressure at approximately 1.2 or greater over the full operating range of the turbine. Since the output of the main atomizing air compressor, driven by the accessory gear, is low at turbine firing speed, a starting atomizing air compressor provides a similar pressure ratio during the firing and warm-up period of the starting cycle, and during a portion of the accelerating cycle. Continuous blow-down to atmosphere is also provided to clear the main gas turbine compressor of accumulated dirt.

Major system components include : the main atomizing air compressor, starting atomizing air compressor, atomizing air heat exchanger(s) and an air filter. See Figure AA-1.

88 AB-1 motor is equipped with a heater 23 AB-1 to prevent condensation when the motor is not operating.

NOTE : For more details about the main components of the atomizing air system, see the Gas turbine equipment publications volumes.

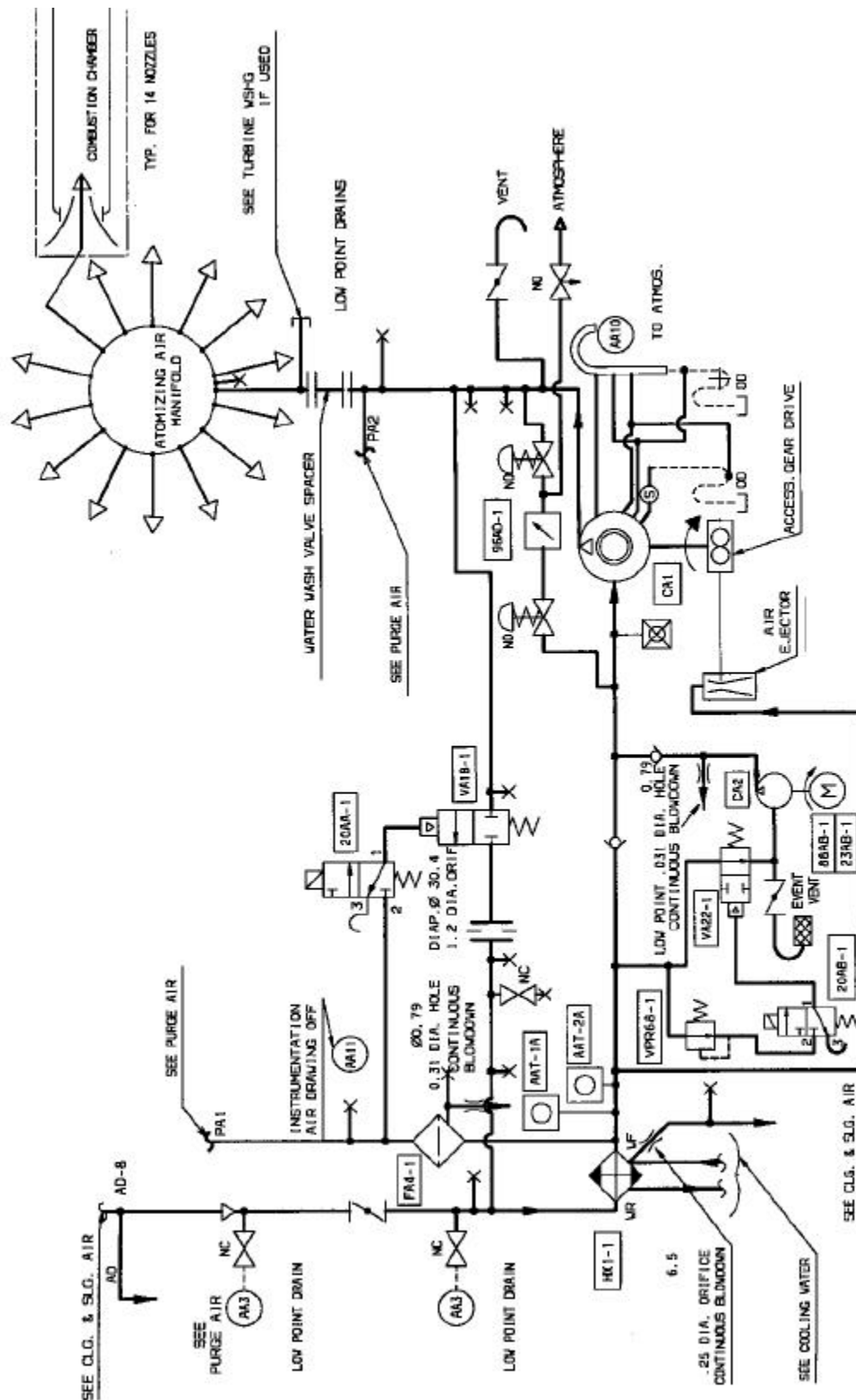
For more details and settings, refer to the piping systems schematic in the Gas turbine operation guide volumes.

DESCRIPTIVE GUIDE

PART	NOMENCLATURE
20 AA-1	Atomizing air bypass solenoid 3 way valve.
20 AB-1	Starting booster atomizing air solenoid valve.
23 AB-1	Space heater - booster motor.
88 AB-1	Starting atomizing air compressor motor.
96 AD-1	Atomizing air compressor differential pressure transmitter.
AAT-1A,-1B	Atomizing air cooler discharge, thermocouple-alarm.
CA 1	Main atomizing air compressor (centrifugal).
CA 2	Booster atomizing air compressor.
FA 4-1	Atomizing air control filter.
HX 1-1	Atomizing air pre-cooler.
VA 18-1	Atomizing air compressor bypass air operated valve.
VA 22-1	Booster atomizing air compressor isolation valve.
VPR 68-1	Pressure regulation valve booster atomizing air isolation valve.

DESCRIPTIVE GUIDE

FIGURE AA-1 : ATOMIZING AIR SYSTEM SCHEMATIC



DESCRIPTIVE GUIDE

3.7.2. FUNCTIONAL DESCRIPTION

(See Figure AA-1)

When liquid fuel oil is sprayed into the turbine combustion chambers it forms large droplets as it leaves the fuel nozzles. The droplets will not burn completely in the chambers and many could go out of the exhaust stack in this state. A low pressure atomizing air system is used to provide atomizing air through supplementary orifices in the fuel nozzle which directs the air to impinge upon the fuel jet discharging from each nozzle. This stream of atomizing air breaks the fuel jet up into a fine mist, permitting ignition and combustion with significantly increased efficiency and a decrease of combustion particles discharging through the exhaust into the atmosphere. It is necessary, therefore, that the air atomizing system be operative from the time of ignition firing through acceleration, and through operation of the turbine.

Air taken from the atomizing air extraction manifold of the compressor discharge casing passes through the air-to-water heat exchanger (pre-cooler) HX1-1 to reduce the temperature of the air sufficiently to maintain a uniform air inlet temperature to the atomizing air compressor.

The atomizing air pre-cooler (heat exchanger), located in the turbine base under the turbine compartment, uses water from the turbine cooling water system as the cooling medium to dissipate the heat.

Thermocouples AAT-1A,-2A are intended to provide an alarm when the temperature of the air from the atomizing air pre-cooler entering the main atomizing air compressor is excessive. When the atomizing air reaches this temperature setting of this switch, the alarm is activated. Improper control of the temperature may be due to failure of the sensor, the pre-cooler or insufficient cooling water flow. Continued operation above 275°F (i.e. 135°C) should not be permitted for any significant length of time since it may result in failure of the main atomizing air compressor or in insufficient atomizing air to provide proper combustion.

Compressor discharge air, now cleaned and cooled reaches the main atomizing air compressor. This is a single stage, flange mounted, centrifugal type compressor driven by an inboard shaft of the turbine accessory gear. It contains a single impeller mounted on the pinion shaft of the integral input speed increasing gear box driven directly by the accessory gear. Output of the main compressor provides sufficient air for atomizing and combustion when the turbine is at approximately 60-per cent speed.

Differential pressure transmitter 96 AD-1 located in a bypass around the compressor, monitor the air pressure and indicate an alarm if the pressure rise across the compressor should drop to a level inadequate for proper atomization of the fuel.

Air, now identified as atomizing air, leaves the compressor and is piped to the atomizing air manifold with "pigtail" piping providing equal pressure distribution of atomizing air to the 14 individual fuel nozzles.

When the turbine is first fired, the accessory gear is not rotating at full speed and the main atomizing air compressor is not outputting sufficient air for proper fuel atomization. During this period, the starting (booster) atomizing air compressor, driven by the starting motor 88 AB-1 is in operation supplying the necessary atomizing air. 88 AB-1 motor is equipped with a heater 23 AB-1 to prevent condensation when the motor is not operating.

The starting atomizing air compressor at this time has a high pressure ratio and is discharging through the main atomizing air compressor which has a low pressure ratio. The main

All right reserved Copyright – Droits de reproduction réservés

DESCRIPTIVE GUIDE

atomizing air compressor pressure ratio increases within increasing turbine speed and at approximately 60 % speed the flow demand of the main atomizing air compressor approximates the maximum flow capability of the starting atomizing air compressor. The check valve in the air input line to the main compressor begins to open allowing air to be supplied to the main compressor simultaneously from both the main air line and the starting atomizing air compressor. The pressure ratio of the starting atomizing air compressor decreases to one and it is shut down at approximately 95 % speed (14 HS pickup). Now all of the air being supplied for atomizing purpose is directed to the main atomizing air main compressor, bypassing the starting air compressor completely. At this time, the (20 AB-1) solenoid is energized and the isolation valve (VA 22-1) is closed preventing any air from getting to the booster compressor.

DESCRIPTIVE GUIDE

3.7.3. DUAL FUEL OPERATION (GAS AND DISTILLATE OIL)

- Recirculation cooling system

On dual fuel (gas and distillate oil) machines, the discharge of the accessory gear driven atomizing air compressor is recirculated through the atomizing air system when the gas turbine is operating 100 percent on gas fuel ; except for a small amount of air flow that is bled off to purge the oil passages in the oil fuel nozzle. The recirculation air is passed through the atomizing air pre-cooler where it is cooled before it reenters the compressor, thus protecting the compressor against overtemperature operation. Piping for the recirculation system includes a normally closed, air-operated-bypass valve (VA18-1) which is controlled by the operation of solenoid valve 20 AA-1. When the fuel system is set for 100 percent gas fuel operation, solenoid valve 20 AA-1 is energized and operating air from the turbine compressor discharge is passed through filter FA4-1 and then admitted to the piston of bypass valve VA18-1. This causes the valve to open allowing the atomizing air to be recirculated back to the piping ahead of the pre-cooler HX1-1.

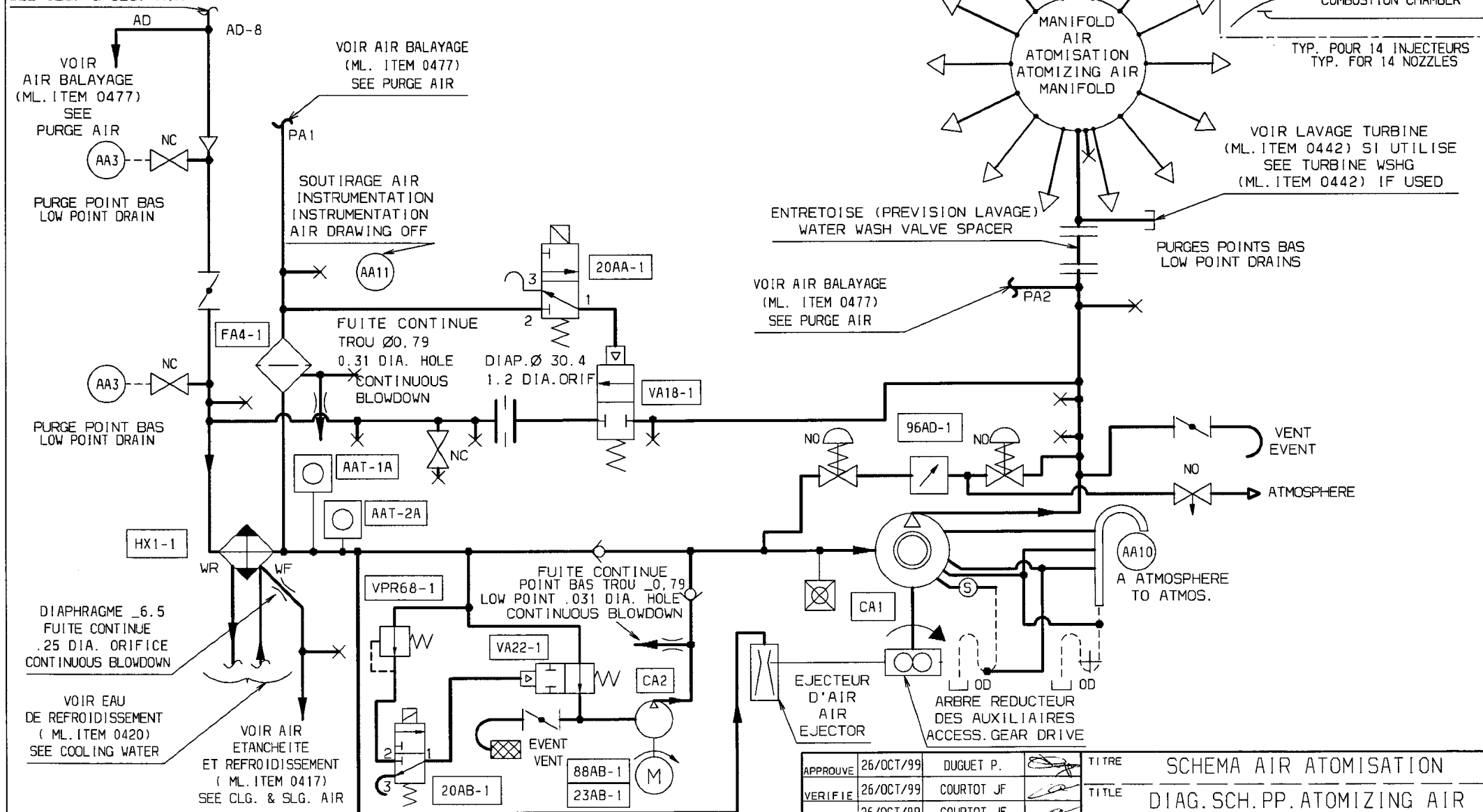
SEE DEVICE SUMMARY FOR CONTROL DEVICE SETTING

APPROUVE	26/OCT/99	DUGUET P.		TITRE	SCHEMA AIR ATOMISATION	
VERIFIE	26/OCT/99	COURTOT JF		TITRE	DIAG. SCH. PP. ATOMIZING AIR	
DES./RED.	26/OCT/99	COURTOT JF				
QA : C	Date	Nom	Visa			
INFO. INTERNE		LANGUE F/E	BELFORT 	SECT. DOC	GE Energy Products - Europe	
	DIFFU 2	NATURE SH	EMETTEUR 91 A	FORMAT A3	CONT. PAGE 2	PAGE 1
					91-	317615

SIMILAIRE A: SIMILAR TO: 91-315706			PREM.EXECUTION: FIRST MADE FOR: MS 9001E			O		M	K
OPTION:									
ITEM: 0425	A	FIRST ISSUE							
	Index	N° Instruction	Modif	Date	Nom	Visa	Nom	Visa	Nom
	MODIFICATIONS				MODIFIE		VERIFIE		APPROUVE

ORIGINAL

VOIR AIR ETANCHEITE
ET REFROIDISSEMENT
(ML. ITEM 0417)
SEE CLG. & SLG. AIR



SIMILAIRE A : 91-315706		PREM. EXECUTION : MS 9001E		O  M K		DES. ZRE		DA : C Dates		Noms		Visas					
OPTION :																	
ITEM : 0425		A FIRST ISSUE															
Indice N°		Instruction Modif		Date		Nom Visa		Nom Visa		Nom Visa		Nom Visa					
MODIFICATIONS		MODIFIER		VERIFIER		APPROUVE											
2		SH		91 A		A3		F		2		91- 317615		A			

~~ORIGINAL~~

Tab 10

DESCRIPTIVE GUIDE**3.6.4. FUEL PURGING SYSTEM****Gas fuel purging system**

A special circuit is provided to purge the circuit to the gas fuel nozzles of the 14 combustion chambers with atomizing air, from the gas manifold located upstream of the combustion system. This gas fuel purging system is actuated during fully liquid fuel operation of the unit.

When the gas turbine is operating on liquid fuel, solenoid valves 20 PG-1, -2 are energized and allow filtered atomizing air to actuate pneumatic valves VA 13-1 and VA 13-2. Being actuated, VA 13-1 and VA 13-2 allow atomizing air from another feeding piping to reach the gas manifold located upstream of the combustion system.

Limit switches 33 PG-2 and 33 PG-4 check that valves VA 13-1 and 13-2 are fully opened, and if not, they will cause an alarm to be annunciated.

Solenoid valve 20 VG-2 is energized when 20 PG-1, -2 are energized, so that no intervalve atomizing air be vented to atmosphere.

Purge pressure switch 63 PG-1 will alarm if excessive pressure builds up between the valves, indicating the presence of too much gas.

On the contrary, during fuel gas operation of the unit, solenoid valves 20 PG-1, -2 are de-energized, so shutting off the pneumatic actuation of VA 13-1 and VA 13-2. Therefore, these valves are closed and no atomizing air reaches the gas fuel manifold. Limit switches 33 PG-1 and 33 PG-3 check that VA 13-1 and VA 13-2 are closed, so allowing solenoid valve 20 VG-2 to be de-energized and intervalve piping to be connected to atmosphere.

Purge air system

As stated above, the bypass valve is open and atomizing air is recirculating. After a short time delay, to allow the pressure ratio (regulated by valve VPR 54-1) of the atomizing air system to reach a lower level, solenoid valve 20 PL-1 is energized. The system then starts operating to purge the oil passages in the oil fuel nozzles during gas fuel operation. The purge air system is necessary to prevent accumulation of oil fuel in the nozzle oil passages, during gas fuel operation, and fouling of the nozzles as a result of oil fuel coking. The purge system minimizes such fouling, and keeps the oil fuel nozzle clean and ready for operation when oil fuel operation is resumed. The small flow of air through the atomizing air passages of the oil fuel nozzle also prevents entry of any combustion products that could foul this section of the oil fuel nozzle.

Initially, compressor discharge air (AD) is used to operate purge valve VA 19-1. At a point in the compressor discharge piping, after filter FA4 compressor discharge air is taken off in a separate piping and pressure regulated by valve VPR 54-1. Regulated air is piped to the energized solenoid valve 20 PL-1. When solenoid valve 20PL-1 is energized, operating air (from the turbine compressor discharge) is admitted to the diaphragm of purge air valve VA19-1 which opens, allowing purge air (atomized) to flow into the purge air manifold on the turbine. A porous filter (FA3) is installed in the purge air piping ahead of the purge valve. The purge air check valves, (VCK2-1 to 14) one for each nozzle, are connected into the oil feed lines to the nozzles. These purge air check valves prevent oil fuel from entering the purge air system when the machine is operating on oil fuel. Similarly, the oil fuel check valves installed in the oil piping to the oil fuel nozzles insure that the purge air is directed to the nozzle and not into the oil fuel system. If any oil leakage should occur through the purge air check valves when operating on oil fuel, it will drain out of the purge air manifold through the normally open port of

All right reserved Copyright – Droits de reproduction réservés

DESCRIPTIVE GUIDE

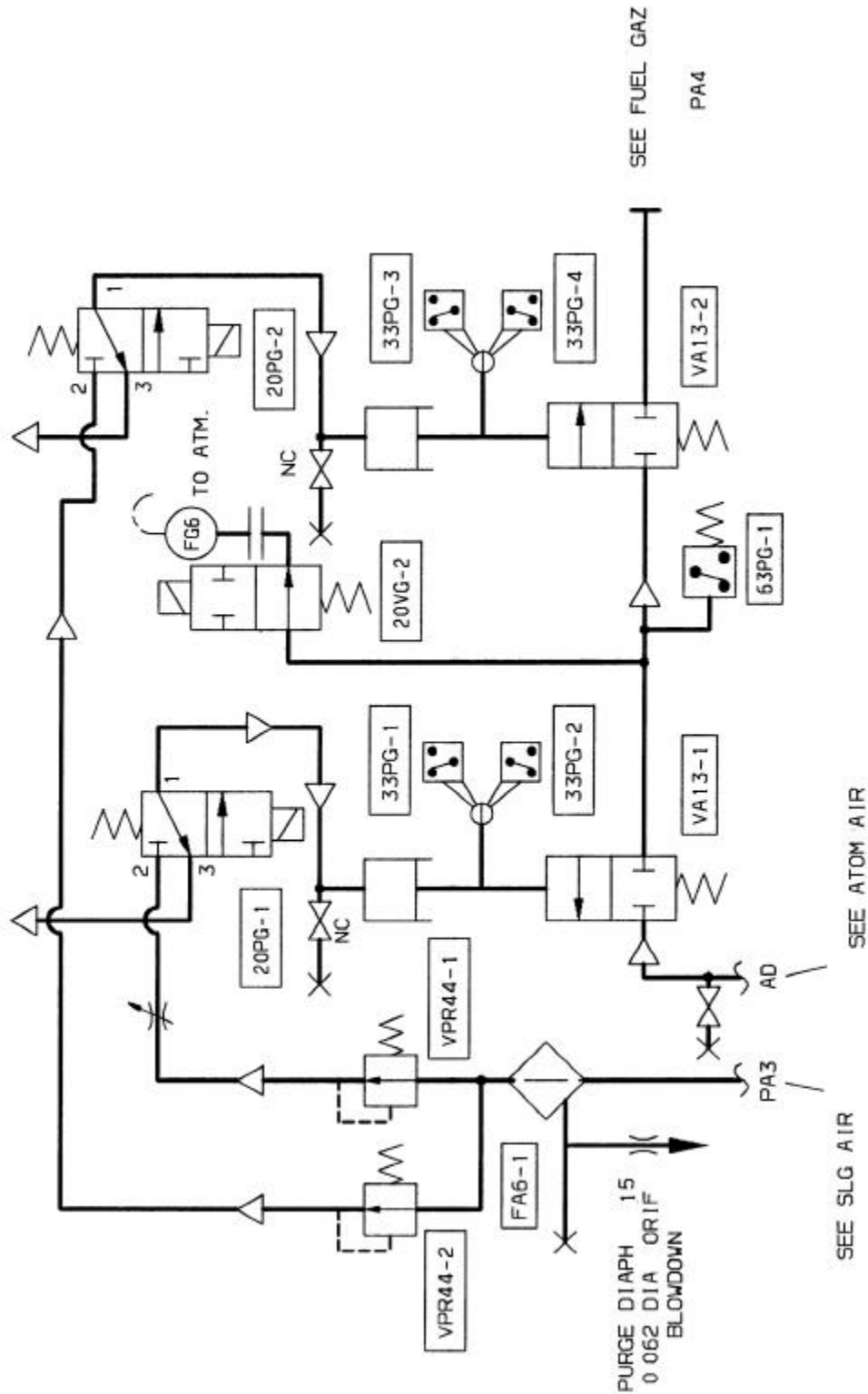
the three-way purge air valve. "Tell-Tale" leak-off piping connected to the purge valve vent port provides a visual means for determining the general condition of the check valves. There should not be any leakage.

DESCRIPTIVE GUIDE

PART	NOMENCLATURE
20 PG-1,-2	Gas fuel system purge solenoid valve.
20 PL-1	Liquid fuel system purge solenoid valve.
20 VG-2	Gas fuel vent solenoid valve.
33 PG-1,-2,-3,-4	Gas fuel system purge valve limit switch.
63 PG-1	Gas fuel system purge pressure switch.
63 PL-21	Purge air pressure.
FA 3-1	Liquid fuel nozzle purge filter.
FA 6-1	Gas fuel system purge filter (atomizing air).
VA 13-1,-2	Gas fuel system purge valve air actuated by 20 PG.
VA 19-1	Liquid fuel nozzle purge valve.
VCK 2-1T14	Liquid fuel nozzle purge check valve.
VPR 44-1,-2	Air pressure regulator - gas fuel purge valve.
VPR 54-1	Pressure regulator - purge control valve liquid manifold.

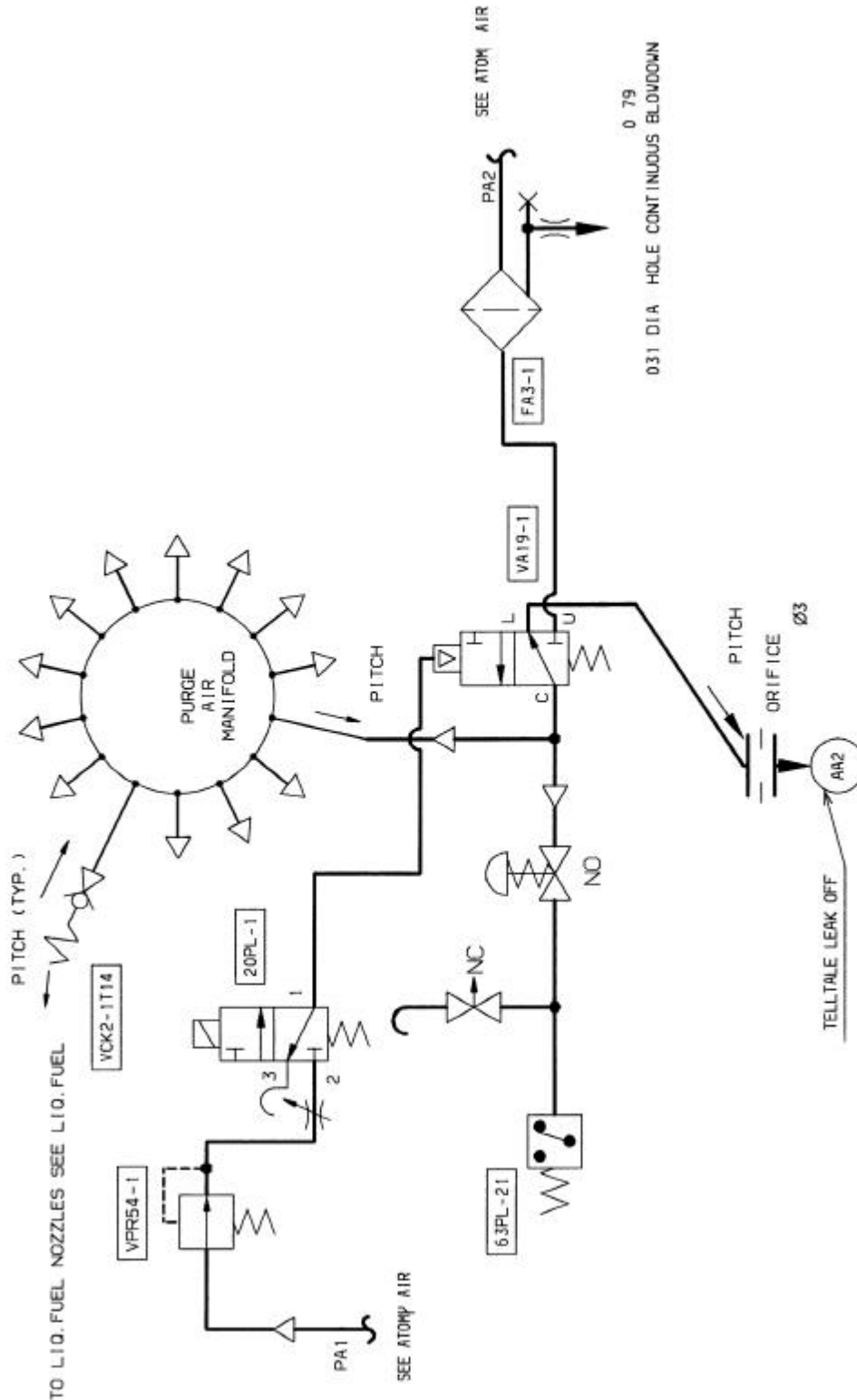
DESCRIPTIVE GUIDE

GAS FUEL PURGING SYSTEM SCHEMATIC (1/2)



DESCRIPTIVE GUIDE

GAS FUEL PURGING SYSTEM SCHEMATIC (2/2)



NOTES: SEE DEVICE SUMMARY (0414) FOR
CONTROL DEVICE SETTINGS

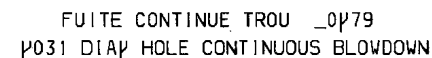
VOIR NOMENCLATURE POUR CONTROLE
ET REGLAGE DES APPAREILS

SYMBOLS PIPING	GE-277A2415
COMPL. DOC.	DOC. N°

SIMILAIRE A: SIMILAR TO:				PREM.EXECUTION: MS 9001E FIRST MADE FOR:				O	M	K
OPTION: STD	E	IM-2000002932	23 OCT 00	THIRION F.		THIRION F.		BITSCH JM.		
	D	IM-1999001965	20 SEP 99	COURTOT JF		COURTOT JF		DUGUET P		
	C	IM-1999000716	19AVR99	BACH J-S		DELOGE D		GOEMINNE Y		
ITEM: 0477	Indice	N° Instruction	Modif	Date	Nom	Visa	Nom	Visa		
	MODIFICATIONS			MODIFIE		VERIFIE		APPROUVE		

APPROUVE	29 SEP 98	REICHART T.		TITRE	SCH. TUY. BALAYAGE COMB.
VERIFIE	29 SEP 98	GOEMINNE Y.		TITRE	DIA. SCH. PP-FUEL PURGE
DES./RED.	29 SEP 98	HYSYS			
QA : C	Date	Nom	Visa		
INFO. INTERNE		LANGUE	BELFORT	SECT. DOC	GE Energy Products - Europe
		F/E		01	
DIFFU	NATURE	EMETTEUR	FORMAT	CONT. PAGE	PAGE
2	SH	91 A	A3	2	1
					91-315618
					E
					D
					C
					B

[illegible]



SIMILAIRE A: SIMILAR TO:				PREM.EXECUTION: MS 9001E				O	M	K	DES./REQ.	DES. 9001E	Visas			E	
OPTION: STD				E	IM-2000002932	23 OCT 00	THIRION F.	~~THIRION F.~~	THIRION F.	BITSCH JM.		LANGUE	BELFORT	SECT. DOC	GE Energy Products - Europe		D
				D	IM-1999001965	20 SEP 99	COURTOT JF	COURTOT JF	DUGUET P.		F/E		01			C	
				C	IM-1999000716	19AVR99	BACH J-S	DELOGE D	GOEMINNE Y							A	
ITEM: 0477				Index	N° Instruction	Modif	Date	Nom	Visa	Nom	Visa	Nom	Visa				
				MODIFICATIONS			MODIFIE			VERIFIE			APPROUVE				
				2	SH	91	A	A3	F	3	91-315618						

Tab 11

DESCRIPTIVE GUIDE

3.10. COOLING AND SEALING AIR SYSTEM

3.10.1. GENERAL

The cooling and sealing air system provides the necessary air flow from the gas turbine compressor to other parts of the gas turbine rotor and stator to prevent excessive temperature buildup in these parts during normal operation and for sealing of the turbine bearings. Air from two centrifugal type blowers is used to cool the turbine exhaust frame. These two motor fans are part of a cooling system located on a base, near the lower part of the gas turbine exhaust system duct.

88 TK-1 and 88 TK-2 motors are equipped with heaters 23 TK-1 and 23 TK-2 to prevent condensation when the motors are not operating.

Cooling and sealing functions provided by the system are as follows :

- Sealing of the turbine bearings.
- Cooling of internal turbine parts subjected to high temperature.
- Cooling of the turbine outer shell and exhaust frame.
- Providing an operating air supply for air operated valves.

The cooling and sealing air system consists of specially designed air passages in the turbine casing, turbine nozzles and rotating wheels, piping for the compressor extraction air and associated components. Associated components used in the system include :

- Turbine exhaust frame cooling blowers (as mentioned here above).
- Air filter (with poro-stone element).
- Pressure gauge.
- Dirt separator.

DESCRIPTIVE GUIDE**3.10.2. FUNCTIONAL DESCRIPTION**

- General

Air from the axial flow compressor, extracted from several points, is used for sealing the bearings, cooling turbine internal parts and to provide a clean air supply for air operated control valves. Compressor extraction air is also used for pulsation protection of the compressor during turbine start-up and shut-down.

Bearing sealing air is extracted from the fifth stage of the compressor. Internal cooling air is extracted from the discharge of the compressor including the internal flow of cooling air through the turbine rotating and stationary parts. Air used in cooling the turbine external casing is ambient air supplied by motor driven blowers. The schematic flow diagram, Figure CS-1, shows both the internal and external flow of cooling and sealing air.

- Bearing cooling and sealing

Cooling and sealing air is provided from two connections on the compressor casing at the fifth stage and is piped externally to each of the three turbine bearings. Orifices in the air lines to the turbine bearings limit the flow of air and the pressure to the proper value. The centrifugal dirt separator located in the fifth-stage piping removes any particles of dirt or foreign matter that might be injurious to the bearings.

This pressurized air cools and seals the bearings by containing any lubricating fluid within the bearing housing that otherwise might seep past the mechanical seals. Air is directed to both ends of each bearing housing providing a pressure barrier to the lubricating fluid. After performing this function, the air is vented via the oil drain passage from the N° 1 and N° 3 bearings while air from the N° 2 bearing is vented to atmosphere.

- Exhaust frame and turbine shell cooling

Cooling of the exhaust frame and turbine shell is accomplished by two electric motor-driven, centrifugal blowers, 88 TK-1 and 88 TK-2, which are mounted external to the turbine. An inlet screen is provided with each blower and the discharge of each passes through a back-draft damper (check valve), VCK7-1 or VCK7-2 before entering openings in the exhaust frame outer sidewall cavity. The cooling air flow splits, with part of the air passing along and cooling the turbine shell and the other portion flowing through the exhaust frame strut passages. The air flow through the struts divides, with a portion directed through passages to cool the third-stage turbine aft wheelspace and the remainder flowing into the load shaft tunnel where it discharges through a duct to atmosphere. See Figure CS-1.

Air for cooling the exhaust frame and turbine shell is normally provided by the two blowers operating simultaneously in parallel. Each blower has a pressure switch, 63 TK-1 or 63 TK-2, to sense blower discharge pressure. If one of the blowers should fail, the loss of blower discharge pressure will cause contacts of the respective 63 TK-1 pressure switch to close and an alarm will be annunciated. The turbine will continue to run with the automatic change over starting the blower. If three blowers should fail, the turbine will continue to run with the other blower providing not in operation cooling air at a reduced flow rates. If all blowers should fail the turbine will be shutdown in a normal shutdown sequence.

DESCRIPTIVE GUIDE

NOTE : If one blower fails, it should be repaired or replaced as soon as possible to preclude the possibility of shutting down the turbine by failure of the remaining blower.

- Pulsation protection

The pressure, speed and flow characteristics of the gas turbine compressor are such that air must be extracted from the 11th-stage and vented to atmosphere to prevent pulsation of the compressor during the acceleration period of the turbine starting sequence and during deceleration of the turbine at shut-down.

Pneumatically operated 11th stage air extraction valves, controlled by a three-way solenoid valve, are used to accomplish the pulsation protection function.

Eleventh stage air is extracted from the compressor at four flanged connections on the compressor casing. Each of these connections is piped through a normally open, piston-operated, butterfly or vee-ball type valve, VA 2-1, -2, -3, and -4, to the turbine exhaust plenum. Limit switches 33 CB-1, -2, -3 and -4 are mounted on the valves to give an indication of valve position. See Figure CS-1.

Compressor discharge air controlled by solenoid valve 20 CB-1 is used to close the compressor bleed valves. Air from 11th-stage compressor discharge is piped to a porous air filter which removes dirt and water from the compressor discharge air, by means of a continuous blow down orifice, before the air enters solenoid valve 20 CB-1. From the solenoid valve, the air is piped to the piston housings of the four extraction valves.

During turbine start-up, 20 CB-1 is deenergized and the 11th-stage extraction valves are open allowing 11th-stage air to be discharged into the exhaust plenum thereby eliminating the possibility of compressor pulsation. Limit switches, 33 CB-1 through -4, on the valves provide permissive logic in the starting sequence and ensure that the extraction valves are fully opened before the turbine is fired. The turbine accelerates to full speed and when the generator circuit breaker closes, the 20 CB-1 solenoid valve is energized to close the extraction valves and allow normal running operation of the turbine. When a turbine shut-down signal is initiated and the generator circuit breaker is opened, 20 CB-1 is deenergized and 11th-stage air is again discharged into the exhaust plenum to prevent compressor pulsation during the turbine deceleration period.

CAUTION : Under no circumstances should attempts be made to start the turbine if all four extraction valves are not fully opened. Serious damage to the gas turbine may occur if all the valves are not opened during the accelerating and decelerating cycle of the turbine.

- Pressurized air supply

Compressor discharge air is also used as a source of air for operating various air-operated valves in other systems. Air for this purpose is taken at the discharge of the compressor and is then piped to the various air operated valves. In addition, compressor discharge pressure is monitored by redundant pressure transducers 96 CD-1A, -1B, -1C for use in control of the gas turbine. Compressor discharge air is also the source of air used as atomizing air if the unit has a liquid fuel system.

NOTE : For turbine buckets and nozzle partitions cooling, refer to 02.05 in the actual volume.

DESCRIPTIVE GUIDE

For components descriptions, see the Gas turbine equipment publications volumes.

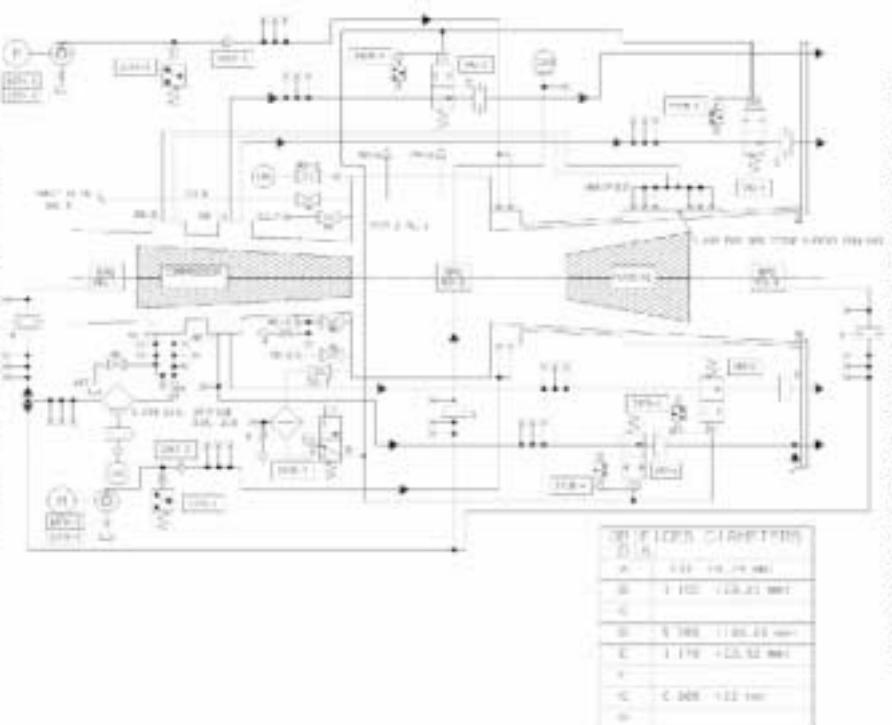
- Water wash provisions

When water washing the gas turbine compressor or turbine section, it is important to keep water out of the components that are actuated by compressor discharge air and out of the turbine bearings. To prevent water from entering these components and the bearings, isolation valves are provided in each compressor discharge extraction line and in the sealing lines to the n° 1, n° 2, n° 3 bearings and in 20 CB-1 and 96 CD feed lines.

During normal operation of the gas turbine, all isolation valves are to be open. Before initiating water wash, the isolation valves must be closed. At the conclusion of the water wash, the isolation valves must be opened to allow normal operation of the turbine.

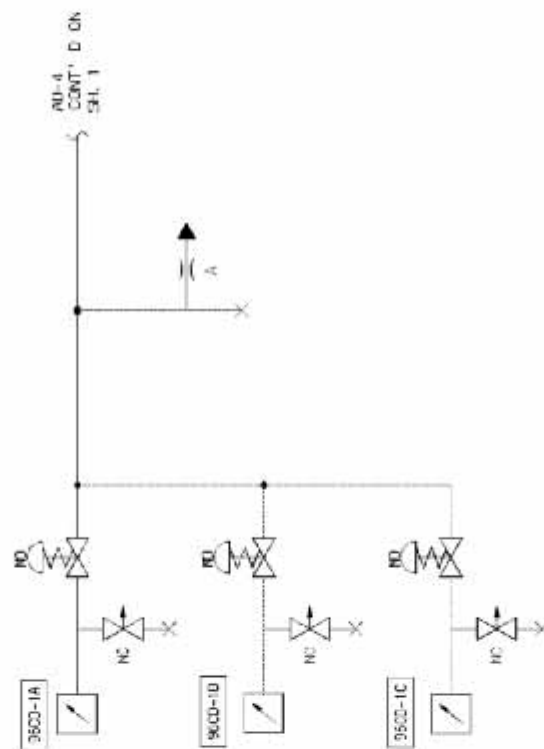
PART	NOMENCLATURE
23 CB-1	Compressor bleed solenoid 3-way valve.
23 TK-1,-2	Motor space heater for 88 TK-1,-2.
33 CB-1,-2,-3,-4	11th stage compressor bleed valve limit switch.
63 TK-1,-2	Turbine exhaust frame cooling air pressure switch.
88 TK-1,-2	Turbine exhaust frame cooling fan motor.
96 CD-1A,1B,1C	Compressor discharge pressure transmitter.
VA 2-1,-2,-3,-4	11th stage compressor bleed valve.
VCK 7-1,-2	Turbine shell cooling air blower check-valve.

FIG. CS-1 : COOLING AND SEALING AIR SYSTEM SCHEMATIC DIAGRAM (1/2)



DESCRIPTIVE GUIDE

FIG. CS-1 : COOLING AND SEALING AIR SYSTEM SCHEMATIC DIAGRAM (2/2)



ECH. / SCALE	DATE	10-Dec-2002	09-Jan-2003	09-Jan-2003
	NOM / NAME	VIPREY CELINE	THIRION FREDERIC	RHIM MEJDI
FORMAT/SIZE A3	VISA	VIPREY CELINE	THIRION FREDERIC	RHIM MEJDI
		REDIGE / MADE	VERIFIE / CHECKED	APPROUVE/APPROVED

TITRE/TITLE

SCHEM.TUY.AIR REFR.ETANC

DIA.SCH.PP-CL AND SLG AIR

Ce document, propriete exclusive de <i>GE Energy Products France SNC</i> est strictement confidentiel. Il ne peut etre communique, copie ou reproduit sans son autorisation ecrite prealable.	<i>GE Energy Products - Europe</i>	REVISION B INSTRUCTION DE MODIFICATION IM-2002006263 Section Doc. GRD F
This document, exclusive property of <i>GE Energy Products France SNC</i> is strictly confidential. It must not be communicated, copied or reproduced without our previous written consent.	 N° 360B1321 SHT.N	

REVISIONS					
REV	DESCRIPTION				NAMES/NOMS
A	FIRST ISSUE				THIRION F.
					JOST JM.
					RHIM M.
B	IM-2002006263	TECHNIREA CV	THIRION F.	RHIM M.	10 DEC 02

NOTES:

1. SEE DEVICE SUMMARY FOR
CONTROL DEVICE SETTINGS
2. AD-2 SEE LIQUID FUEL /ML 0424
3. AD-6 SPARE CONNECTION
4. AD-7 SPARE CONNECTION
5. AD-8 SEE ATMG AIR /ML 0425 IF USED
6. BEARING SEALING AIR DIRT SEPARATOR BLOW-DOWN VALVE
IS TO BE OPEN DURING ALL ABRASIVE AND WATER WASH
AND IS TO BE CLOSED AT ALL OTHER TIMES
7. AD-3 SPARE EXTRACTION AIR CONNECTION IF USED
8. PA-3 SEE NOZZELES PURGE PIPING ML 0477

1. VOIR NOMENCLATURE POUR REGLAGE
ET CONTROLE DES APPAREILS
2. AD-2 VOIR COMB. LIQUIDE ML 0424
3. AD-6 CONNEXION DISPONIBLE
4. AD-7 CONNEXION DISPONIBLE
5. AD-8 VOIR AIR ATOM. ML 0425 SI UTILISE
6. LA VANNE "FUIITE CONTINUE" D'AIR ETANCHEITE DU SEPARATEUR
DOIT ETRE OUVERTE DURANT TOUTE LA SEQUENCE DE LAVAGE ET
NETTOYAGE DE LA TG ET DOIT ETRE FERMEE LE RESTE DU TEMPS
7. AD-3 EXTRACTION DISPONIBLE SI UTILISE
8. PA-8 VOIR TUY. BALAYAGE COMB. ML 0477

ORIFICES DIAMETERS
DIA. DIAPHRAGMES

A	.031 (0,79 mm)
B	1.150 (29,21 mm)
C	
D	5.766 (146,46 mm)
E	1.178 (29,92 mm)
F	
G	0.866 (22 mm)
H	

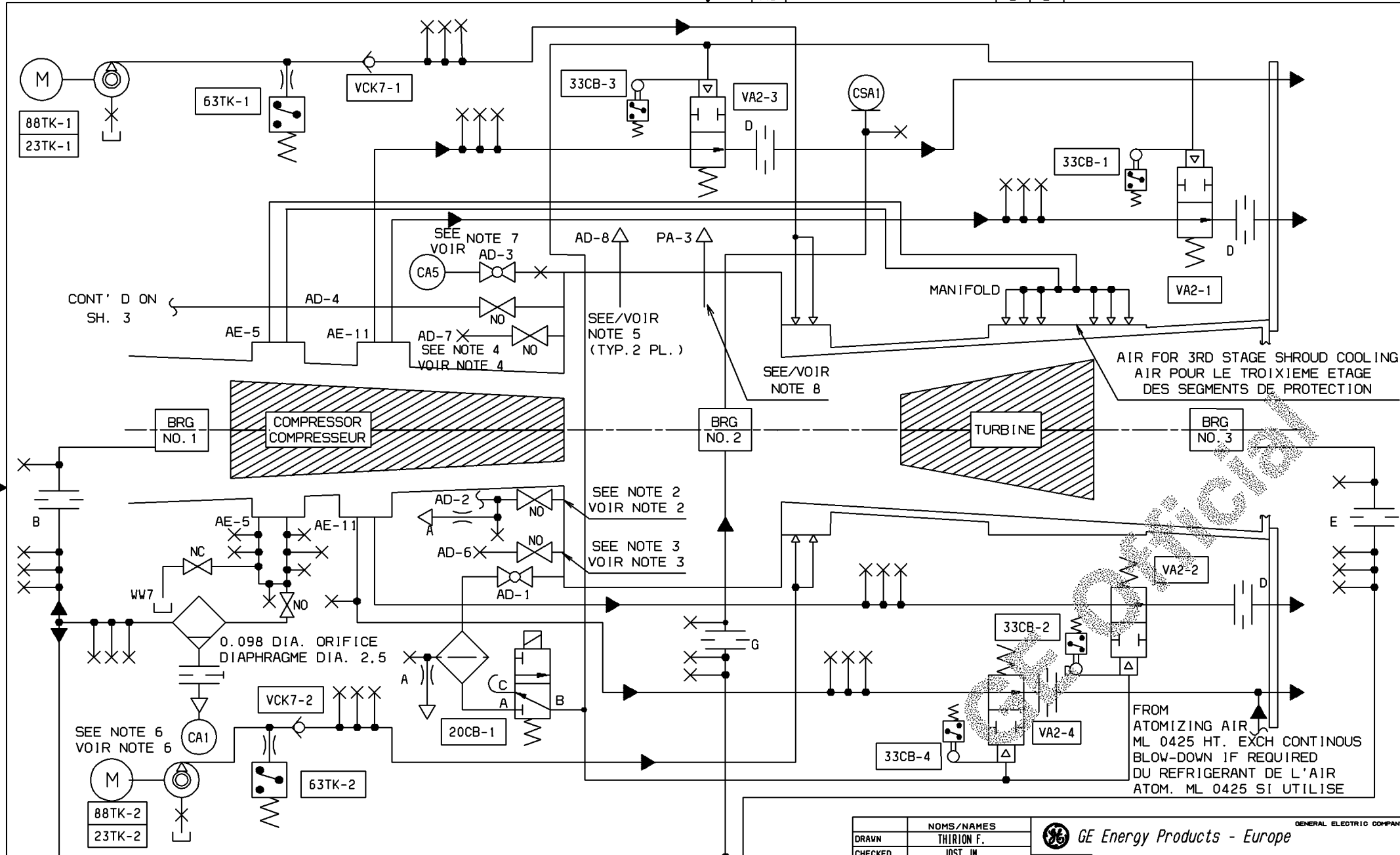
SPECIFICATION P&ID	277A2415
NOMENCLATURE	IDENT
LIST OF COMPLEMENTARY DOCUMENTS	
FIRST MADE FOR : MS 9001E	ITEM : 0417

A	B	B	REV	REV STATUS OF SHEETS
3	2	1	SH	

This document, exclusive property of
GE Energy Products France SNC
is strictly confidential. It must not be communicated
copied or reproduced without our previous written consent.

Ce document, propriété exclusive de
GE Energy Products France SNC est
strictement confidentiel. Il ne peut être communiqué,
copié ou reproduit sans son autorisation écrite préalable

NAMES/NOMS		GE Energy Products - Europe			
DRAWN	THIRION F.	SCH. AIR REFROID. & ETANCH. DIAG. SCH. PP-CLG & SLG AIR			
CHECKED	JOST JM.				
APPROVED	RHIM M.				
		SIZE A3	CAGE CODE	DWG. NO. 360B1321	DISTR TO
SIM TO : 356B3051		SCALE	REV. : B	SHEET 1	

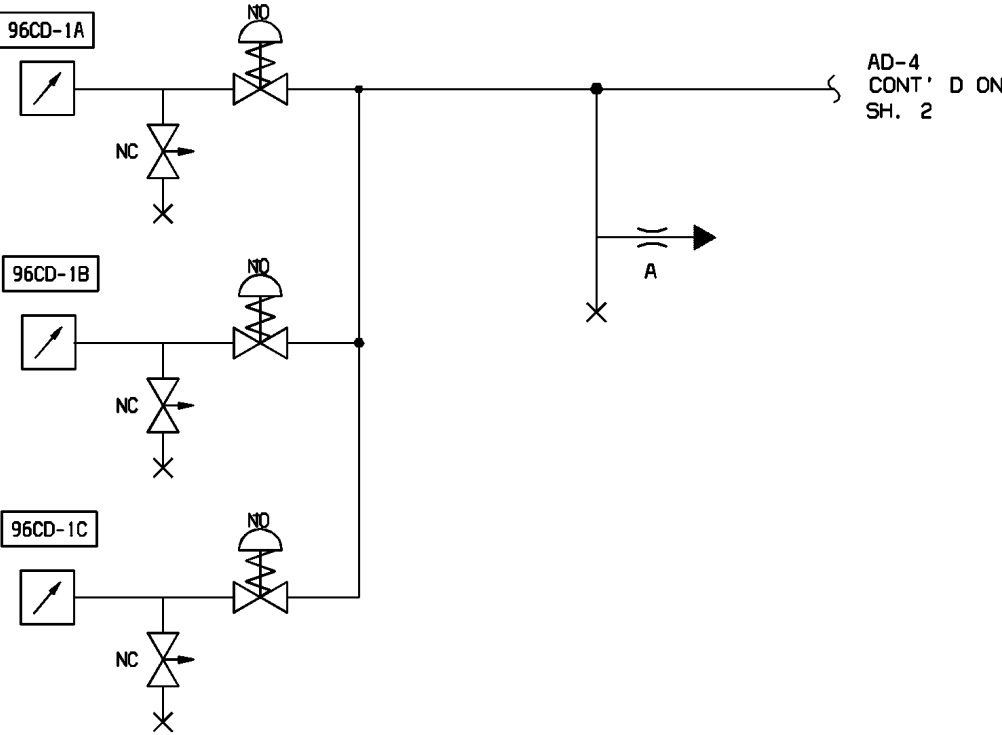


This document, exclusive property of
GE Energy Products France SNC
is strictly confidential. It must not be communicated
copied or reproduced without our previous written consent.

Ce document, propriété exclusive de
GE Energy Products France SNC est
strictement confidentiel. Il ne peut être communiqué,
copié ou reproduit sans son autorisation écrite préalable

NOMS/NAMES		 <i>GE Energy Products - Europe</i>		GENERAL ELECTRIC COMPANY	
DRAWN	THIRION F.				
CHECKED	JUST JM.	SCH. AIR REFROID. & ETANCH. DIAG. SCH. PP-CLG & SLG AIR			
APPROVED	RHIN M.				
		nt.			
		le			
		SIZE A3	CAGE CODE	DWG. NO. 360B1321	
SIM TO : 356B3051		SCALE	REV. : B		SHEET 2

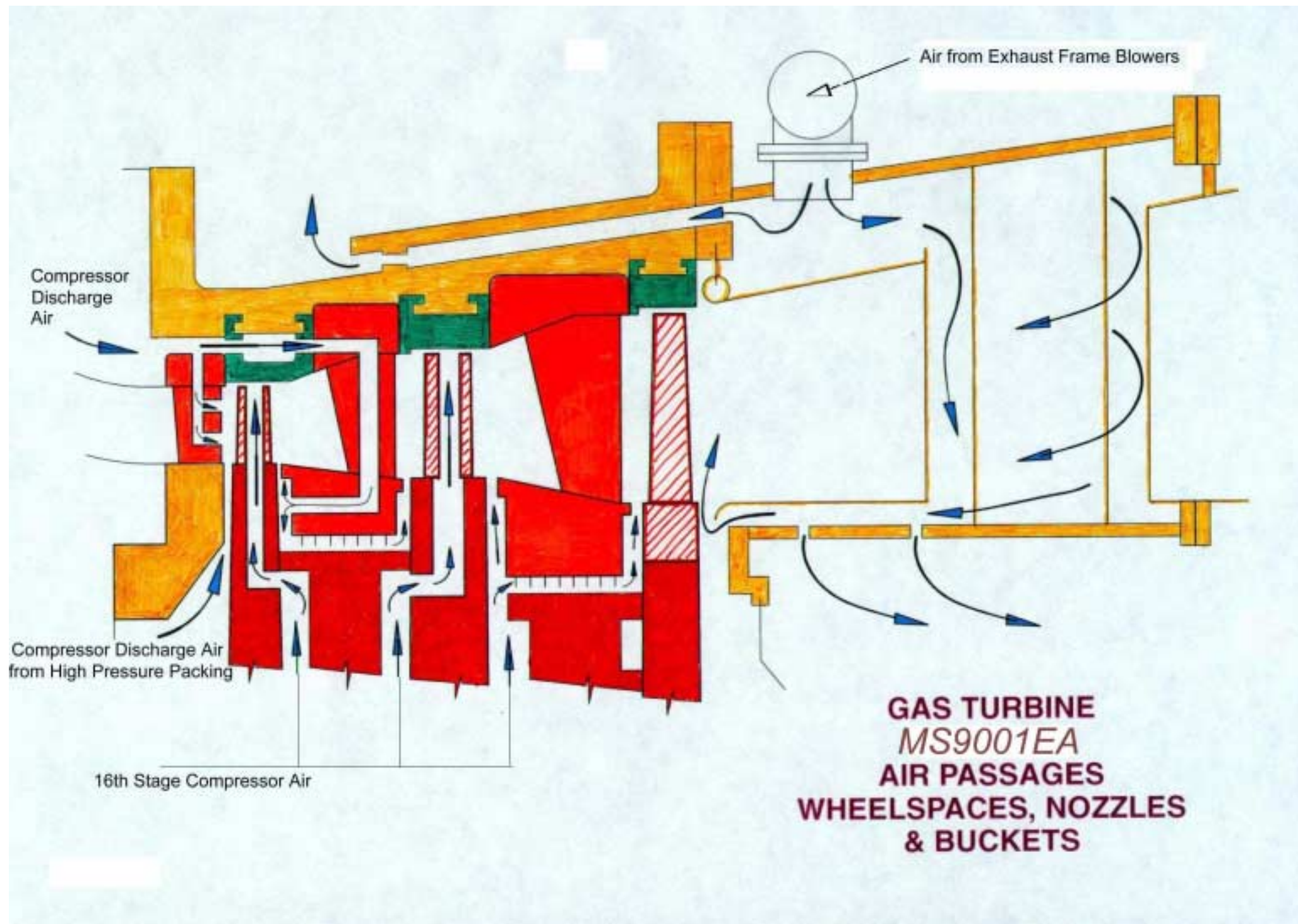
11-Sep-2003-12:12



GE Official

This document, exclusive property of
GE Energy Products France SNC
is strictly confidential. It must not be communicated
copied or reproduced without our previous written consent.
Ce document, propriété exclusive de
GE Energy Products France SNC est
strictement confidentiel. Il ne peut être communiqué,
copié ou reproduit sans son autorisation écrite préalable

NOMS/NAMES		GE Energy Products - Europe	
DRAWN	THIRION F.	SCH. AIR REFROID. & ETANCH. DIAG. SCH. PP-CLG & SLG AIR	
CHECKED	JOST JM.		
APPROVED	RHIM M.		
		SIZE	CAGE CODE
		A3	DWG. NO. 360B1321
SIM TO : 356B3051		SCALE	REV. : A
		SHEET 3	



Tab 12

DESCRIPTIVE GUIDE

3.5. COOLING WATER SYSTEM

3.5.1. GENERAL

The cooling water system is a pressurized, closed system, designed to accommodate the heat dissipation requirements of the turbine, the lubrication system, the turbine support legs and the flame detectors. An aqueous solution of ethylene glycol is used in the system ; therefore, it is capable of performing its function throughout the year if the ambient temperatures are not too high. During frost the cooling system must be filled with an aqueous solution of ethylene glycol. During high temperatures it is necessary to fill the system with a solution whose quality is specified in the Gas turbine equipment publications volumes. In the text that follows, this solution is referred to as the cooling water.

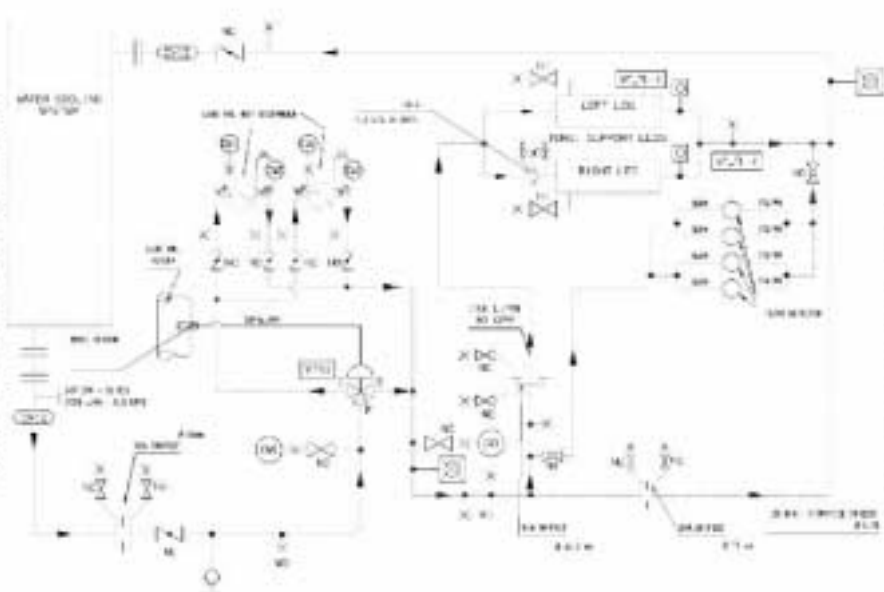
Included in the cooling water system are the cooling cells, the pumps, miscellaneous valves and certain control and protection devices. See figure CW-1.

The cooling system is connected to the customer's cooling water system.

DESCRIPTIVE GUIDE

PART	NOMENCLATURE
VTR 1	Bearing header temperature regulating valve.
WT_TL-1,-2	Water system temperature turbine support legs.

FIGURE CW-1: COOLING WATER SYSTEM SCHEMATIC



DESCRIPTIVE GUIDE

3.5.2. FUNCTIONAL DESCRIPTION

The cooling water system circulates water as a cooling medium to maintain the lubricating oil at acceptable lubrication system temperature levels and to cool several turbine components.

The system normally operates at a slightly positive pressure which results when the fuel in the system expands with the increase in temperature during operation.

During operation the coolant is supplied by the owner's cooling system and circulates through the chosen lube oil, the turbine support legs (in parallel with the system of heat exchangers) and the flame detectors. After absorbing the heat rejected by these items, the coolant flows through the owner's water cooling system where it is cooled.

Flow regulating valves

The coolant circuit for the lube oil has a temperature actuated 3-way valve (VTR-1) installed in the coolant inlet line to the heat exchanger.

This type of valve, which controls coolant flow to the heat exchanger, has a manually operated device which can override the thermal element. The manual override device should be used only when the valve's thermal element is inoperative but machine operation is required. Lube oil feed header temperature is sensed by the bulb associated with the valve which controls the flow of coolant through the heat exchanger and maintains the lube oil temperatures at predetermined values. The valve automatically controls flow of the medium passing through it (coolant) to the heat exchanger by responding to temperature changes affecting the bulb.

The bulb contains a thermal-sensitive liquid which vaporizes when heated. Pressure thus generated in the bulb is transmitted through the capillary tube to the bellows, which positions the valve disc to control the flow of coolant through the heat exchanger. The valve is closed during turbine startup, and will start to open as the sensed fluid temperature approaches the control setting.

At the inlet of each cooling water circuit (lube oil heat exchanger circuit and turbine support legs circuit), an orifice allows water flow rate calibration to the circuit concerned.

Shut-off valves

Shut-off valves are provided in the piping so that the tube side of the lube oil heat exchanger may be isolated from the water system for maintenance.

Temperature, pressure measuring and/or protective devices

Thermocouples, WT_TL-1,-2 at turbine support legs outlet located at GT cooling system outlet, give a GT cooling water temperature indication.

NOTE : For the recommendations about the various components of the circuits, refer to the Gas turbine equipment publications volumes.

REVISIONS

REV	DESCRIPTION	SIGNATURES		
		DATE	NAMES/NOMS	SIGNATURES
A	FIRST ISSUE	27 SEP 01	THIRION F.	
		27 SEP 01	JOST JM.	
		27 SEP 01	ANCEL T.	

NOTES:

- 1- SEE DEVICE SUMMARY FOR CONTROL DEVICE SETTINGS.
- 1- VOIR NOMENCLATURE DES APPAREILS POUR REGLAGE DES APPAREILS DE CONTROLE.
- 2- HIGH POINT VENTS AND LOW POINT DRAINS ARE PROVIDED IN EACH LOOP AS REQUIRED .
- 2- DES EVENTS SONT EN PLACE SUR LES POINTS HAUTS AINSI QUE DES PURGES AUX POINTS BAS LA OU CELA EST NECESSAIRE SUR LES TUYAUTERIES .
- 3- INLET AND OUTLET CONDITION:
PRESSURE DROP: 29 PSIG
MAXI. INLET PRESSURE: 152 PSIG
MINI. OUTLET PRESSURE: 11 PSIG
INLET TEMPERATURE: 140 °F
OUTLET TEMPERATURE: 194 °F
- 3- CONDITION D' ENTREE ET DE SORTIE:
PERTE DE CHARGE: 2 BARS
PRESSION MAXI. D'ENTREE: 10.5 BARS
PRESSION MINI. DE SORTIE: 0.75 BARS
TEMPERATURE D'ENTREE: 60 °C
TEMPERATURE DE SORTIE: 90 °C
- 4- ONLY ONE LUBE COOLER IS TO BE IN SERVICE DURING NORMAL OPERATION. THE OTHER LUBE COOLER BEING ISOLATED ON WATER-SIDE
- 4- UN SEUL REFRIGERANT D'HUILE DE GRAISSAGE DOIT ETRE EN SERVICE PENDANT LA MARCHE NORMALE DU SYSTEME. L'AUTRE REFRIGERANT DOIT ETRE ISOLE COTE EAU.

SPECIFICATION P&ID	277A2415
NOMENCLATURE	IDENT
LIST OF COMPLEMENTARY DOCUMENTS	
FIRST MADE FOR : MS 9001E	ITEM : 0420

A	A	REV	REV STATUS
2	1	SH	OF SHEETS

SIGNATURES	DATE
DRAWN THIRION F.	27 SEP 01
CHECKED JOST JM.	27 SEP 01
APPROVED ANCEL T.	27 SEP 01



GE Energy Products - Europe

GENERAL ELECTRIC COMPANY

SCH.TUY.EAU DE REFROIDISSEMENT
DIAG.SCH.PP-COOLING WATER

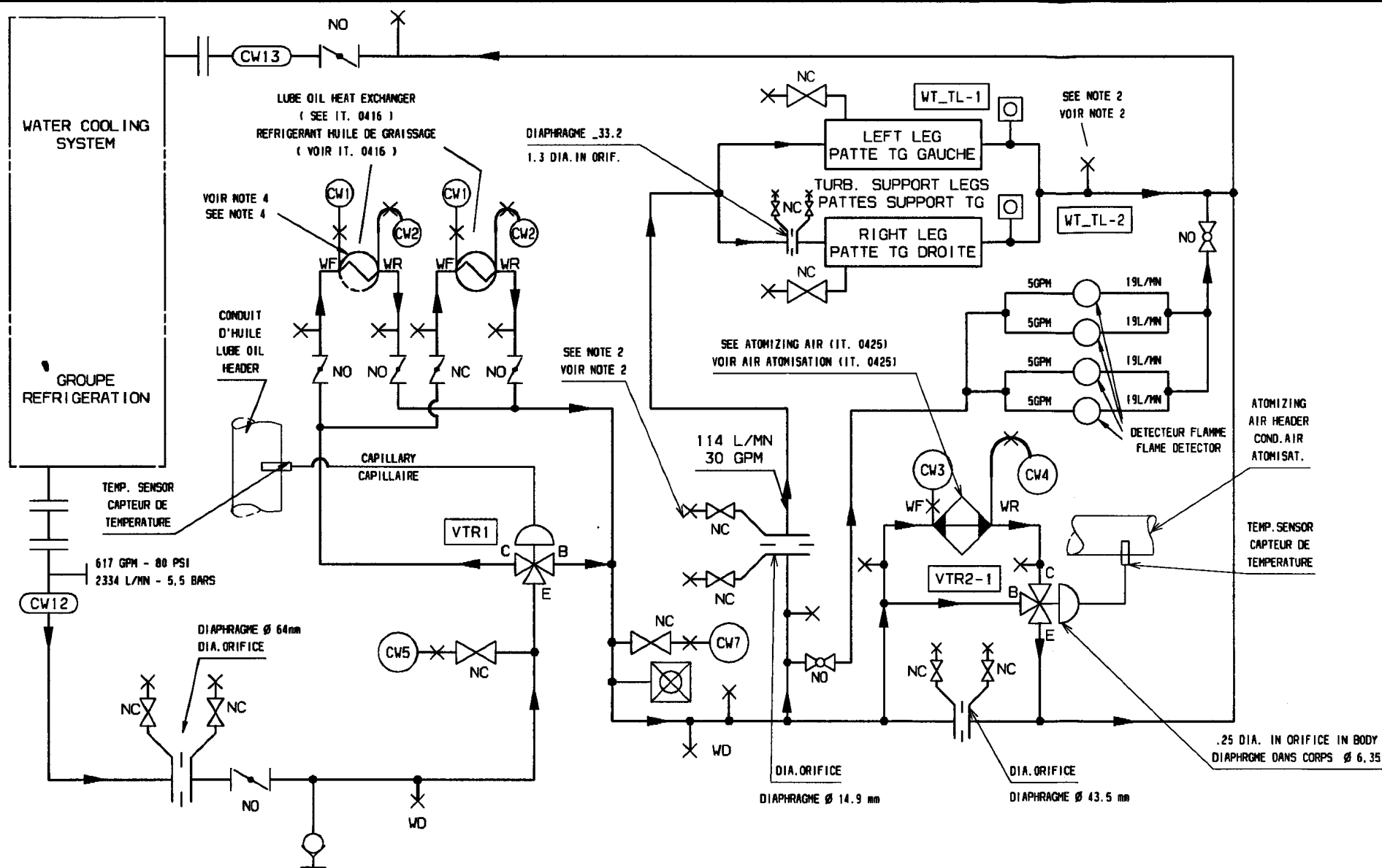
This document, exclusive property of
GE Energy Products France SNC
is strictly confidential. It must not be communicated
copied or reproduced without our previous written consent.

Ce document, propriété exclusive de
GE Energy Products France SNC est
strictement confidentiel. Il ne peut être communiqué,
copié ou reproduit sans son autorisation écrite préalable

SIZE A3 CAGE CODE DWG. NO. 356B3088

SIM TO : 91-315704 SCALE REV. : A SHEET 1

DISTR
TO



SIGNATURES		DATE		 GE Energy Products - Europe		GENERAL ELECTRIC COMPANY					
DRAWN THIRION F.		27 SEP 01									
CHECKED JOST JM.		27 SEP 01		SCH. TUY. EAU DE REFROIDISSEMENT DIAG. SCH. PP-COOLING WATER							
APPROVED ANCEL T.		27 SEP 01									
				SIZE		CAGE CODE		DWG. NO.		356B3088	
		A3									
SIM TO : 91-315704				SCALE		REV. : A			SHEET 2		

This document, exclusive property of
GE Energy Products France SNC
is strictly confidential. It must not be communicated
copied or reproduced without our previous written consent.

Ce document, propriété exclusive de
GE Energy Products France SNC est
strictement confidentiel. Il ne peut être communiqué,
copié ou reproduit sans son autorisation écrite préalable.

Tab 13

DESCRIPTIVE GUIDE

3.13. COMPRESSOR WASHING**3.13.1. DESCRIPTION OF THE SYSTEM**

Gas turbines experience a degradation of performance during operation as the result of deposits on internal components of the compressor. Compressor deposits occur with the ingested air. The fouling of this section will reduce the thermal efficiency and power output of the gas turbine.

Two methods are used to determine the cleanliness of the compressor :

- Visual inspection
- Performance monitoring

1 Visual inspection

- Unit shutdown, the visual inspection includes inspection of the compressor inlet, bellmouth, inlet guide vanes and the first stage of the compressor blades.
- If the fouling is caused by "dry" contaminants a water solution is enough.
- If the deposits are "oily", a water/detergent wash and water rinse should be performed.

2 Performance monitoring

- The performance data is obtained by running the unit at steady state base load and recording output, exhaust temperature, inlet air temperature, barometric pressure, compressor discharge pressure and temperature and fuel consumption.
- If performance analysis indicates compressor fouling, it should be verified by a visual inspection.

Equipment concerning the compressor washing consist of a piping from the customer's connection on the turbine base, of motor-driven valves 20 TW-1 and 20 TW-3 and of push-buttons 43 TW-1/PB of those same valves, and a compressor spray manifold feeding the compressor through spray nozzles located in the compressor bell-mouth.

There are also some customer's connections on the drain pipings.

DESCRIPTIVE GUIDE

PART	NOMENCLATURE
20 TW-1	Compressor water wash solenoid valve.
20 TW-3	Compressor water wash solenoid valve.
43 TW-1/PB	Solenoid valve 20 TW-1 push-button.
VA 17-1	False start drain valve – combustion wrapper.
VA 17-2	False start drain valve – exhaust frame.

All right reserved Copyright – Droits de reproduction réservés

DESCRIPTIVE GUIDE

3.13.2. OFF-LINE COMPRESSOR WASHING OPERATION**1 Functional description**

Unit The wash water solution in the proper mix is delivered to the turbine unit at the proper pressure, temperature and flow rate to wash the gas turbine.

Wash solution from the skid flows from the customer's connection through the motorized valve 20 TW-1 to the compressor spray manifold. The valve is motor-driven and is manually opened by a push-button 43 TW-1/PB. It is closed automatically when the wash selector switch is in the OFF position.

During compressor washing, valve 20 TW-1 is opened allowing the wash solution from the skid to flow into the compressor spray manifold and through the spray nozzles into the compressor bell-mouth to accomplish the washing.

False start drain valve (VA17-1) shown on the washing diagram are opened for washing purpose. Air pressure from the discharge of the unit's axial-flow compressor is used to actuate these valve. Valve VA 17-1 drain excessive water from the combustion chambers.

2 Off-line washing procedure

Before water washing of the compressor begins, the turbine blading temperature must be low enough so that the wash water does not cause thermal shock. The differential temperature between the wash water and the interstage wheelspace temperature must not be greater than 120°F (67°C). For wash water of 180°F (82,3°C), the maximum wheelspace temperature must be no greater than 300°F (149°C) as measured by the digital thermocouple readout system on the turbine control panel.

Scheduling of the water wash should occur during the normal machine shut down. This would allow sufficient time for the internal machine temperature to drop to acceptable levels for the washing.

During the cooling of the turbine, the wash water is to be heated to the proper level.

WARNING : The water wash operation involves water under high pressure. Caution must be exercised to insure the proper valve is either in a fixed open or a fixed closed position at any time during system operation.

NOTE : Before water washing the compressor, inspect the inlet plenum and gas turbine bell-mouth for large accumulations of atmospheric contaminants which could be washed into the compressor. These deposits can be removed by washing with a garden hose.

Prepare the cooling and sealing air circuit and the skid.

The compressor OFF-LINE washing is done with the machine cold, at crank speed so to have a good cleaning of the rotor. The washing compressor selection will led to the opening of the IGV.

The valves that have been operated before the compressor washing operation must be returned to their previous positions to allow the turbine to fire.

DESCRIPTIVE GUIDE

3.13.3. ON-LINE COMPRESSOR WASHING OPERATION

1 Functional description

The wash water solution is delivered to the turbine unit at the proper pressure temperature and flow rate to wash the gas turbine. For the specific values for this gas turbine unit refer to the piping schematic diagram in the Operation volume and in the Maintenance volume.

The valve 20 TW-3 is automatically regulated by the SPEEDTRONIC control. During compressor washing valve 20 TW-3 is opened allowing the wash solution from the skid to flow into the compressor spray manifold and through the spray nozzles into the compressor bell-mouth to accomplish the washing.

2 On-line washing procedure

Turbine must be running at full speed and not in the process of shutting down. Washing is allowed at any load, but not at any ambient air temperature and humidity.

The ambient temperature must be superior to 10°C.

WARNING : The water wash operation involves water under high pressure. Caution must be exercised to insure the proper valve is either in a fixed open or a fixed closed position at any time during system operation.

NOTE : Before water washing the compressor, inspect the inlet plenum and gas turbine bell-mouth for large accumulations of atmospheric contaminants which could be washed into the compressor. These deposits can be removed by washing with a garden hose.

REVISIONS		
REV	DESCRIPTION	
A	FIRST ISSUE	NAMES/NOMS TECHNICREA LM
		JOST J-M
		BLEIN O.

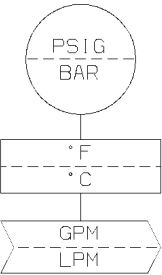
NOTES :

- 1- SEE DEVICE SUMMARY (MLJ 0414) FOR CONTROL DEVICE SETTINGS.
- VOIR NOMENCLATURE DES APPAREILS POUR REGLAGE DES APPAREILS DE CONTROLE

PC DESIGN REQUIREMENTS
CONDITIONS EN TEMPERATURE, PRESSION
ET DEBIT DU RACCORDEMENT CLIENT

PC	TEMP. MAX	PRESS. MAX	FLOW MAX
IE4	180°F (82°C)	2 PSIG 0.13 BAR	.25 GPM (1 LPM)
LF2	180°F (82°C)	2 PSIG 0.13 BAR	4 GPM (15 LPM)
LF3	180°F (82°C)	2 PSIG 0.13 BAR	4 GPM (15 LPM)
LF10	180°F (82°C)	2 PSIG 0.13 BAR	1 GPM (3.8 LPM)
WW1	180°F (82°C)	110 PSIG 7.58 BARS	72 GPM (273 LPM)
WW11	140°F (60°C)	100 PSIG 6.9 BAR	10 GPM 37.8 LPM)

PURCHASER'S CONNECTIONS
CONNEXIONS CLIENT(S)



LINE PRESSURE

TEMPERATURE

FLOW RATE

LEGEND

- A - WASH WATER DRAIN FROM INLET PLENUM
PURGE EAU DE LAVAGE DU CAISSON ASPIRATION
- B - WASH WATER DRAIN FROM EXHAUST PLENUM
PURGE EAU DE LAVAGE DU CAISSON ECHAPPEMENT
- C - WASTE FUEL DRAIN FROM EXHAUST PLENUM
PURGE FUEL-OIL CADRE ECHAPPEMENT
- D - WASH WATER DRAIN FROM EXHAUST PLENUM
PURGE EAU DE LAVAGE DU CAISSON ECHAPPEMENT
- E - WASH WATER DRAIN FROM COMBUSTION SYSTEM
PURGE EAU DE LAVAGE DU CARTER DES CHAMBRES
- F - WASTE FUEL DRAIN FROM COMBUSTION SYSTEM
PURGE FUEL-OIL DU CARTER DES CHAMBRES
- G - WASH WATER DRAIN FROM EXHAUST FRAME
PURGE EAU DE LAVAGE DU CORPS ECHAPPEMENT TURBINE
- H - WASTE FUEL DRAIN FROM EXHAUST FRAME
PURGE FUEL-OIL DU CORPS ECHAPPEMENT TURBINE

SPECIFICATION P&ID	277A2415
NOMENCLATURE	IDENT
LIST OF COMPLEMENTARY DOCUMENTS	
FIRST MADE FOR : MS 9001E	ITEM : 0442

A	A	REV	REV STATUS
2	1	SH	OF SHEETS

This document, exclusive property of
GE Energy Products France SNC
is strictly confidential. It must not be communicated
copied or reproduced without our previous written consent.

Ce document, propriété exclusive de
GE Energy Products France SNC est
strictement confidentiel. Il ne peut être communiqué,
copié ou reproduit sans son autorisation écrite préalable.

NOMS/NAMES	
DRAWN	TECHNICREA LM
CHECKED	JOST J-M.
APPROVED	BLEIN O.



GE Energy Products - Europe

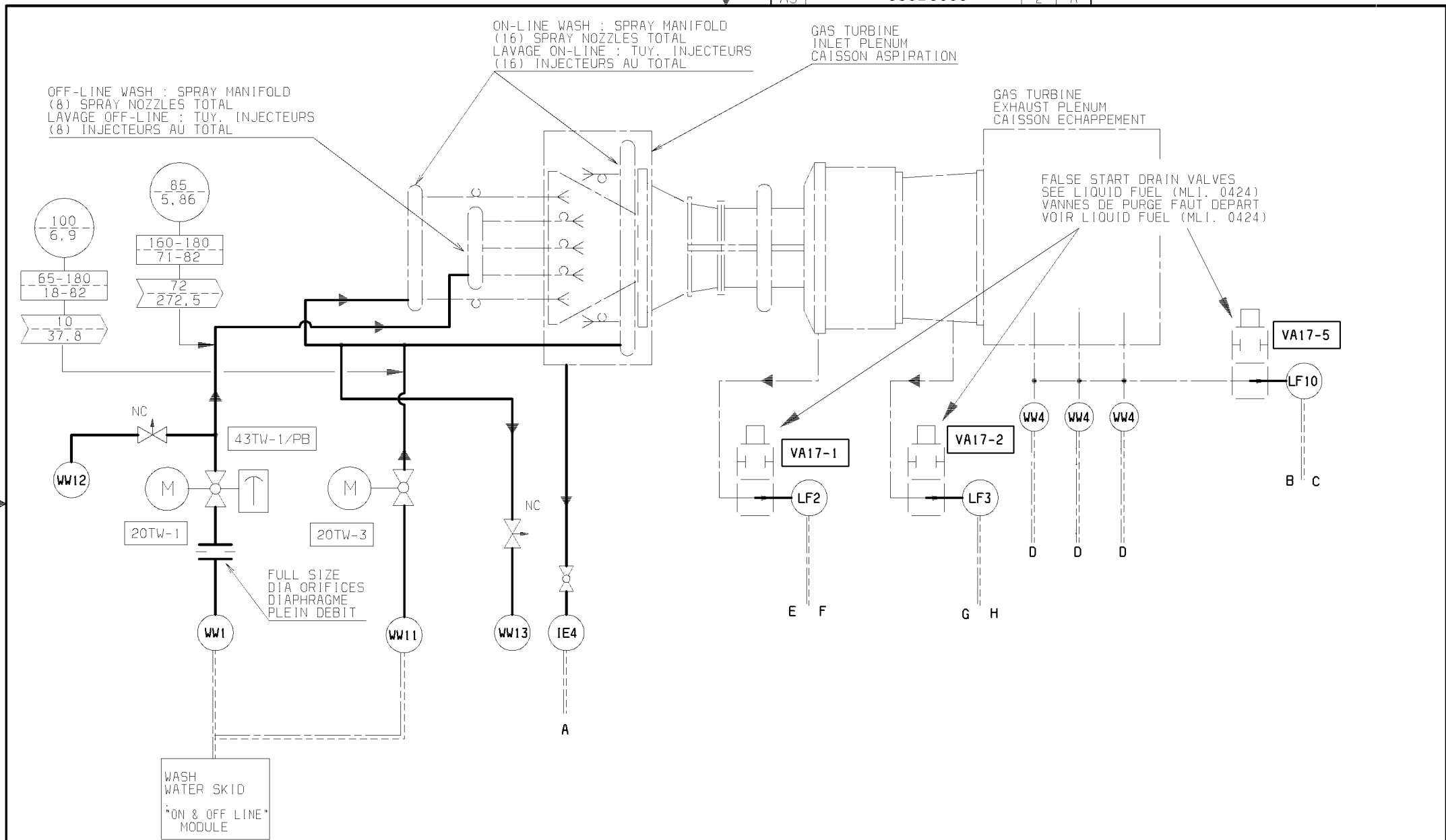
GENERAL ELECTRIC COMPANY

SCH. LAVAGE TG ET COMPRESSEUR
DIAG. SCH. PP-TG & COMPRESSOR WSHG

SIZE A3	CAGE CODE	DWG. NO. 356B3388
SIM TO : 356B2415		

SCALE	REV. : A	SHEET 1

DISTR
TO



This document, exclusive property of GE Energy Products France SNC is strictly confidential. It must not be communicated copied or reproduced without our previous written consent
Ce document, propriété exclusive de GE Energy Products France SNC est strictement confidentiel. Il ne peut être communiqué, copié ou reproduit sans son autorisation écrite préalable

		NOMS / NAMES		 GE Energy Products - Europe		GENERAL ELECTRIC COMPANY	
DRAWN		TECHNICREA LM					
CHECKED		JOST J-M.					
APPROVED		BLEIN O.		SCH. LAVAGE TG ET COMPRESSEUR <i>DIAG. SCH. PP-TG & COMPRESSOR WSHG</i>			
				SIZE		CAGE CODE	
		A3				DWG. NO.	
						356B3388	
SIM TO :		356B2415		SCALE		REV. : A	
						SHEET 2	



GEK 110220a
Revised May 2002

GE Power Systems

Gas Turbine

Gas Turbine Compressor Water Wash System

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes the matter should be referred to the GE Company.

© 2002 GENERAL ELECTRIC COMPANY

I. GENERAL

Gas turbines can experience a loss of performance during operation as result of deposits of contaminants on internal components. This loss is indicated by a decrease in power output and an increase in heat rate. The deposits of atmospheric contaminants on compressor parts occurs with the ingestion of air.

The ingested air may contain dirt, dust, insects, and hydrocarbon fumes. A large portion of these can be removed before they get to the compressor by inlet air filtration. The dry contaminants that pass through the filters as well as wet contaminants, such as hydrocarbon fumes, have to be removed from the compressor by washing with a water-detergent solution followed by a water rinse.

A. On-Base Supplied Equipment

The on-base turbine equipment supplied with this compressor wash system consists of piping from the purchaser's connection on the base, air operated water injection valve(s), and the appropriate spray manifold(s). Drains from the inlet plenum, combustion area, exhaust frame, and the exhaust plenum are also provided. In addition, there are purchaser connections in these drain lines. The schematic for this on-base water wash equipment is located in the Reference Drawing sections of this manual.

B. Off-Base Equipment

The off-base portion of the water wash system, known as the water wash skid, contains both a water tank and a detergent tank. The water tank is equipped with temperature sensors and electric heaters to maintain proper water temperatures. The skid is equipped with a centrifugal water pump motor (88TW-1) and a venturi used with the water pump to mix detergent solution. Also included on the skid are the various control panels to initiate wash and to manually start/stop the appropriate devices. All equipment is made of corrosion resistant material. The schematic for the water wash skid is included in the Reference Drawings section of this manual.

All devices are set to give proper temperature, pressure, and flow. The settings for these devices can be found in the device summary for the corresponding system.

C. Functional Description

During the washing operation, water or wash solution is delivered through customer piping to the gas turbine in the proper mix ratio. The wash water solution is delivered to the turbine unit at the proper pressure, temperature, and flow rate to wash the gas turbine compressor. Refer to the system schematic in the Reference Drawing section for proper pressure(s), temperature(s), and flow rate(s) for this gas turbine.

1. System Requirements

Water used for washing turbine parts should be reasonably clean so that it does not cause fouling or corrosion in itself. Distilled or deionized water is recommended. Water quality requirements are listed in Table 1 of GEK-107122 (Latest Revision). Oily or varnished oil deposits on internal gas turbine parts require that a detergent solution be used during the washing operation. The detergent shall meet the requirements of GEK-107122 (Latest Revision), Appendix 1.

2. Compressor Washing Frequency

The frequency of compressor washing depends upon the severity and type of atmospheric contamination that fouls the compressor and reduces performance. The recommended method for establishing the frequency is to monitor gas turbine performance, comparing the routine performance with the baseline performance to observe the performance trends.

If the performance has fallen significantly, and compressor fouling is suspected, it must be verified by visual inspection. This visual inspection should include the compressor inlet, bellmouth, inlet guide vanes and the first and, possibly, the second stage of the compressor blades.

NOTE

Inspection should be made for the source of the oily deposits. If possible, corrective action should be taken.

D. Washing System Operation

1. General

a. Off-line Water Wash

Off-line water washing should be scheduled during a normal shutdown, if possible. This will allow enough time for the internal machine temperature to drop to the required levels for the washing. The time required to cool the machine can be shortened by maintaining the unit at crank speed. During this cooling of the turbine, the wash water may be heated to the proper level.

Refer to GEK-107122 (Latest Revision) for gas turbine compressor liquid washing recommendations

b. On-line Water Wash

The period between off-line water washes can be extended via frequent on-line washing. When the compressor is suspected of being heavily fouled, an off-line wash should be performed.

The on-line compressor wash system allows an operator to water wash the turbine compressor without having to shut down the turbine. The method of washing is similar in many ways to the off-line system. Both systems use the same pump, 88TW-1, and piping to supply high quality wash solution to the compressor. When the supply pipe reaches the vicinity of the turbine base, it splits into two branches, one for the off-line system and one for the on-line system. Each branch contains a stop valve, flow control orifice, manifold(s) and spray nozzles.

There are significant differences, though, between the two systems. GE recommends against the use of detergents during on-line washing, while the use of detergents during off-line washing are encouraged. The on-line wash water requirements differ from that of off-line wash solution and must meet the requirements of Table 1 of GEK-107122 (Latest Revision) for on-line washing. Finally, the on-line system proceeds automatically after it is manually initiated; whereas, the off-line system requires operator intervention before and after the wash.

NOTE

When using a detergent solution for on-line washing, it is recommended that the wash be followed by enough rinse water to remove the detergent residue from the wash nozzles at the spray manifold. This will prevent the detergent solutions from drying and clogging the nozzles.

2. Mandatory Precautions

Before water washing of the compressor begins, the turbine blading temperature must be low enough so that the water does not cause thermal shock.

CAUTION

The differential temperature between the wash water and the interstage wheelspace temperature must not be greater than 120°F (67°C) to prevent thermal shock to the hot gas parts. The maximum wheelspace temperature as per TIL 1196–1 must be no greater than 150°F (65.5°C) as measured by the digital thermocouple readout system on the turbine control panel.

To reduce this difference, the wash water may be heated and the turbine kept on crank until the wheelspace temperatures drop to an acceptable level. The wheelspace temperatures are read in the control room.

CAUTION

If, during operation, there has been an increase in exhaust temperature spread above the normal 15°F to 30°F (8.3°C to 16.6°C), the thermocouples in the exhaust plenum should be examined. If they are coated with ash, the ash should be removed.

Radiation shields should also be checked. If they are not radially oriented relative to the turbine, they should be repositioned per the appropriate drawing. If the thermocouples are coated with ash, or if the radiation shields are not properly oriented, a correct temperature reading will not be obtained.

If neither of the above conditions exists and there is no other explanation for the temperature spread, consult the General Electric Service Engineering representative.

*****WARNING*****

THE WATER WASH OPERATION INVOLVES WATER UNDER HIGH-PRESSURE. CAUTION MUST BE EXERCISED TO ENSURE THE PROPER POSITIONING OF ALL VALVES DURING THIS OPERATION. SINCE THE WATER MAY ALSO BE HOT, NECESSARY PRECAUTIONS SHOULD BE TAKEN IN HANDLING VALVES, PIPES, AND POTENTIALLY HOT SURFACES.

NOTE

Before water washing the compressor, inspect the inlet plenum and gas turbine bellmouth for large accumulations of atmospheric contaminants that could be washed into the compressor. The deposits can be removed by washing with a garden hose.



GE Power Systems

*General Electric Company
One River Road, Schenectady, NY 12345
518 • 385 • 2211 TX: 145354*



GEK 28166A
Revised January 1997

GE Power Systems Gas Turbine

Field Performance Testing Procedure

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes the matter should be referred to the GE Company.

© 1997 GENERAL ELECTRIC COMPANY

TABLE OF CONTENTS

I. GENERAL 3

II. PURPOSE OF TEST 3

III. TEST PROCEDURE 3

 A. Fuel Consumption 4

IV. EVALUATION 6

V. CONCLUSION 6

GAS TURBINE PERFORMANCE DATA 7-11

FIGURE

Figure 1. Gas Flow Measurement Instrumentation 5

I. GENERAL

This instruction specifies the methods and equipment to be used during field performance tests of heavy-duty gas turbines using station instrumentation. It applies only to turbine generator power plants.

II. PURPOSE OF TEST

The primary purpose of the test shall be the measurement of turbine or generator output and fuel heat consumption at one or more load conditions.

Sufficient supporting data shall be recorded to enable the "as tested" performance to be corrected to the standard conditions so that an accurate comparison may be made between tested and base line machine capability and heat rate at specified conditions.

The attached data sheets should be used to record the test data. They are designed to provide the information required to evaluate the aero-thermodynamic performance of the gas turbine only. Any other operating data should be taken separately to prevent interference with the timing required for the performance test.

III. TEST PROCEDURE

These testing procedures are patterned after those specified and described by the American Society of Mechanical Engineers Power Test Code PTC-22-1966, "Gas Turbine Power Plants," with the following additions and/or exceptions. Figures in parentheses refer to the relevant paragraph in the code. Past experience has shown that a gas turbine operator and four (4) test assistants are required for testing. One day of setup time and one day of testing are usually needed per machine.

A test point will consist of four sets of instrument readings taken at 10-minute intervals over a 30-minute time span after steady-state conditions have been established (3.12).

The machine will be considered to be in a steady-state condition when turbine wheelspace temperatures do not change more than 5°F (2.77°C) in 15 minutes prior to the test point.

Past experience has shown that test points for gas turbines that cover longer than a half-hour time span are apt to experience changes in inlet air temperatures, which change the operating characteristics of the power plant and make the test less accurate.

Speed measurements may not be required when a single-shaft generator drive unit is connected into a large power system. When the power system is small or frequency variations of more than 0.5% occur, then turbine speed (or frequency) must be measured by an electronic tachometer or equivalent.

Average generator output must be measured by a polyphase watt-hour meter (4.24).

Load is to be calculated by carefully timing, with stopwatch or equivalent, a fixed number of disc revolutions throughout the test point, averaging those times and calculating the resulting average power output by applying the appropriate factor (pri. K_h) stamped on the face of the meter.

$$\text{Power Output} = \frac{n \text{ revolutions}}{\text{Sec. for } n \text{ rev.}} + \text{Pri } K_h + (3,600/1,000)$$

where;

$$\text{Pri } K_h = \text{PTR} + \text{CTR} + \text{meter } K$$

PTR = Potential Instrument Transformer Ratio

CTR = Current Instrument Transformer Ratio

Ideally, the total number of disc revolutions should be counted for the entire test point. This is, however, a tedious task and seldom worthwhile. Instead, a count of 20 revolutions should be made continuously throughout the point with the only interruption being the recording of the elapsed time for each group of revolutions.

Gas turbine exhaust temperature will be measured by the unit control thermocouples mounted in the exhaust plenum (4.56).

It is essential that the temperature-indicating system be adjusted and calibrated in place with a known millivolt source prior to the test so that it reports reliable data. If more than 25% of the control thermocouples are inoperative, the performance test should not be conducted.

When liquid-in-glass manometers are used, bores of smaller than 5/16 inch (0.079 cm) will be permitted (4.59).

Barometric pressure at the gas turbine site shall be measured with a mercury or aneroid barometer. A minimum reading accuracy of 0.01 inch (0.03 cm) Hg is required (4.65).

As stated in paragraph 5.33 of the code, inlet air relative humidity has negligible effects on power output and heat consumption. It will therefore be ignored for performance evaluation.

A. Fuel Consumption

For units designed to burn more than one type of fuel, liquid fuel generally yields higher test accuracy and repeatability and should therefore be preferred. If there is a choice of liquid fuels, lighter fuels yield more accurate test results.

1. Liquid Fuel

Liquid fuel flow is to be measured by a positive displacement meter which has been calibrated. The total fuel consumed during the exact 30-minute test as measured with a stopwatch must be recorded. The fuel temperature at the meter must also be measured.

A sample of the fuel consumed during the test must be taken for laboratory measurement of higher heating value (HHV) and specific gravity. The lower heating value (LHV) will be determined by the method specified in paragraph 4.45 of PTC 22-1966.

If the fuel is drawn from a large storage tank, a single sample will suffice for several test points; however, if variations in fuel characteristics are suspected, a fuel sample should be taken for each test point. Fuel samples of one pint are sufficient for HHV and specific gravity measurement.

The heat consumption will be calculated using

$$\begin{aligned} \text{Heat Consumption (Btu/hr)} = & \text{gal/min} + 8.33 \text{ lb/gal (H}_2\text{O)} \\ & + \text{Specific Gravity (Oil) at metering temp.} \\ & + \text{Heating Value * Btu/lb} + 60 \text{ min/hr.} \end{aligned}$$

2. Gas Fuel

Gas fuel is to be measured with a flat-plate orifice installed in accordance with ASME or AGA standards. See Figure 1. The upstream pressure will be measured with a precision test gauge, the pressure drop with a manometer, the gas temperature with a thermometer or thermocouple.

A gas sample must be taken from the fuel system during the test for laboratory measurement of higher heating value and specific gravity. A ratio (HHV/LHV) of 1.11 will be used to calculate the lower heating value.

Calculation of gas flow will be done in accordance with ASME or AGA standards as described in ASME PTC 19.5; 4-1959 or AGA Report #3.

Inlet air temperature will be measured with at least two thermometers or thermocouples installed in the inlet plenum near the gas turbine compressor inlet. The compressor inlet air temperature must be measured with an accuracy of $\pm 1.0^\circ\text{F}$ ($.5^\circ\text{C}$) (4.55).

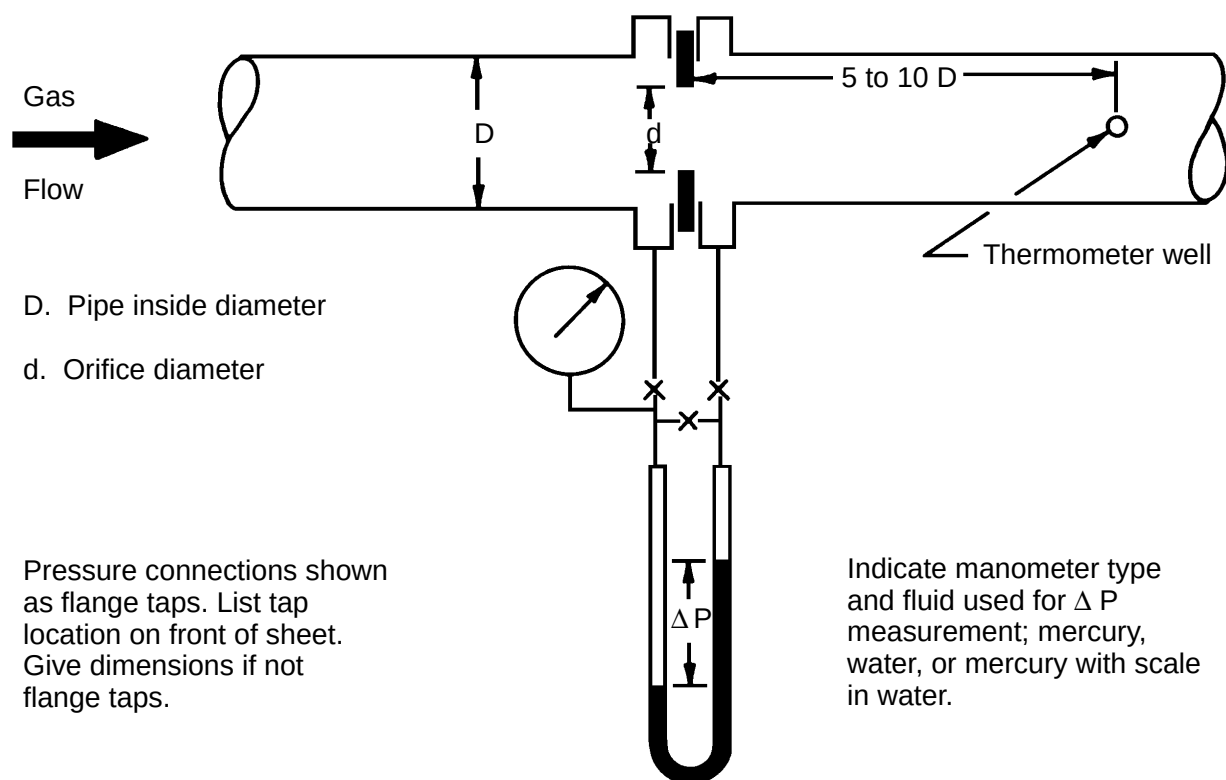


Figure 1. Gas Flow Measurement Instrumentation.

*Use HHV or LHV as specified by rating.

If waste heat recovery equipment is used, turbine exhaust static pressure at or near the gas turbine flange must be measured using at least four-disc type static pressure probes.

When the tests are performed at “Base” and “Peak” mode, the gas turbine control system must be adjusted to operate at the correct average gas turbine exhaust temperature for the test conditions, as defined by the appropriate control curve.

IV. EVALUATION

Test results are based on the averaged data taken during the test. The averaged results are corrected to the standard conditions using the appropriate correction curves for the installation. Performance as indicated by determining the heat rate based on the test results is defined by:

$$\text{Heat Rate} = \frac{\text{Heat Consumption}}{\text{Power Output}}$$

When decisions are required based on test results, one should recognize the tolerance due to measurement uncertainties associated with each particular test result.

The tolerances around the test results are defined as twice the estimated standard deviation (2Σ), computed from the tolerances associated with each measured test parameter and the influence of that parameter on the calculation of the corrected test results.

The resulting performance tolerances of a single unit station instrumentation test, when performed as described in this document are

Power output: $\pm 3.01\%$

Heat rate (oil fuel): $\pm 2.09\%$

Heat rate (gas fuel): $\pm 2.32\%$

V. CONCLUSION

This procedure may be used to periodically measure unit performance in order to establish trends and to determine the effectiveness of compressor cleaning. This data should be retained for historical reference.

GAS TURBINE PERFORMANCE DATA

CUSTOMER_____

STATION_____

Unit ID_____	Date_____
Gas Turbine S/N_____	Operating Mode_____
Generator S/N_____	Data Page_____
Fired Hours_____	Test Number_____
Fired Starts_____	

Reading Number	1	2	3	4
Starting Time of Reading	_____	_____	_____	_____

Ambient Condition

Compressor Inlet Temp. °F	_____	_____	_____	_____
	_____	_____	_____	_____
	_____	_____	_____	_____
	_____	_____	_____	_____
	_____	_____	_____	_____
	_____	_____	_____	_____

Barometric Pressure				
Inches of Mercury	_____	_____	_____	_____
Compressor Discharge				
Pressure PSIG				
Unit Gauge	_____	_____	_____	_____
Precision Gauge	_____	_____	_____	_____

Fuel Measurement - Oil*

Fuel Meter Reading - Gal.	_____	_____	_____	_____
Elapsed Time - Min.	_____	_____	_____	_____
Fuel Temperature °F	_____	_____	_____	_____
Fuel Meter Type & S/N	_____			

Lube Oil

Turbine Header Temp. °F.	_____	_____	_____	_____
Lube Oil Tank Temp. °F	_____	_____	_____	_____

Recorded By _____

*For Gas Fuel use data under Fuel Consumption

GAS TURBINE PERFORMANCE DATA

CUSTOMER _____

STATION _____

Unit ID _____

Date _____

Gas Turbine S/N _____

Operating Mode _____

Generator S/N _____

Data Page _____

Test Number _____

Reading Number	1	2	3	4
Starting Time of Reading	_____	_____	_____	_____
<u>Wheelspace Temperatures °F</u>				
Comp. Disch. Left	_____	_____	_____	_____
Comp. Disch. Right	_____	_____	_____	_____
1st Stage Forward	_____	_____	_____	_____
1st Stage Forward	_____	_____	_____	_____
1st Stage Aft	_____	_____	_____	_____
1st Stage Aft	_____	_____	_____	_____
2nd Stage Forward	_____	_____	_____	_____
2nd Stage Forward	_____	_____	_____	_____
2nd Stage Aft	_____	_____	_____	_____
2nd Stage Aft	_____	_____	_____	_____
3rd Stage Aft	_____	_____	_____	_____
3rd Stage Aft	_____	_____	_____	_____
3rd Stage Forward	_____	_____	_____	_____
3rd Stage Forward	_____	_____	_____	_____
Exhaust Temperatures - Control T/C °F				
1.	_____	_____	_____	_____
2.	_____	_____	_____	_____
3.	_____	_____	_____	_____
4.	_____	_____	_____	_____
5.	_____	_____	_____	_____
6.	_____	_____	_____	_____
7.	_____	_____	_____	_____
8.	_____	_____	_____	_____
9.	_____	_____	_____	_____
10.	_____	_____	_____	_____
11.	_____	_____	_____	_____
12.	_____	_____	_____	_____
Exhaust Average				
Electrical	_____	_____	_____	_____
Calculated	_____	_____	_____	_____
Recorded By	_____			

GAS TURBINE PERFORMANCE DATA

CUSTOMER_____

STATION_____

Unit ID_____Date_____

Gas Turbine S/N_____Operating Mode_____

Generator S/N_____Data Page_____

Test Number_____

Reading Number	1	2	3	4
Starting Time of Reading	_____	_____	_____	_____

Turbine Panel Board

Set Point_____

VCE_____

Generator Panel Board

Megawatts_____

Record WHM Time on Pg. 10

WHM (sec/20 rev)_____

Megavars_____

Generator Voltage, KV_____

Phase 1-2_____

Phase 2-3_____

Phase 3-1_____

Generator Amperes, KA_____

Phase 1_____

Phase 2_____

Phase 3_____

Excitation Voltage_____

Excitation Amperes_____

Frequency, Hertz_____

Recorded By_____

GAS TURBINE PERFORMANCE DATA

CUSTOMER _____

STATION _____

Unit ID _____

Date _____

Gas Turbine S/N _____

Operating Mode _____

Generator S/N _____

Data Page _____

Test Number _____

Power Measurement (Cont'd)

WHM (Sec/20 Revs.)

Begin Test _____

End Test _____

Repeatedly Time 20 Revolutions of Watt Hour Meter Disc

During Entire Test Period

Pri K_h Factor _____

1) _____

2) _____

3) _____

4) _____

5) _____

6) _____

7) _____

8) _____

Auxiliary WHM (Sec/Rev.)

1) _____

2) _____

3) _____

4) _____

Pri K_h Factor _____Comment/Calculations

Recorded By _____

GAS TURBINE PERFORMANCE DATA

CUSTOMER _____

STATION _____

Unit ID _____

Date _____

Gas Turbine S/N _____

Operating Mode _____

Generator S/N _____

Test Number _____

Data Page _____

Fuel Gas Flow (Record data every two minutes)

<u>Time</u>	<u>Pressure</u>	<u>ΔP</u>	<u>Temp</u>
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Pipe Size _____

Pressure Tap Location _____

Orifice Size _____

Pressure Measured Upstream or
Downstream of Orifice _____

Fuel Heating Value _____

Specific Gravity _____

*See Figure 1, Gas Flow Measurement Instrumentation

Recorded By _____



GE Power Systems

General Electric Company
One River Road, Schenectady, NY 12345
518 • 385 • 2211 TX: 145354

Tab 14

DESCRIPTIVE GUIDE

3.3. STARTING SYSTEM

3.3.1. GENERAL AND SIMPLIFIED SCHEMATIC

Before the gas turbine can be fired and started it must be rotated or cranked by the accessory equipment. This is accomplished by an induction motor, operating through a torque converter to provide the cranking torque and speed required by the turbine for start-up.

The starting system consists of an induction motor and torque converter coupled to the accessory gear.

A motor driven torque adjustor drive, which is an integral part of the torque converter system, provides the means for adjusting torque output within specified ranges. Also control of the torque converter is achieved via an integrally mounted unloading solenoid valve 20 TU-1 and a hydraulically operated dump valve. Refer to Figure SS-1.

After a shut down order, when the decreasing speed reaches about 50 R.P.M, the torque converter motor sets it to the minimum torque and a motor specially provided to rotate the turbine for cooldown purpose starts. It is the motor provided for turning.

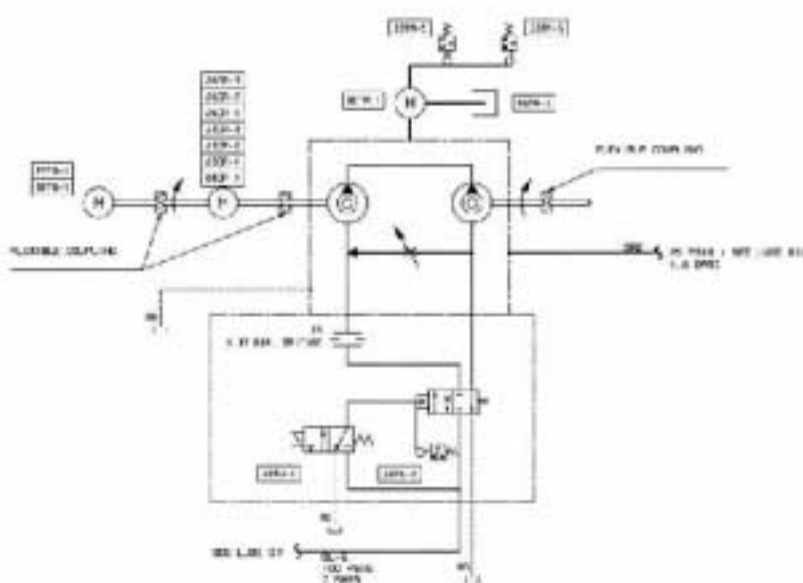
Turning speed value is about 120 R.P.M.

88 TG-1 motor is equipped with an heater 23 TG-1 to prevent condensation when the motor is not operating.

DESCRIPTIVE GUIDE

PART	NOMENCLATURE
20 TU-1	Torque converter unloading (drain) solenoid valve.
23 CR-1,-2,-3	Heater in cranking motor.
23 TG-1	Turning gear motor heater.
26 CR-1,-2,-3	Cranking motor, high temperature.
33 TC-1	Limit switch torque converter filling valve.
33 TM-5	Torque adjustor-limit switch / low torque limit.
33 TM-6	Torque adjustor-limit switch / high torque limit.
88 CR-1	Cranking motor.
88 TG-1	Turbine gear motor.
88 TM-1	Torque adjustor-drive motor.
96 TM-1	Position transmitter.

FIGURE 89-1 : STARTING MEANS SCHEMATIC



DESCRIPTIVE GUIDE

3.3.2. FUNCTIONAL DESCRIPTION

NOTE : Detailed sequences and settings indicated in the Control Specifications and the Fluid Flow Diagrams are described in the Operation guide volumes.

Start-up function description

In the normal starting sequence, fluid is admitted into the torque converter hydraulic circuit from the lubrication system by the integral 20 TU-1 valve at the same time the starting motor 88 CR-1 is energized. Breakaway is achieved and the turbine starts to rotate. The turbine begins to increase in speed and continues to accelerate until firing speed is attained and relay 14 HM picks up. When the turbine has reached this speed (14 HM setpoint), the internal geometry of the torque converter is adjusted by the torque adjustor drive 88 TM-1 to hold firing speed constant through the firing and warm-up cycle.

Readjustment of the converter geometry (torque adjustment) at the end of warm-up allows the torque converter to assist in accelerating the unit up to self sustaining speed. At this speed, (about 70 % normal speed), the torque converter hydraulic circuit is drained, by deenergizing solenoid valve 20 TU-1, at the same time cranking motor 88 CR-1 is deenergized, which effects disconnect. A crank and restart can be initiated at any time below 14 HM speed.

Various switches provide torque adjustment range limits. There are :

33 TM-5 and -6, to limit the torque in case of malfunction of the system.

Shut-down

The shut-down order is given and the turbine speed slows down. When relay 14 HM drops out (at about 48 R.P.M), the turning motor 88 TG-1 starts. Solenoid valve 20 TU-1 is energized and the torque is adjusted to a value allowing to turn the turbine at a speed of about 120 R.P.M for cooldown purposes after shut down. This cooldown sequence lasts at least 20 hours. It must be manually stopped.

Turning

The turbine is at standstill and all circuits are ready for turning. The operator turns the operation selector switch 43 of the turbine control panel to position TURNING, then gives a START order. The starting motor 88 CR-1 starts and 20 TU-1 is energized. When the speed reaches about 50 R.P.M., motor 88 CR-1 is stopped. The speed decreases a little and at about 48 R.P.M., turning motor 88 TG-1 starts. Readjustment of the converter geometry (torque adjustment) will allow a turning speed of about 120 R.P.M. Turning will last at least 20 hours. It must be manually stopped.

88 TM-1 is the motor that operates the buckets.

The position transmitter 96 TM-1 indicates the position of the buckets on the wheels of the torque converter.

DESCRIPTIVE GUIDE

3.3.3. TORQUE CONVERTER AND STARTING DRIVE COMPONENTS

The starting motor drives the torque converter input through a flexible coupling. The torque converter output is coupled to the accessory gear and provides the required torque multiplication for the starting motor to drive the turbine. The main parts of the torque converter are the impeller driven by the input shaft, the turbine wheel which drives the output shaft, and the stator which directs fluid from the impeller to the turbine at the correct angle to produce the required output torque.

The function of the accessory gear in this system is to drive a number of the control components as well as to provide the connection between the starting motor and the gas turbine compressor. It is permanently coupled to the turbine compressor shaft by a flexible coupling.

NOTE : For more details about the starting motor 88 CR-1, the turning motor 88 TG-1 with space heater 23 TG-1 and other components of the starting system, see the Gas turbine equipment publications volumes.

ECH. / SCALE None	DATE	10-Oct-2000	13-Oct-2000	13-Oct-2000
	NOM / NAME	HANNON PASCAL	HANNON PASCAL	GRABINSKY HERVE
FORMAT/SIZE A3	VISA	HANNON PASCAL	HANNON PASCAL	GRABINSKY HERVE
		REDIGE / MADE	VERIFIE / CHECKED	APPROUVE/APPROVED

TITRE/TITLE

SCHEMA MOTEUR DE LANCEMENT
DIAG., SCH. PP-STARTING MOTOR

Ce document, propriete exclusive de
GE Energy Products France SNC
est strictement confidentiel. Il ne peut
etre communique, copie ou reproduit
sans son autorisation ecrite prealable.

This document, exclusive property of
GE Energy Products France SNC
is strictly confidential. It must not be
communicated, copied or reproduced
without our previous written consent.

*GE Energy Products - Europe**GE Energy Products France SNC*

N° 356B2630

SHT.N

REVISION

A

INSTRUCTION DE
MODIFICATION

Section Doc.

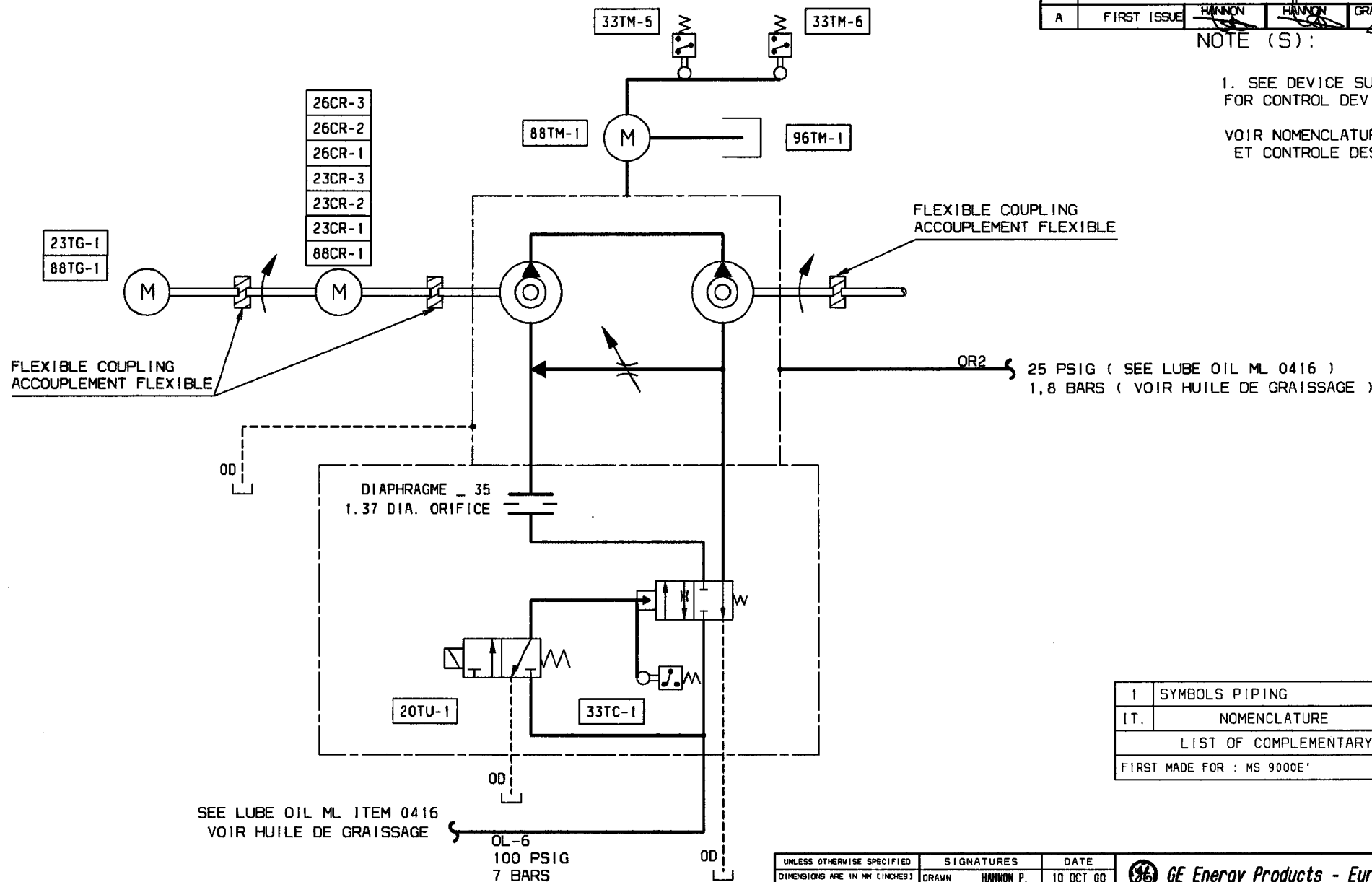
GRD F

REVISIONS				DATE
REV	DESCRIPTION			
A	FIRST ISSUE	HANNON	HANNON	GRABINSKI

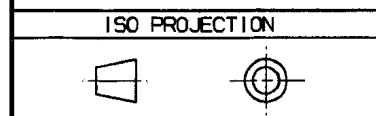
NOTE (S):

1. SEE DEVICE SUMMARY (0414)
FOR CONTROL DEVICE SETTINGS

VOIR NOMENCLATURE POUR REGLAGE
ET CONTROLE DES APPAREILS



1	SYMBOLS PIPING	GE-277A2415
IT.	NOMENCLATURE	IDENT
LIST OF COMPLEMENTARY DOCUMENTS		
FIRST MADE FOR : MS 9000E'		ITEM : 0421



This document, exclusive property of
GE Energy Products France SNC
is strictly confidential. It must not be communicated
copied or reproduced without our previous written consent.

Ce document, propriété exclusive de
GE Energy Products France SNC est
strictement confidentiel. Il ne peut être communiqué,
copié ou reproduit sans son autorisation écrite préalable.

UNLESS OTHERWISE SPECIFIED	SIGNATURES	DATE
DIMENSIONS ARE IN MM (INCHES)	DRAWN HANNON P.	10 OCT 00
TOLERANCES ON	CHECKED HANNON P.	10 OCT 00
1 (2) PL. DECIMALS * /	APPROVED GRABINSKI H.	10 OCT 00
2 (3) PL. DECIMALS * /		
ANGLES * /		
FRACTIONS * /		
WEIGHT :	SIM TO : 91-304411	

GE Energy Products - Europe		
SCHEMA MOTEUR DE LANCEMENT DIAG. SCHEM. PP-STARTING MEANS		
SIZE A3	CAGE CODE	DWG. NO. 356B2630
SCALE	REV. : A	SHEET 1

Tab 15

NOTES

VOIR NOMENCLATURE DES APPAREILS (IT 0414)
POUR REGLAGE DES APPAREILS DE CONTROLE

SEE DEVICE SUMMARY (0414) FOR
CONTOL DEVICE SETTINGS

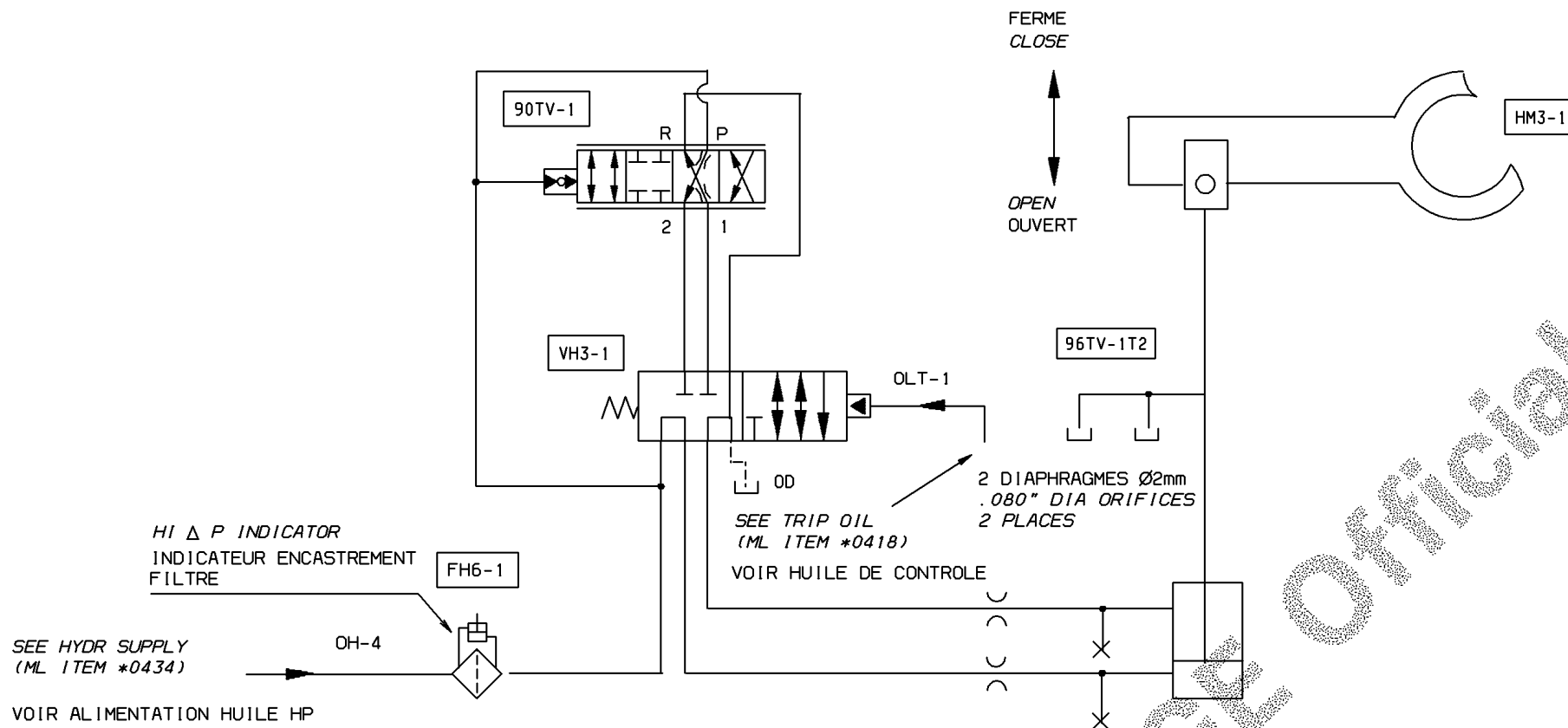
GT6D/5/17/001 REV 3

GE Official

SIMILAIRE A: SIMILAR TO:		PREM. EXECUTION: FIRST MADE FOR:		MS 9001E		O	M	K
OPTION: _____	7	IM-2002004533	10 SEP 02	CTR(TP)	THIRION F.	DAIRE D.		
	6	IM-2000002932	23 OCT 00	THIRION F.	THIRION F.	BITSCH JM.		
	5	IM-1999001726	12AOU99	COURTOT J.F	COURTOT J.F	HANNON P.		
ITEM: 0469	Indice	N° Instruction Modif	Date	Nom	Visa	Nom	Visa	Nom
MODIFICATIONS				MODIFIE	VERIFIE	APPROUVE		

APPROUVE	22/DEC/87	GULDEMANN	
VERIFIE	22/DEC/87	VILLER	
DES./RED.	22/DEC/87	VILLER	
QA : C	Date	Nom	Visa
INFO. INTERNE		LANGUE F/E	BELFORT ☒
DIFFU	NATURE	EMETTEUR	FORMAT
2	SH	91 A	A3

SYMBOLS PIPING		GE-277A2415	
COMPL. DOC.		DOC. N°	
TITRE SCH.CDE AUBES VARIAB.			
TITLE DIA.SCH.PIPING IGV.			
SECT. DOC		7	
91-242B9854		6	
CONT. PAGE PAGE		5	
2 1		4	
91-242B9854			



GT6D/5/17/002 REV 3

SIMILAIRE A : SIMILAR TO: _____										PREM. EXECUTION : FIRST MADE FOR: MS 9001E				O	M	K
OPTION: _____		7	IM-2002004533	09 SEP 02	CTR(TP)		THIRION F.		DAIRE D.							
		6	IM-2000002932	23 OCT 00	THIRION F.		THIRION F.		BITSCH JM.							
		5	IM-1999001726	12AOU99	COURTOT JF		COURTOT J.F		HANNON P.							
ITEM: 0469		Indices	N°	Instruction	Modif	Date	Nom	Visa	Nom	Visa	Nom	Visa				
					MODIFICATIONS		MODIFIE		VERIFIE		APPROUVE					

APPROUVE	22/DEC/87	GULDEMANN		TITRE	SCH.CDE AUBES VARIAB.				
VERIFIE	22/DEC/87	VILLER		TITLE	DIA.SCH.PIPING IG.V.				
DES./RED	22/DEC/87	VILLER							
QA : C	Dates	Noms	Visas					7	
INFO. INTERNE			LANGUE F/E	BELFORT	☒	SECT. DOC	GE Energy Products - Europe		6
					☐	____01			5
	DIFFU	NATURE	EMETTEUR	FORMAT		CONT. PAGE	PAGE	91-242B9854	4
	2	SH	____91A	A3		F	2		

Tab 16

DESCRIPTIVE GUIDE

3.12. VENTILATION AND HEATING SYSTEM

3.12.1. GENERAL

Both heating and ventilating capabilities have been incorporated into the turbine and accessory compartments (enclosures), with each utilizing thermally insulated side panels and roofs. The heaters, in this installation, provide humidity control for both areas and are mounted on the forward bulkhead. The four compartments, accessory, turbine, load and gas shaft are, independently ventilated as shown in Figure VH-1.

Gravity operated dampers are used in the system to automatically provide a tight enclosure when the fire protection system is activated. The gravity closing dampers are normally held open by the pressure-operated latches which must be manually reset after damper release. When the extinguishing agent is discharged, pressure on the latch forces a piston against a spring moving a locking lever which releases the latch allowing the damper to close. In the text that follows, the location of the latches is defined, as is the component on which they are mounted.

Wall mounted air conditioners maintain the acceptable temperature for the control compartment.

NOTE : For the ventilation and heating system components, refer to the Gas turbine equipment publications volumes for more information. As for the settings, refer to the Device Summary of the piping (fluid flow) diagrams and to the Control Specifications in the Gas turbine operation guide volumes.

DESCRIPTIVE GUIDE

3.12.2. FUNCTIONAL DESCRIPTION

- Accessory compartment

Space heater 23 HA-1, mounted on the forward bulkhead, provide the heat for the area.

At this time an integral circuit is closed and the heater and its blower motor 88 HA-1 are energized.

Cooling air for the compartment is brought in through ventilation openings located in the sidewalls in a position close to the turbine base. Gravity operated damper closes when the extinguishing system for the turbine is activated.

- Turbine compartment

Ventilation of this compartment occurs when exhaust fan 88 BT-1 or 88 BT-2 is in operation pulling air out of the turbine compartment. This air circulates through the compartment collecting heat which is then vented to atmosphere through the exhaust fan 88 BT.

The fan motors 88 BT-1,-2 are equipped with heaters 23 BT-1,-2 to prevent condensation when the motors are not operating.

Switches 33 BT-1,-2 give further information on the position of the valves. The warm air flows to the gas turbine compartment through openings in the partition wall between GT compartment.

One space heater 23 HT-1 is installed in the gas turbine enclosure to maintain the required interior temperature during plant shutdowns.

At this time an integral circuit is closed and the heater and its blower motor 88 HT-1 are energized.

When the temperature in the enclosure increases above the set point (26 HT-1) it switches off the electric power to the space heater. The heater is switched off on detection of fire in the enclosure.

- Load compartment

The load coupling is contained in its own enclosure and situated between the exhaust plenum and the generator. This separate compartment has its own roof section, side panels, and an access door. Cooling air for the compartment is brought in through a centrifugal vent fan driven by AC motor 88 VG-1, or 88 VG-2 located on the load compartment roof.

Switches 33 VG-1,-2 give further information on the position of the valves. The warm air flows to the gas turbine compartment through openings in the partition wall between load compartment and GT compartment.

The fan motors 88 VG-1,-2 are equipped with heaters 23 VG-1,-2 to prevent condensation when the motors are not operating.

Thermocouple AT_LC-1 is a high temperature alarm which indicates fan failure.

Heated air, after circulating through the compartment, vents upward and is exhausted through a ventilation opening with gravity operated damper closing when the extinguishing system for the turbine is activated.

DESCRIPTIVE GUIDE

- Gas compartment

Ventilation of this compartment occurs when exhaust fan 88 VL-1 or -2 is in operation pulling air out of the gas compartment. This air circulates through the compartment collecting heat which is then vented to atmosphere through the exhaust fan 88 VL.

PART	NOMENCLATURE
23 BT-1,-2	Motor space heater for 88 BT-1,-2.
23 HA-1	Acoustic enclosure heater (auxiliary).
23 HT-1	Acoustic enclosure heater (turbine).
23 VG-1,-2	Motor space heater for 88 VG-1,-2.
26 HA-1	Thermostat lower temperature.
26 HT-1	Thermostat lower temperature.
33 BT-1,-2	Position control 88BT-1,-2.
33 VG-1,-2	Position control 88 VG-1,-2.
63 VL	Gas valve compartment differential pressure valve.
88 BT-1,-2	Cooling air fan motor turbine compartment.
88 HA-1	Space heater blower motor accessory compartment.
88 HT-1	Space heater blower motor turbine compartment.
88 VG-1,-2	Cooling air fan motor load compartment.
88 VL-1,-2	Gas compartment fan motor.
AT_LC-1	Load compartment resistance thermometer detector.
AT_TC-1	Turbine compartment resistance thermometer detector.

REV D	00564-C	205D4462	1	REV B	1
REV OF TIME					
REV	SECURITY JIM				THANSON KORN
A	FIRST ISSUE				THIRION F. JOSE JIM CROCKENBERG
B	IM-200205871				THIRION F. JOSE JIM CROCKENBERG

NOTES

- 1- SEE DEVICE SUMMARY FOR CONTROL DEVICE SETTINGS
- 1- VOIR NOMENCLATURE DES APPAREILS POUR REGLAGE DES APPAREILS DE CONTROL
- 2- AT-TC-1 and AT-LC-1 : ON BASE SUPPLY
- 2- AT-TC-1 and AT-LC-1 : FOURNITURE SUR LA TURBINE
- 3- 88BT : AIR FLOW : 15 m³/s
TEMPERATURE : 110°C MAXI
- 3- 88BT : DEBIT D'AIR : 15 m³/s
TEMPERATURE : 110°C MAXI
- 4- 88VG : AIR FLOW : 6.6 m³/s
TEMPERATURE : 180°C MAXI
AVAILABLE STATIC DISCHARGE PRESSURE FOR DUCTING TO BUILDING OUTLET 250 Pa
- 4- 88VG : DEBIT D'AIR : 6.6 m³/s
TEMPERATURE : 180°C MAXI
PERTE DE CHARGE STATIQUE ADMISSIBLE DU TUYAU A LA SORTIE DU BATIMENT 250 Pa
- 5- FG61 : AIR FLOW : 0.16 m³/s
PRESURE DROP FOR PIPE : 750 Pa MAXI
INTERFACE FLANGE DIAMETER : 3"
- 5- FG61 : DEBIT D'AIR : 0.16 m³/s
PERTE DE CHARGE DU TUYAU : 750 Pa MAXI
DIAMETRE DES BRIDES : 3"
- 6- FG62 : TO BE DUCTED OUTSIDE TO SAFE LOCATION
AIR FLOW : 0.16 m³/s
TEMPERATURE : 60°C
PRESSURE DROP : 250Pa
INTERFACE FLANGE DIAMETER : 6"
- 6- FG62 : CONNECTE A L'EXTERIEUR DANS UN ENDROIT SANS RISQUE
DEBIT D'AIR : 0.16 m³/s
TEMPERATURE : 60°C
PERTE DE CHARGE : 250 Pa
DIAMETRE DES BRIDES : 6"
- 7- FANS : 2 x 100%
- 7- VENTILATION : 2 x 100%

LEAVE THIS SPACE BLANK

1	SPECIFICATION P&ID	123E4888
IT.	NOMENCLATURE	IDENT
LIST OF COMPLEMENTARY DOCUMENTS		
FIRST MADE FOR : MS 9001E		ITEM : 0436

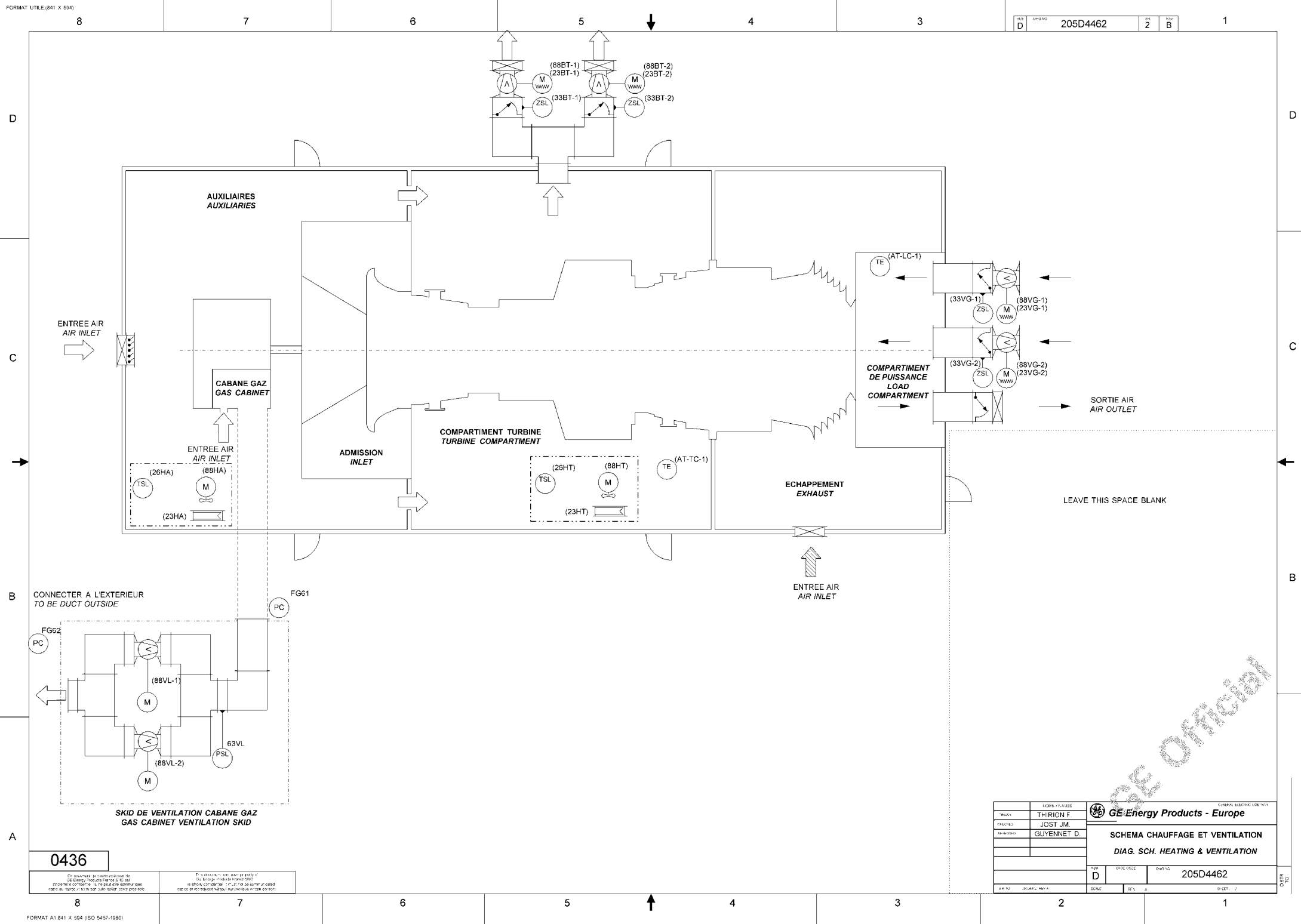
B	8	REV	REV STATUS OF SHEETS
2	1	SH	

		"SCHEMATA"			GE Energy Products - Europe										(OPTIONAL) SPECIFIC COMMENTS												
EQUIPE:		THIRION F.																									
DRAWING:		JOST JM																									
PROJECT:		GUYENNET D.																									
SCHEMA CHAUFFAGE ET VENTILATION																											
DIAG. SCH. HEATING & VENTILATION																											
SVP D				CODE CODE				NOM SVO				205D4462															
REF NO : (CLASSE) / AN N°				SCALE				37%				T				SHEET " 1 "											

0436

Le document propre à utiliser en
GE Energy Products France SIA est
strictement confidentiel. Il ne peut être communiqué
hors du cercle d'experts sans autorisation écrite préalable.

This document, and any part of it,
 GE Energy Products France SFG
 is strictly confidential. It must not be put to a medium
 copied or reproduced without our previous written consent.



Tab 17

DESCRIPTIVE GUIDE

3.11. FIRE PROTECTION SYSTEM**3.11.1. GENERAL**

The carbon dioxide (CO₂) fire protection system supplied is designed to extinguish fires by reducing the oxygen content of the air in a compartment from an atmosphere normal of 21 per cent to less than 15 per cent ; an insufficient concentration to support the combustion of turbine fuel or lubricating oil. System design is in accord with the requirements contained in the Fire Protection recommendations and recognizing the reflash potential of combustibles exposed to high temperature metal it provides an extended discharge to maintain an extinguishing concentration for a prolonged period to minimize the likelihood of a reflash condition.

Major system components include :

Carbon dioxide cylinders, (in and off-base station), discharge pipes and nozzles, pilot valves, fire detectors, and pressure switches. Refer to the schematic diagram (Figure FP-1) where system components are shown in their respective compartments.

Carbon dioxide is supplied from an off-base skid where banks of high pressure cylinders are connected to a distribution system which conducts the carbon dioxide through pipes to discharge nozzles located among others in the various compartments of the gas turbine unit.

For the gas turbine itself, there are two distinctive zones (see Figure FP-1 here after) :

- Zone 1 : turbine accessory compartment and turbine compartment ;
- Zone 2 : tunnel of bearing number 3 and load shaft compartment.

Two sorts of discharge are used : initial discharge and extended discharge. Within a few seconds after actuation, sufficient CO₂ flows from the initial discharge system into the compartment of the machine to rapidly build up an extinguishing concentration. This concentration is maintained for a prolonged period of time by the gradual addition of more CO₂ from the extended discharge system.

WARNING : Carbon Dioxide, in a concentration sufficient to extinguish fire, creates an atmosphere that will not support life. It is extremely hazardous to enter the compartments after the CO₂ system has been discharged. Anyone rendered unconscious by CO₂ should be rescued as quickly as possible and revived immediately with artificial respiration. The extend and type of safeguards and personnel warnings that may be necessary must be designed to meet the particular requirements of each situation. It is recommended that personnel be adequately trained as to the proper action to take in case of such an emergency.

DESCRIPTIVE GUIDE

3.11.2. FUNCTIONAL DESCRIPTION

To better understand the CO₂ system, a brief description of its operation and distinctive features is given in the following paragraph only for the load shaft compartment. For the rest of the compartments, refer to the concerned Environment volume. Refer to the Fire Protection System schematic Figure FP-1 here after.

Should a fire occur in one of the protected compartments of the unit, the pilot valves in the off-base skid will be energized by one of the heat-sensitive fire detectors, more exactly : 45 FA-1A,-1B, 45 FA-2A,-2B in the accessory compartment, 45 FT-1A,-1B ; 45 FT-2A,-2B ; 45 FT-3A,-3B in the turbine compartment and 45 FT-8A,-8B, -9A,-9B in the tunnel of bearing n° 3.

The CO₂ flow rate is controlled by the size of the orifices to the discharge nozzles in each compartment for the initial and extended discharge system. The orifices for the initial discharge must permit a rapid discharge of CO₂ to quickly build up an extinguishing concentration. The orifices for the extended discharge are smaller and permit a relatively slow discharge rate in order to maintain the extinguishing concentration over a prolonged period of time. By maintaining the extinguishing concentration, the likelihood of a fire reigniting is minimized.

In the bearing no 3 zone, there is one nozzle for the initial discharge and the other is for the extended discharge.

When fire is detected and CO₂ is emitted, CO₂ operated latches close the shutter provided for the load shaft compartment.

Note that the CO₂ latches located in the ventilation path must be opened manually after a fire. the latches are provided with a limit switch preventing a gas turbine restart after a fire.

Emergency stop buttons 5E1-1,-2 called blow of fist and fire alarm strobe SL1-1,-2 are installed in the accessory compartment.

In addition to the thermostatic sensors, fire detection can also be actuated by mean of break glass (43 CP) unit located near each zone package access door.

Horn and flashing light units (SLI) are installed inside and outside protected zones.

DESCRIPTIVE GUIDE

PART	NOMENCLATURE
43 CP-1,-2,-3,-4,-5	CO2 release break glass unit.
45 FA-1A,-1B	Accessory compartment fire detector.
45 FA-2A,-2B	Accessory compartment fire detector.
45 FT-1A,-1B	Turbine compartment fire detector.
45 FT-2A,-2B	Turbine compartment fire detector.
45 FT-3A,-3B	Turbine compartment fire detector.
45 FT-8A,-8B	N° 3 bearing fire detector.
45 FT-9A,-9B	Load compartment fire detector.
5 E-1,-2	Button of stop of emergency.
SL1-1,-2	Fire alarm strobe and horn.
SLI-1A,-1B,-1C	Horn and flashing light unit – electrical signal.
SLI-2C,-3C	Horn and flashing light unit – electrical signal.

DESCRIPTIVE GUIDE

FIGURE FP-1: FIRE PROTECTION SYSTEM SCHEMATIC DIAGRAM (1/2)

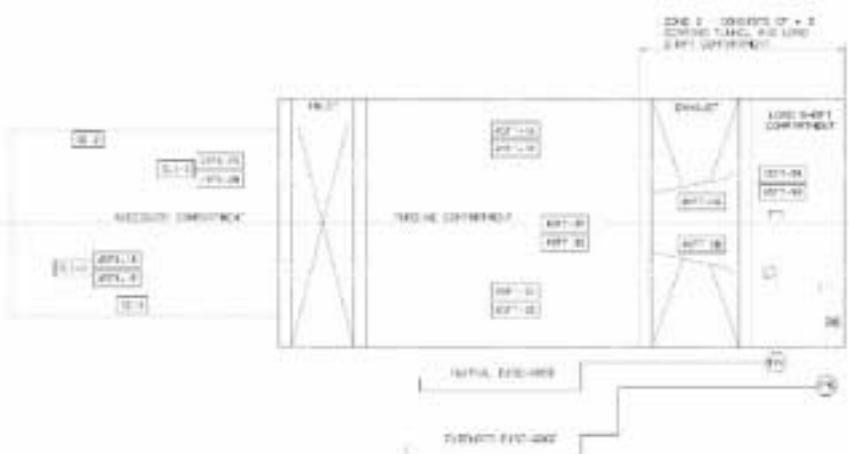
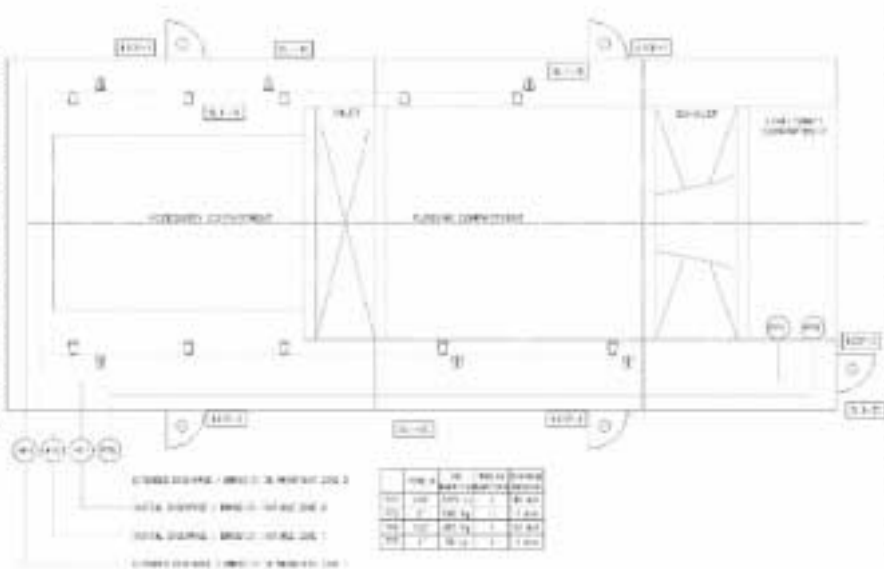


FIGURE FP-1: FIRE PROTECTION SYSTEM SCHEMATIC DIAGRAM (2/2)



DESCRIPTIVE GUIDE

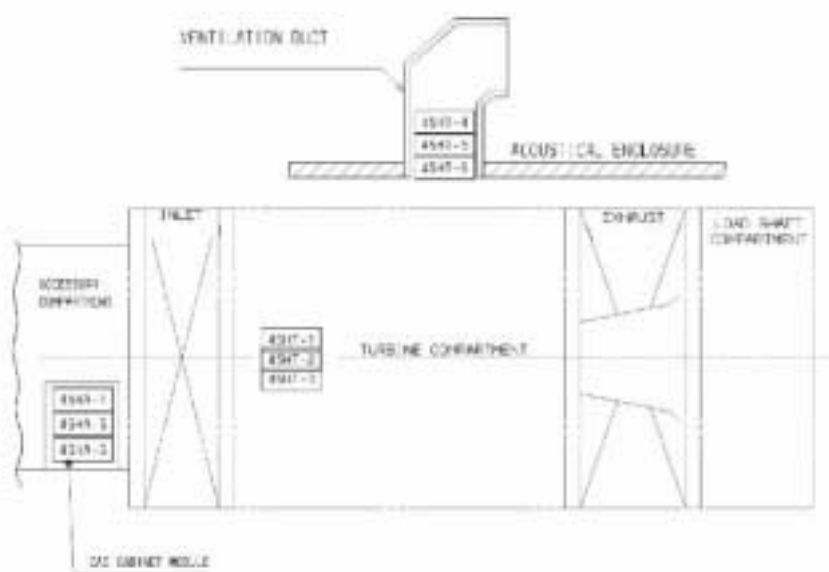
3.11.3. GAS DETECTORS : FUNCTIONAL DESCRIPTION

Should a fire or a gas leakage occur in one of the protected compartments of the unit, the pilot valves in the off-base skid will be energized by one of the hazardous atmosphere detector 45 HA-4-5,-6, in the gas module compartment, 45 HT-1,-2,-3 in the turbine compartment and 45 HT-4,-5,-6 in the ventilation duct.

DESCRIPTIVE GUIDE

PART	NOMENCLATURE
45 HA-4,-5,-6	Gas module compartment gas detector.
45 HT-1,-2,-3	Turbine compartment gas detector.
45 HT-4,-5,-6	Turbine compartment gas detector (ventilation duct).

GAS DETECTOR SCHEMATIC DIAGRAM



ECH. / SCALE		DATE	09-Apr-2002	30-May-2002	31-May-2002
		NOM / NAME	THIRION FREDERIC	THIRION FREDERIC	GROSLAMBERT STEPHANE
FORMAT/SIZE		VISA	THIRION FREDERIC	THIRION FREDERIC	GROSLAMBERT STEPHANE
A3			REDIGE / MADE	VERIFIE / CHECKED	APPROUVE/APPROVED
TITRE/TITLE					
SCH.PROTECTION INCENDIE					
DIA.SCHEM.PP-FIRE PROTEC					
Ce document, propriete exclusive de GE Energy Products France SNC est strictement confidentiel. Il ne peut etre communique, copie ou reproduit sans son autorisation ecrite prealable.			GE Energy Products - Europe		REVISION
This document, exclusive property of GE Energy Products France SNC is strictly confidential. It must not be communicated, copied or reproduced without our previous written consent.			N° 360B1239		A
SHT. N					INSTRUCTION DE MODIFICATION
					Section Doc.
					GRD F

NOTES:

1- SEE DEVICE SUMMARY FOR CONTROL
 DEVICE SETTINGS.

1- VOIR NOMENCLATURE DES APPAREILS
 POUR REGLAGE DES APPAREILS DE
 CONTROLE.

REVISIONS		
REV	DESCRIPTION	NAMES/NOMS
A	FIRST ISSUE	THIRION F.
		JUST JM.
		GROSLAMBERT

SYMBOLS PIPING	277A2415
NOMENCLATURE	IDENT
LIST OF COMPLEMENTARY DOCUMENTS	
FIRST MADE FOR : MS 9001E	ITEM : 0426

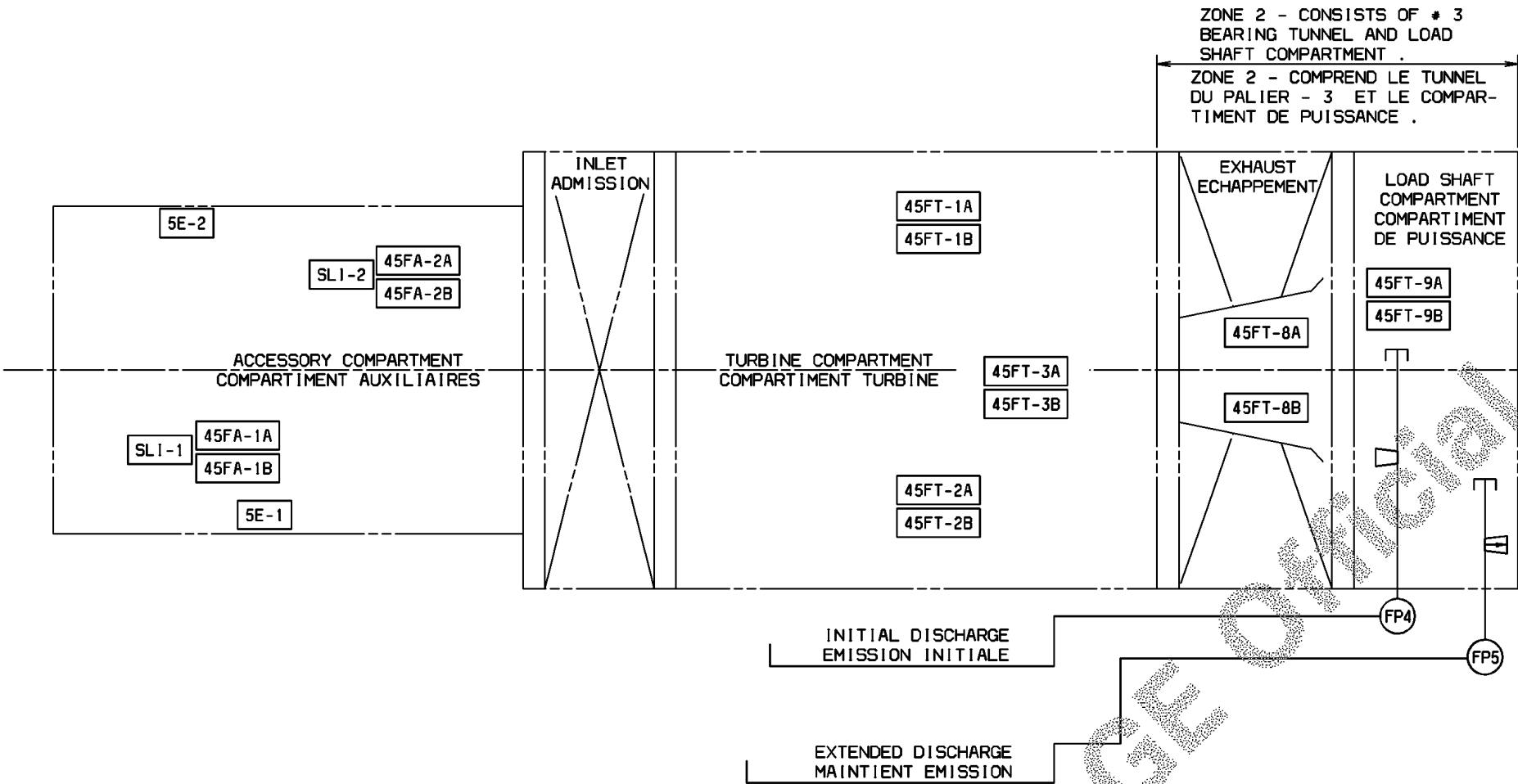
A	A	A	REV	REV STATUS
3	2	1	SH	OF SHEETS

This document, exclusive property of
 GE Energy Products France SNC
 is strictly confidential. It must not be communicated
 copied or reproduced without our previous written consent.

Ce document, propriété exclusive de
 GE Energy Products France SNC est
 strictement confidentiel. Il ne peut être communiqué,
 copié ou reproduit sans son autorisation écrite préalable

		NOMS/NAMES		 <i>GE Energy Products - Europe</i>		GENERAL ELECTRIC COMPANY	
DRAWN		THIRION F.					
CHECKED		JUST JM.					
APPROVED		GROSLAMBERT					
				SCHEMA PROTECTION INCENDIE <i>DIAG. SCH. PP-FIRE PROTECTION</i>			

ON BASE EQUIPMENT



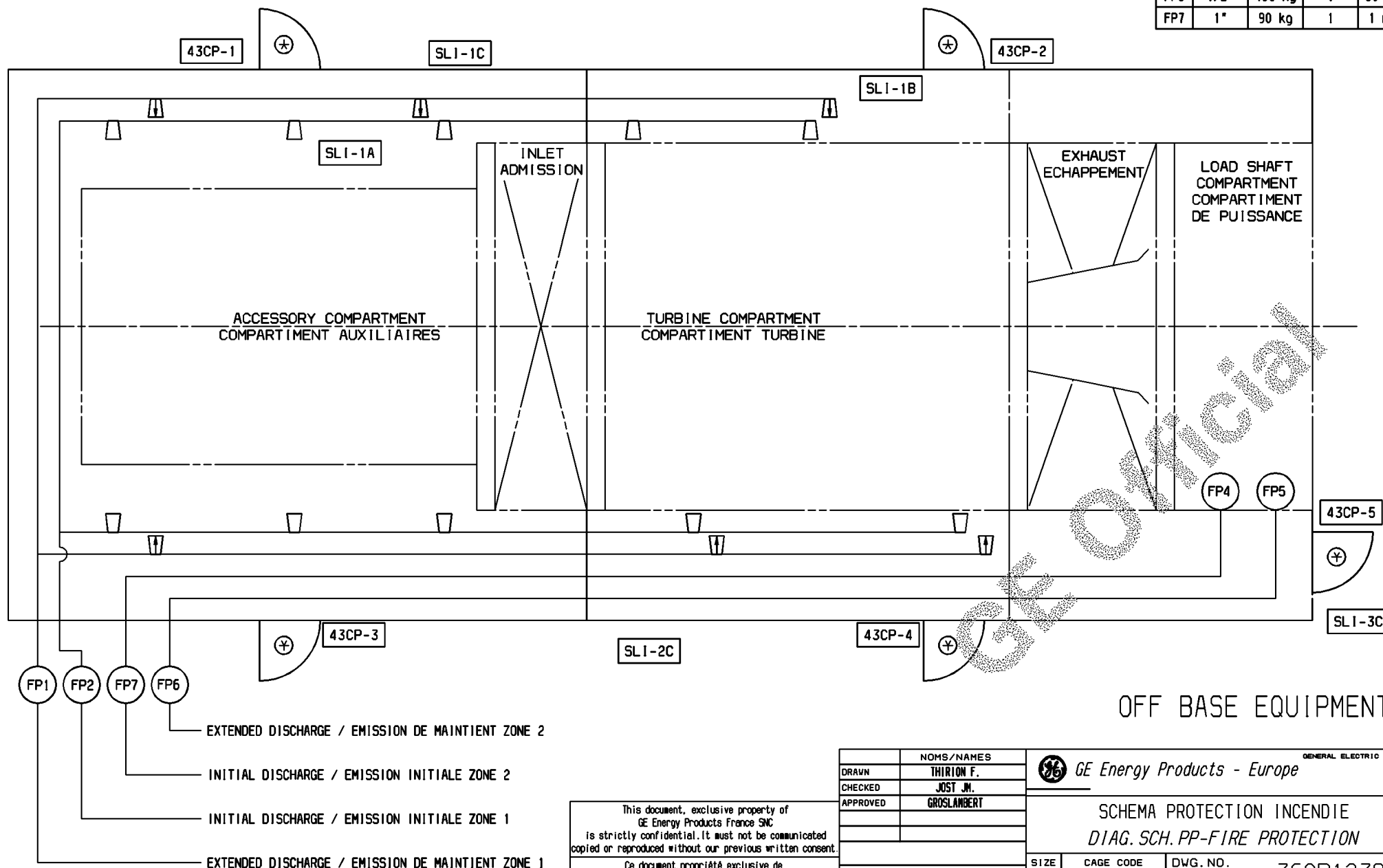
This document, exclusive property of GE Energy Products France SNC is strictly confidential. It must not be communicated copied or reproduced without our previous written consent.
Ce document, propriété exclusive de GE Energy Products France SNC est strictement confidentiel. Il ne peut être communiqué, copié ou reproduit sans son autorisation écrite préalable

NOMS/NAMES		GE Energy Products - Europe	
DRAWN	THIRION F.		
CHECKED	JUST JM.		
APPROVED	GROSLAMBERT		
SIZE A3		CAGE CODE	DWG. NO. 360B1239
SIM TO : 360B1114		SCALE	REV. : A
		SHEET 2	

 WARNING SIGNS:

**WARNING CARBONE DIOXIDE GAS
WHEN ALARM OPERATES.
DO NOT ENTER UNTIL VENTILATED.**

	PIPE Ø	CO2 Quantities	Nozzles Quantities	Discharge Duration
FP1	3/4"	2025 kg	7	40 min
FP2	2"	540 kg	11	1 min
FP6	1/2"	495 kg	1	60 min
FP7	1"	90 kg	1	1 min



OFF BASE EQUIPMENT

	NOMS/NAMES	 <i>GE Energy Products - Europe</i>		GENERAL ELECTRIC COMPANY	
DRAWN	THIRION F.	SCHEMA PROTECTION INCENDIE <i>DIAG. SCH. PP-FIRE PROTECTION</i>			
CHECKED	JUST JM.				
APPROVED	GROSLAMBERT				
		SIZE	CAGE CODE	DWG. NO.	360B1239
		A3			
SIM TO : 360B1114		SCALE	REV. : A	SHEET 3	

This document, exclusive property of
GE Energy Products France SNC
is strictly confidential. It must not be communicated
copied or reproduced without our previous written consent

Ce document, propriété exclusive de
GE Energy Products France SNC est
strictement confidentiel. Il ne peut être communiqué,
copié ou reproduit sans son autorisation écrite préalable

DESCRIPTIVE GUIDE

3.11.3. GAS DETECTORS : FUNCTIONAL DESCRIPTION

Should a fire or a gas leakage occur in one of the protected compartments of the unit, the pilot valves in the off-base skid will be energized by one of the hazardous atmosphere detectors 45 HA-4,-5,-6 in the gas compartment and 45 HT-1,-2,-3,-4,-5,-6 in the turbine compartment.

8

7

6

5

4

3

A1

CHG NO.

202D8322

REV

A

1

NOTES

1- SEE DEVICE SUMMARY FOR CONTROL DEVICE SETTINGS.

1- VOIR NOMENCLATURE DES APPAREILS POUR LE REGLAGE DES APPAREILS DE CONTROLE.

REVISIONS		
REV	DESCRIPTION	DATE
A	FIRST ISSUE	NAMES/NOMS THIRION F. JUST J.M. PELLE F.

DATE / DATE	15-JUN-2002	15-JUN-2002	15-JUN-2002
NOM / NAME	THIRION FREDERIC	JUST JEAN-MARIE	PELLE FRANCOIS
THIRION FREDERIC	THIRION FREDERIC	JUST JEAN-MARIE	PELLE FRANCOIS
A1	DESIGNED / DRAFT	ENGINEER / CHECKED	APPROVED / APPROVED

SCHEMA DETECTION GAZ GAS DETECTION SCH. DIAG.			

GE Energy Products - Europe GE Energy Products France SNC 202D8322 1/2	REVISED A 1 01 F

GE Energy Products - Europe
GE Energy Products France SNC
202D8322
1/2

Tab 18

DESCRIPTIVE GUIDE

3.14. WATER INJECTION

3.14.1. GENERAL

The function of the water injection system is to supply pure water at the required pressure and flow rate for injection into the combustion system of the turbine in order to reduce emissions of NOx.

The filtered water is introduced to the turbine combustion system through manifolding on the gas turbine feeding the water injection nozzles. The water is injected as a water mist through water spray orifices which are installed in each of the turbine fuel nozzle assemblies. The water is injected into the combustion zones of each combustion chamber.

DESCRIPTIVE GUIDE**3.14.2. FUNCTIONAL DESCRIPTION**

The water injection system supplies treated and filtered water at the proper pressure and variable flow rates to the combustion system of the gas turbine. Water from the customer's treatment and storage facility is filtered and delivered at a controlled rate to the turbine water manifolds by the water forwarding skid.

Water enters the skid through a Y-type strainer FW1-1 which protects the pump from damage by foreign material. A pressure transmitter, 96 WN-1, senses the pressure in the pump suction line and shuts the pump off if pressure is too low. The water forwarding centrifugal pump is driven by an electric motor, 88 WN-1. After the pump, the flow is divided into a mainstream to the turbine and a slipstream to be returned to the storage tank via the cascade orifice (recirculation flow). This recirculation line maintains the pump flow at a predetermined region where the pump is stable and not dead-headed. Extreme care should be taken to ensure that this recirculation flow is returned to the storage tank and not to the inlet to the pump.

A second pressure transmitter, 96 WN-3, senses delivery pressure and stops the pump if this pressure is too low.

The fluid is then filtered through 5 micron filter elements FW2-1. These elements are enclosed in a case which has a vent, drain and differential pressure gauge connected between the clean and dirty sides of the filter. The differential pressure across the filter assembly is sensed by 96 WN-4, which signals an alarm if this pressure differential is too high.

Quick connections with check valves into the transmitters pressure lines allow checking of the pressure with a pressure gauge.

Instrumentation air is provided from air atomizing system to operate VC4-1 and VC5-1 control valves. Filtration requirements for instrumentation air is obtained through FA90-1 filter.

Following downstream is the water flow air operated control valve VC4-1, which is positioned by a servovalve actuator, 90 WN-1, controlled by the redundant controllers RST of the SPEEDTRONIC controls. Instrumentation air to servovalve is pressure adjusted through VPR 90-1. This valve controls the volume of water delivered to the combustors. 33 WN-1,-6 are respectively the open and close limit switches for control valve.

The flow control loop utilizes flowmeter FM1-1 equipped with 3 redundant magnetic pick-up, 77 WN-1,-2,-3, which provides electrical feedback signals to the control system controlling the water flow. Downstream of the flowmeter is a second Y-type strainer FW3-1 to protect turbine nozzles.

The air operated stop solenoid valve 20 WN-4, shuts off water flow if a water shutdown command is given driven by the SPEEDTRONIC, allows the opening and closing of the control valve.

The delivery line beyond solenoid valve is then split. Part of the flow goes through piping which connects the off-base skid to the low (primary) flow rate water manifold on the turbine base and to through another piping for test only. The manifold supplies water to the 14 combustors. In the other branch line, the rest of the water flows to the combustors through the high (secondary) flow rate manifold and to another piping for test only. The division of flow between the two manifolds is controlled by a transfer valve, VC5-1, in the line to the high flow rate manifold. This valve is opened at a preselected water flow rate as turbine operating conditions demand higher water flow rates.

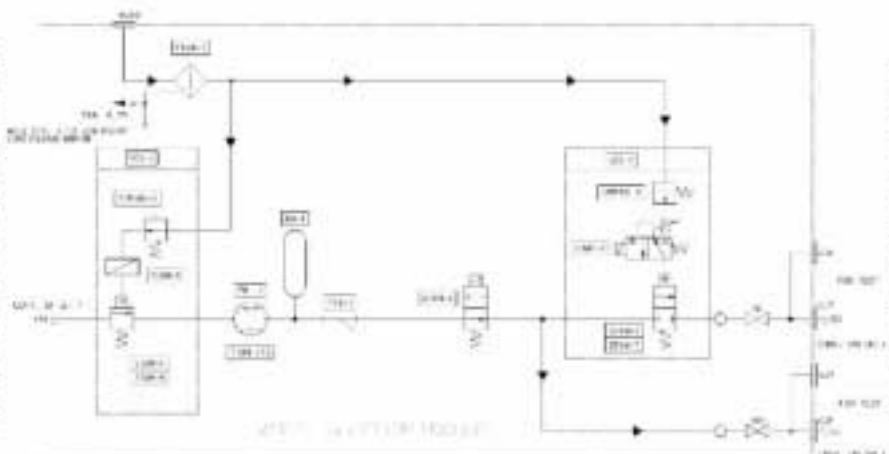
DESCRIPTIVE GUIDE

A solenoid valve 20 WN-2 supplies pressure adjusted instrumentation air (through VPR 90-2) to flow transfer valve VC5-1. 33 WN-3,-7 are respectively the open and close limit switches for flow transfer valve.

DESCRIPTIVE GUIDE

PART	NOMENCLATURE
20 WN-2	Water injection transfer valve VC5-1 control solenoid valve.
20 WN-4	Water injection stop solenoid valve.
33 WN-1,-6	VC4-1 control valve limit switch.
33 WN-3,-7	VC5-1 transfer valve limit switch.
77 WN-1,-2,-3	Water injection common circuit flow pick-up.
88 WN-1	Water injection system pump motor.
90 WN-1	Servo valve for VC4-1 control valve.
96 WN-1	Servovalve for VC4-1 control valve.
96 WN-3	Water injection pump outlet relative pressure transmitter.
96 WN-4	Water injection filters differential pressure transmitter.
AW-1	Water injection common circuit accumulator - hale.
FA 90-1	Strainer on control air supply circuit.
FM 1-1	Water injection common flowmeter.
FW 1-1	Water injection system low pressure strainer.
FW 2-1	Water injection system high pressure filter.
FW 3-1	High pressure strainer downstream flowmeter water injection.
VC 4-1	Water injection flow control valve – common circuit.
VC 5-1	Big flow manifold water injection transfer valve.
VPR 90-1	Water injection VC4-1 control valve air pressure regulation.
VPR 90-2	Water injection VC5-1 transfer valve air pressure regulation.

WATER INJECTION SYSTEM SCHEMATIC (3/3)





ECH. / SCALE	DATE	08-Sep-2003	15-Sep-2003	
	NOM / NAME	TECHNICREA JCP	JOST JEAN-MICHEL	DELIMOGES SYLVAIN
FORMAT/SIZE A3	VISA	TECHNICREA JCP	JOST JEAN-MICHEL	DELIMOGES SYLVAIN
		REDIGE / MADE	VERIFIE / CHECKED	APPROUVE/APPROVED

TITRE/TITLE

SCH.TUY.INJECTION D'EAU

WATER INJ. PP. DIAGRAM

Ce document, propriete exclusive de <i>GE Energy Products France SNC</i> est strictement confidentiel. Il ne peut etre communique, copie ou reproduit sans son autorisation ecrite prealable. This document, exclusive property of <i>GE Energy Products France SNC</i> is strictly confidential. It must not be communicated, copied or reproduced without our previous written consent.	<i>GE Energy Products - Europe</i>	REVISION C INSTRUCTION DE MODIFICATION IM-2003006086 Section Doc. GRD F
	 <i>GE Energy Products France SNC</i> N° 356B3359 SHT. N	

NOTES:

- 1- SEE DEVICE SUMMARY (MLI.0414) FOR CONTROL DEVICE SETTINGS.
- 2- EXPOSED WATER PIPING AND COMPONENTS MUST BE INSULATED AND HEAT TRACED TO PREVENT WATER FROM FREEZING IF THE SKID IS INSTALLED IN AREA WHERE SURROUNDING TEMPERATURE COULD FALL BELOW 32°F (0°C).
- 3- WATER ENTERING THE SKID MUST MEET THE QUALITY REQUIREMENTS IN GE DWG.334A7731
- 4- ALL INTERCONNECTING PIPING, FLANGES AND ETC BOTH TO AND FROM THE WATER INJ. SKID MUST BE STAINLESS STEEL (AISI 304L OR 316L). THE WATER STORAGE FACILITY SHOULD BE STAINLESS STEEL OR SUITABLY COATED. COATING TO BE SUBMITTED FOR APPROVAL TO GEEPE BEFORE MANUFACTURING.
- 5- THE RECIRCULATION FLOW SHOULD BE RETURNED TO THE STORAGE TANK AND NOT SHORT-CIRCUITED TO THE PUMP INLET. IT IS RECOMMENDED THAT NO VALVES BE INSTALLED IN THIS LINE. IF THE CUSTOMER DECIDES TO INSTALL ANY VALVES IN THE THEY MUST BE TAGGED OR LOCKED OPEN DURING OPERATION TO PREVENT SERIOUS DAMAGE TO THE PUMP.
- 6- CONTROL VALVE (VC4-1) SHALL BE INSTALLED AT A LOW POINT IN SKID PIPING IN ORDER TO ENSURE THAT THE VALVE REMAINS FLOODED DURING SHUTDOWN PERIODS.
- 7- CUSTOMER/OPERATOR IS RESPONSIBLE FOR MAINTAINING PROCESS CONDITIONS AT SKID INLET (WJ1) AND RECIRCULATION CONNECTION (WJ9) WITHIN THE LIMITS SPECIFIED IN THE P.I.D. OPERATION OUTSIDE OF THESE LIMITS MAY CAUSE SKID MALFUNCTION.

8 - "THE SUPPLY INSTRUMENT AIR HAS TO BE DRY (THE DEW POINT HAS TO BE 10° C LOWWER THAN THE LOWEST SITE TEMPERATURE) AND CLEAN (FILTRATION TO REMOVE THE PARTICLES WHOSE SIZE IS GREATER THAN0.01 MICRON WITH AN EFFICIENCY OF 99.5%) OIL CARRY OVER OF THE AIR SHOULD BE £ 0.1 MG/M3."

REVISIONS		
REV	DESCRIPTION	
A	FIRST ISSUE	NAMES/NOMS TECHNICREA JR THIRION F. OBRIST A.
B	IM-2003001062	NAMES/NOMS TECHNICREA JR THIRION F. OBRIST A.
C	IM 2003006086	NAMES/NOMS TECHNICREA-JCP J.M. JOST S. DELIMOGE

PARAMETERS AT CONNECTIONS

INTERFACE POINT NAME PC	FLUID TYPE	TEMPERATURE ° F ° C			PRESSURE PSIG Kpa			FLOW GPM L/MIN			CONNECTION DESCRIPTION
		MINI	NOMI	MAXI	MINI	NOMI	MAXI	MINI	NOMI	MAXI	
WJ1	DEMINERALISED WATER	39.4 4	—	158 70	14,5 100	—	29 200	32,6 123	—	134 383	SKID INLET
WJ2	DEMINERALISED WATER	39.4 4	—	158 70	261 1800	—	377 2600	13 50	—	44 167	SKID OUTLET LOW FLOW
WJ7	DEMINERALISED WATER	39.4 4	—	158 70	261 1800	—	377 2600	31 117	—	66 250	SKID OUTLET HIGH FLOW
WJ3	DEMINERALISED WATER	39.4 4	—	158 70	65 450	—	80 550	—	32,6 123	—	SKID RECIRCULATION
WJ5	DEMINERALISED WATER	39.4 4	—	158 70	—	—	—	—	—	—	SKID WATER DRAIN
WI1	DEMINERALISED WATER	39.4 4	—	158 70	254 1750	—	370 2550	13 50	—	44 167	GAS TURBINE INLET LOW FLOW
WI2	DEMINERALISED WATER	39.4 4	—	158 70	254 1750	—	370 2550	31 117	—	66 250	GAS TURBINE INLET HIGH FLOW
WJ10	INSTRUMENT AIR (SEE NOTE 8)	-20 -29	—	150 66	29 200	—	250 1700	—	2,6 9,8	35,7 135	AIR PRESSURE CONNECTION

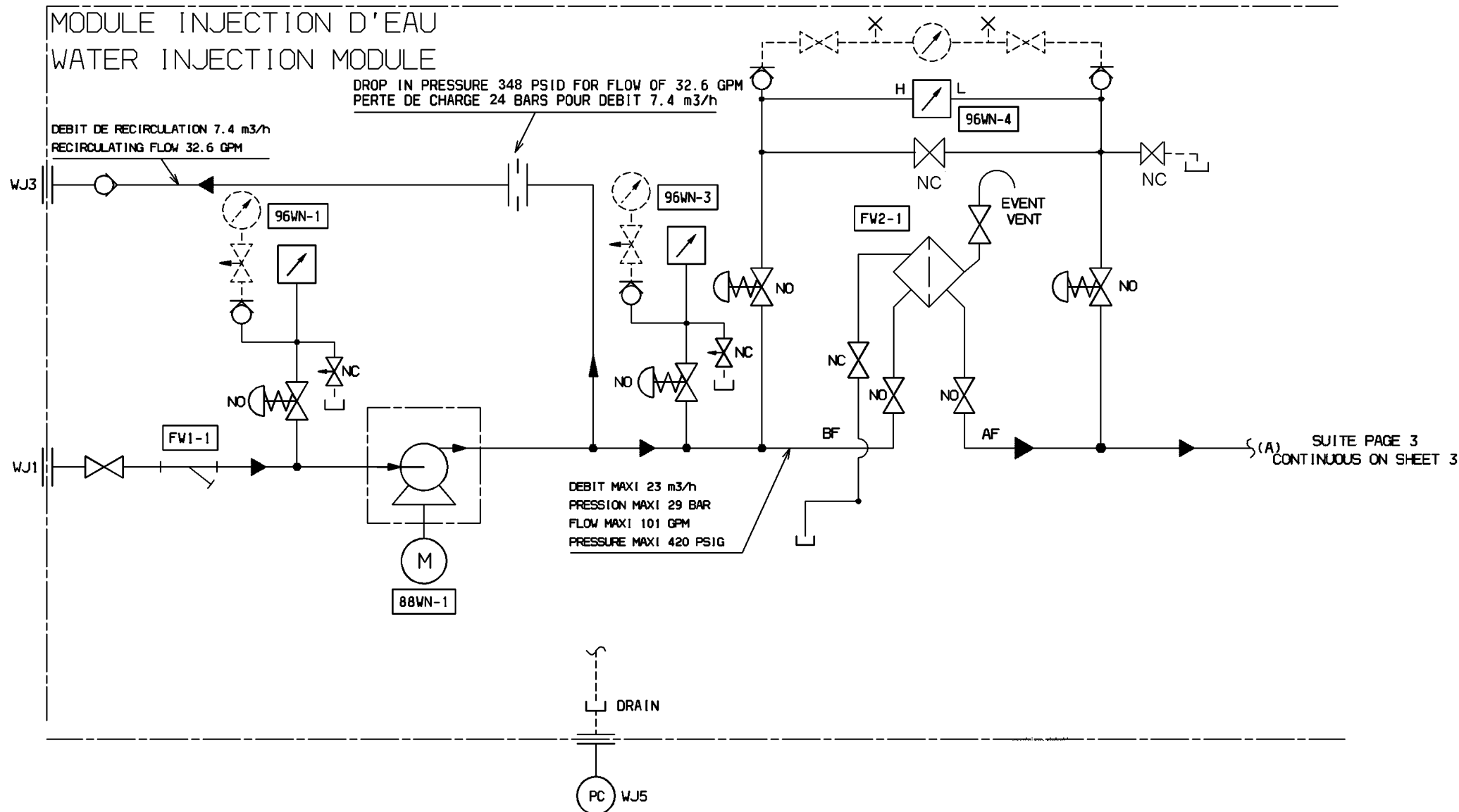
SYMBOLS PIPING	277A2415
NOMENCLATURE	IDENT
LIST OF COMPLEMENTARY DOCUMENTS	
FIRST MADE FOR : MS 9001E	ITEM : 0462

A	A	B	C	REV	REV STATUS
4	3	2	1	SH	OF SHEETS

This document, exclusive property of GE Energy Products France SNC is strictly confidential. It must not be communicated copied or reproduced without our previous written consent.

Ce document, propriété exclusive de GE Energy Products France SNC est strictement confidentiel. Il ne peut être communiqué, copié ou reproduit sans son autorisation écrite préalable

NOMS/NAMES		 GE Energy Products - Europe		GENERAL ELECTRIC COMPANY	
DRAWN	TECHNICREA JR			SCH.TUY. INJECTION EAU DIAG. SCH. PP-WATER INJECTION	
CHECKED	THIRION F.				
APPROVED	OBRIST A.			SIZE	CAGE CODE
				A3	DWG. NO.
				356B3359	
SIM TO : 360B1323		SCALE		REV. : B	SHEET 1



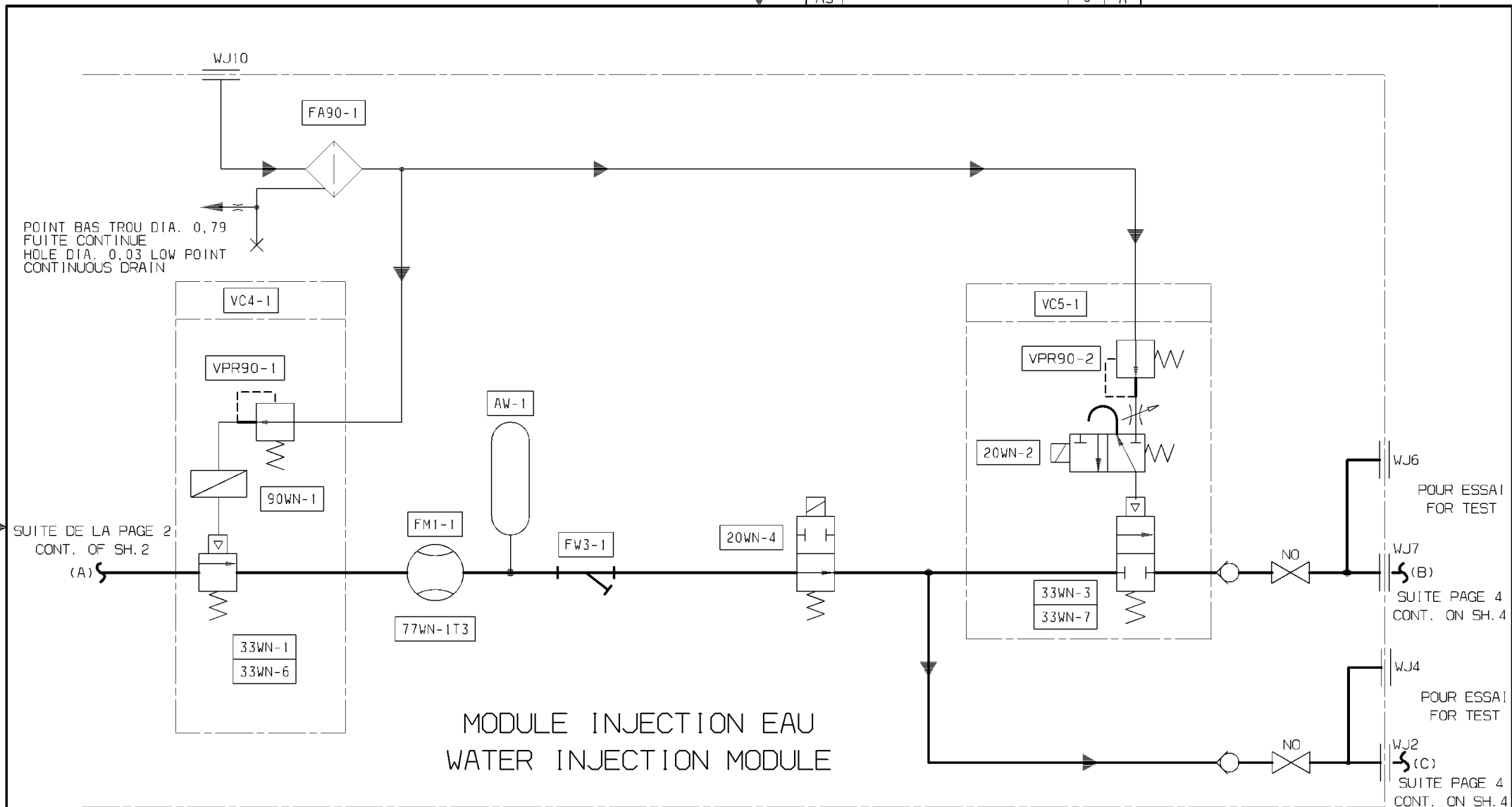
SUITE PAGE 3
CONTINUOUS ON SHEET 3

03-Dec-2002-13:46

This document, exclusive property of GE Energy Products France SNC is strictly confidential. It must not be communicated copied or reproduced without our previous written consent
Ce document, propriété exclusive de GE Energy Products France SNC est strictement confidentiel. Il ne peut être communiqué, copié ou reproduit sans son autorisation écrite préalable

NOMS/NAMES		 <i>GE Energy Products - Europe</i>		GENERAL ELECTRIC COMPANY	
DRAWN	TECHNICREA JR				
CHECKED	THIRION F.	SCH.TUY. INJECTION EAU <i>DIAG. SCH. PP-WATER INJECTION</i>			
APPROVED	OBRIST A.				
		SIZE	CAGE CODE	DWG. NO.	356B3359
		A3			
SIM TO : 360B1323		SCALE	REV. : B		SHEET 2

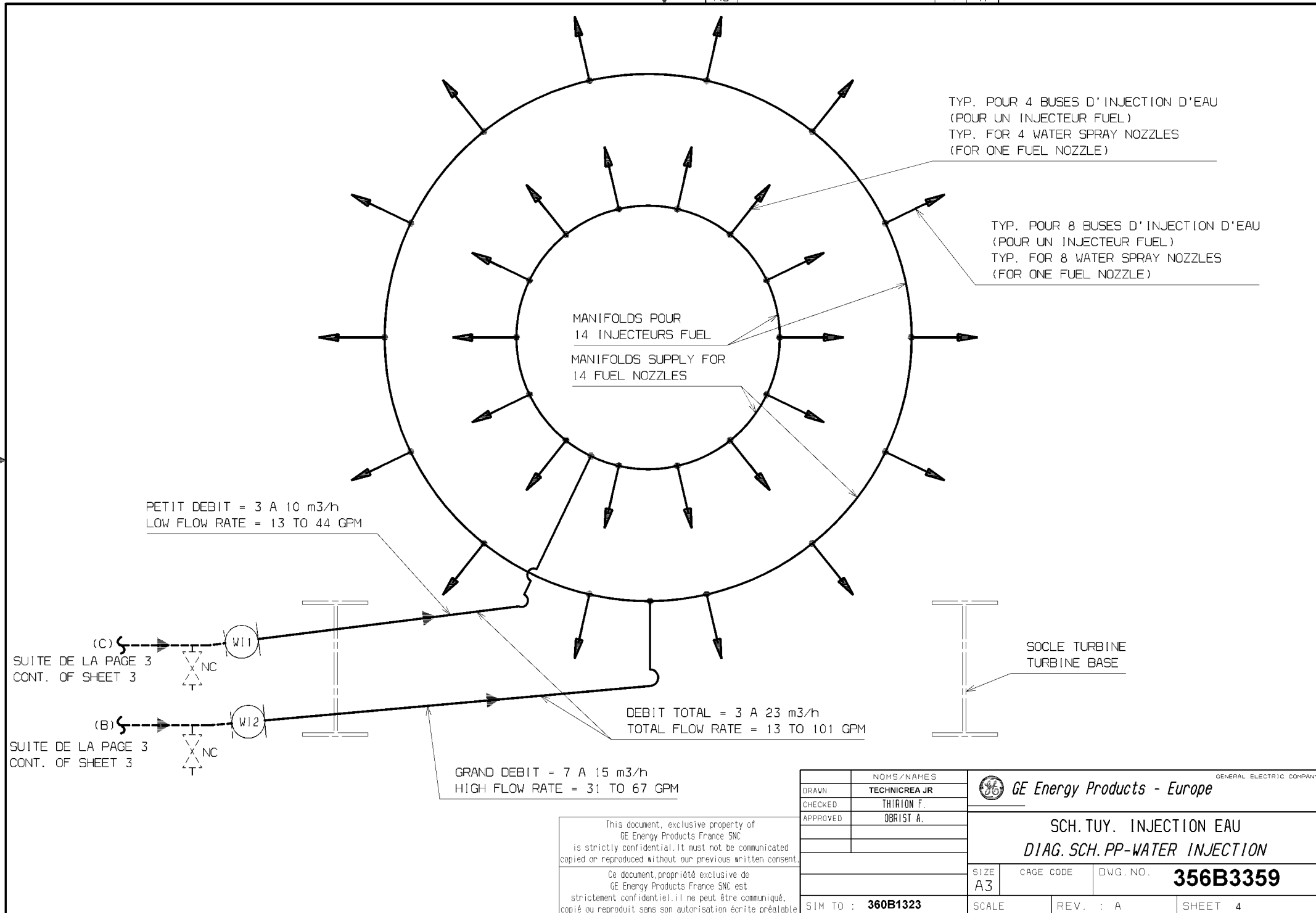
DISTR
TO



This document, exclusive property of
GE Energy Products France SNC
is strictly confidential. It must not be communicated
copied or reproduced without our previous written consent.

Ce document, propriété exclusive de
GE Energy Products France SNC est
strictement confidentiel. Il ne peut être communiqué,
copié ou reproduit sans son autorisation écrite préalable.

		NOMS / NAMES		 <i>GE Energy Products - Europe</i>		GENERAL ELECTRIC COMPANY	
DRAWN		TECHNICREA JR					
CHECKED		THIRION F.					
APPROVED		OBRIST A.					
				SCH. TUY. INJECTION EAU <i>DIAG. SCH. PP-WATER INJECTION</i>			
				SIZE A3			
				CAGE CODE		DWG. NO. 356B3359	
SIM TO : 360B1323		SCALE		REV. : A		SHEET 3	



Tab 19

NOTES:

1- SEE DEVICE SUMMARY (MLI.0414) FOR CONTROL DEVICE SETTINGS.

PARAMETERS AT CONNECTIONS

PC	TEMPERATURE			PRESSURE			FLOW		
	MINI	NOMINAL	MAXI	MINI	NOMINAL	MAXI	MINI	NOMINAL	MAXI
PM03	—	AMBIENT	—	—	ATMOS.	—	—	—	—

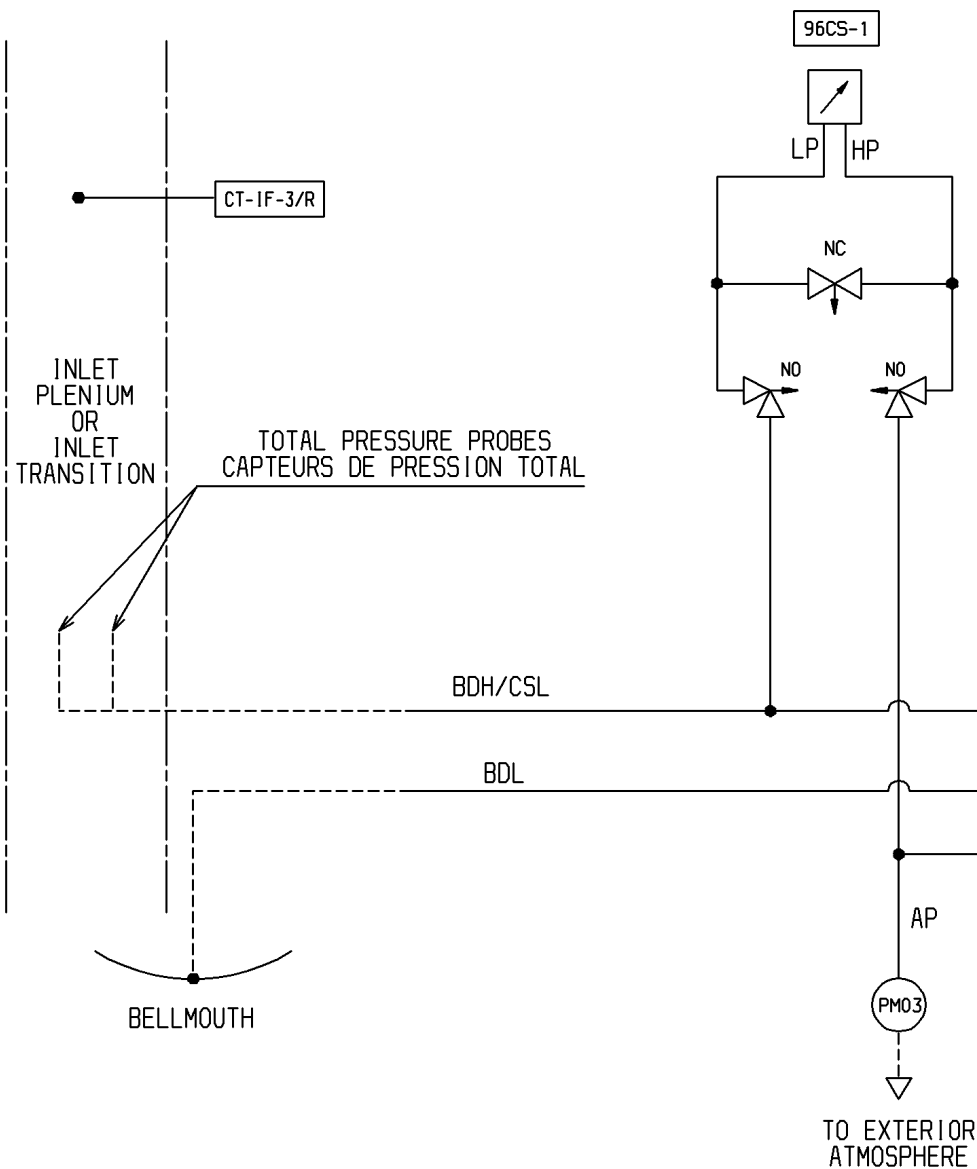
ECH. / SCALE	DATE	19-Sep-2002	23-Sep-2002	23-Sep-2002
	NOM / NAME	TECHNCREA	THIRION FREDERIC	JANIN PASCAL
FORMAT/SIZE A3	VISA	TECHNCREA	THIRION FREDERIC	JANIN PASCAL
		REDIGE / MADE	VERIFIE / CHECKED	APPROUVE / APPROVED

TITRE/TITLE

SCH.SURVEILLANCE PERFORMANCE
DIA.SCH. SURVEILLANCE MONITORING

Ce document, propriété exclusive de <i>GE Energy Products France SNC</i> est strictement confidentiel. Il ne peut être communiqué, copié ou reproduit sans son autorisation écrite préalable.	<i>GE Energy Products - Europe</i>		REVISION B INSTRUCTION DE MODIFICATION IM-2002004598 Section Doc. 01 F
	 <i>GE Energy Products France SNC</i>	N° 356B2419	
This document, exclusive property of <i>GE Energy Products France SNC</i> is strictly confidential. It must not be communicated, copied or reproduced without our previous written consent.	SHT. N 1/2		

This document, exclusive property of
GE Energy Products France SNC
is strictly confidential. It must not be
communicated, copied or reproduced
without our previous written consent.



ECH. / SCALE	DATE	19-Sep-2002	23-Sep-2002
	NOM / NAME	TECHNICREA	THIRION FREDERIC
FORMAT/SIZE	VISA	TECHNICREA	THIRION FREDERIC
A3		REDIGE / MADE	VERIFIE / CHECKED
			APPROUVE/APPROVED

TITRE/TITLE

SCH.SURVEILLANCE PERFORMANCE
DIA.SCH. SURVEILLANCE MONITORING

Ce document, propriété exclusive de
GE Energy Products France SNC
est strictement confidentiel. Il ne peut
être communiqué, copié ou reproduit
sans son autorisation écrite préalable.

This document, exclusive property of
GE Energy Products France SNC
is strictly confidential. It must not be
communicated, copied or reproduced
without our previous written consent.

GE Energy Products - Europe



GE Energy Products France SNC

N°	

356B2419

SHT, N 2/2

REVISION

B

INSTRUCTION DE
MODIFICATION

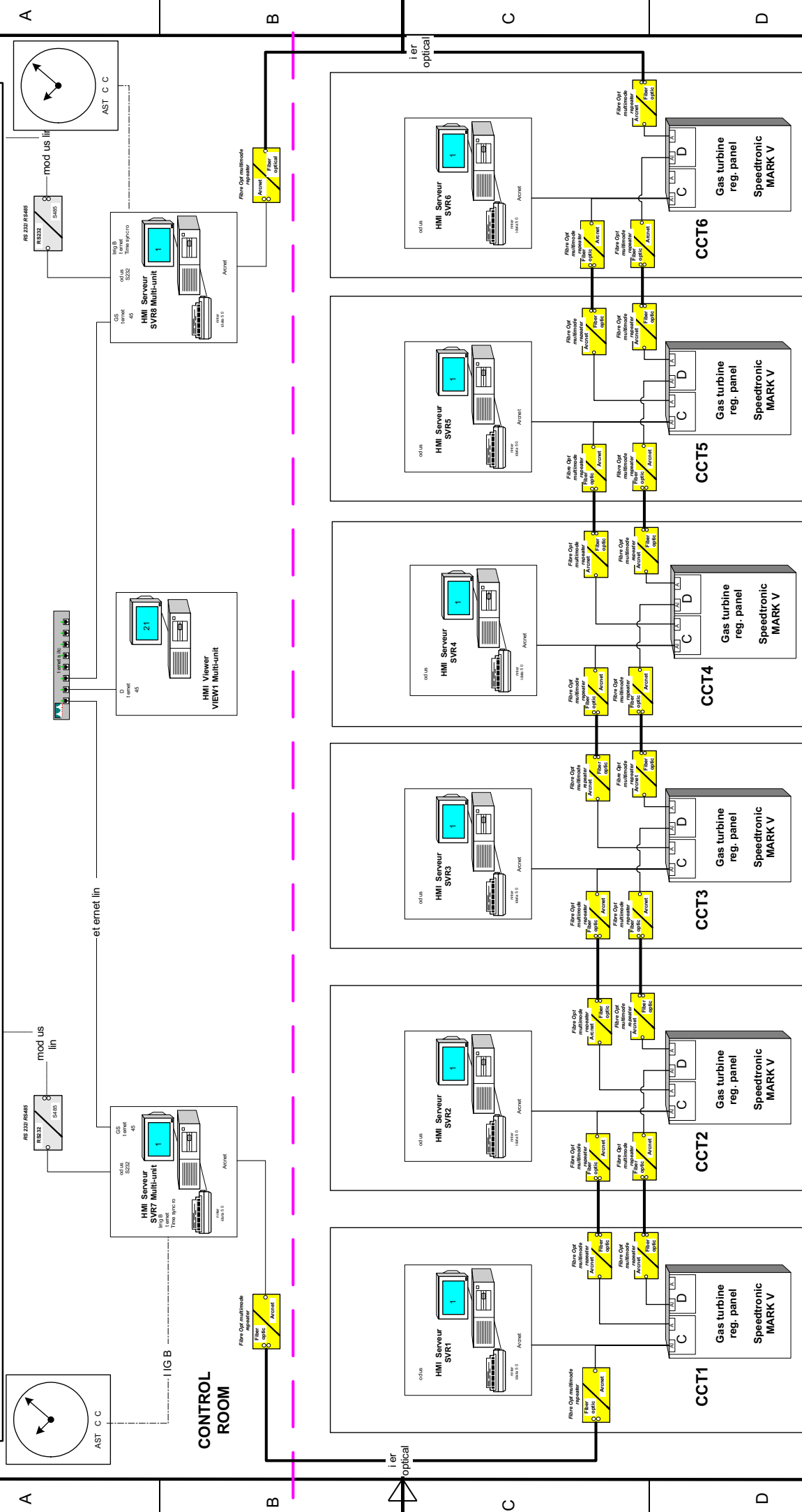
IM-2002004598

Section Doc.

01 F

Tab 20

DCS (in CCR)



A3 420		2	1	2		3	4										5	6				
GE Energy Products - Europe				TIT		TIT		ASSALUYEH														
GE Energy Products France SNC				GAS TURBINE & AUXILIARIES																		
				CONTROL HIERARCHY																		
				AD		C C D		A D		N 3 2 4 2 4												
				J.LEFIN		M.KESSLER		NAME														
				07/08/03		07/08/03		DATE														



GAS TURBINE OPERATOR COMMANDS

INTRODUCTION

Issuing the command to start a unit generally involves selecting a fuel, selecting a mode of operation, initiating a unit start, synchronizing and loading the unit. After selecting an operating mode and initiating a unit start, the unit can be synchronized manually or automatically and loaded manually or automatically.

After the unit has reached full speed no load (FSNL), the unit may be transferred from operation on one fuel to another. Some units have the option of operating on a fuel mix, though mixed fuel operation must be done within certain parameters.

Before or after the unit has been started, one of several automatically controlled load setpoints can be selected, e.g., BASE, PEAK, PRE-SELECT.

ET OFF command. If at zero speed, the unit can be placed “ON COOLDOWN” by using the COOLDOWN ON or RATCHET ON command.

“OFF” OPERATING MODE

The “OFF” mode is usually selected by the operator after a unit stop has been initiated or completed and there is no anticipated need to start the unit; the OFF command prevents “inadvertently” starting of the unit. OFF cannot be selected while the unit is starting or running. A unit start cannot be initiated from the OFF mode; this is an unalarmed start—check permissive. When OFF mode is selected, the status message field will display either “ON COOLDOWN” or “OFF COOLDOWN”.

“CRANK” OPERATING MODE

The “CRANK” mode is usually selected when the unit is to be rotated at or near its purge speed without admitting fuel to the combustion chambers. Examples of such instances include axial-compressor cleaning, “forced” cooling of the unit or heat recovery steam generator or shaft rotation after a failure of the unit to go on cooldown after a shutdown or trip. With the CRANK mode selected and the unit at zero speed, the status message field will display either “READY TO START” or “NOT READY TO START”. If the unit is “READY TO START”, a unit start must be initiated in order for the unit to be cranked. After a unit start has been initiated, the status message field will display “CRANKING” while the unit remains in CRANK mode. CRANK mode cannot be selected any time after the unit has fired. Exercise caution if it is necessary to crank the unit for extended periods of time or several times in succession so as not to damage the starting means. After starting the unit in CRANK mode it can be accelerated to full speed no load (FSNL) by selecting AUTO, or FIRE and then AUTO.

OPERATING MODE COMMANDS

MODE OF OPERATION

OFF

CRANK

FIRE

AUTOMATIC

REMOTE

A normal unit shutdown is initiated by selecting the STOP command, after which the unit will be unloaded automatically and decelerated in a manner which reduces the turbine’s thermal stresses gradually; this is a “fired shutdown”. The unit will then be placed “ON COOLDOWN” automatically.

If desired, the unit can be taken “OFF COOLDOWN” after an appropriate period of time has passed by using the COOLDOWN OFF or RATCH-

“FIRE” OPERATING MODE

The “FIRE” mode is selected when it desired to “fire” the unit (admit and ignite fuel) but not bring it to full speed. This may be useful to dry the unit after a water wash if it is not going to be operated within the next 12 hours, to do start checks, or to straighten a bowed rotor. When a unit start is initiated after the FIRE mode has been selected, the status message field will display “STARTING”, then “FIRING”, and after flame has been initiated, “WARMING UP”. Once flame has been initiated, fuel flow will remain at the pre-set warm-up value. Since the unit is not self-sustaining at low speeds, the starting means will continue to provide torque to the unit. Exercise caution if it is necessary to run the unit at FIRE for extended periods of time so as not to damage the starting means. After starting the unit in FIRE mode it can be accelerated to full speed no load (FSNL) by selecting AUTO.

“AUTO” OPERATING MODE

The “AUTO” mode is the normal mode of operation selected when a unit is to be started from the local operator interface and brought to full speed. After selecting the AUTO mode, the status message field will display either “READY TO START” or “NOT READY TO START”, indicating whether or not all the unit start-check permissives have been satisfied. After a unit start has been initiated, the status message field will display “STARTING”, “FIRING”, “WARMING UP”, “ACCELERATING”, and then “FULL SPEED NO LOAD” or “SYNCHRONIZING” and “LOADING”, depending on whether automatic synchronization has been selected. When AUTO is selected and the generator panel is in the Auto Synch mode, the unit will crank, fire, accelerate, synchronize automatically, and load to Spinning Reserve if no other load command is given. Spinning Reserve is a pre-selected load level stored as a control constant in the SPEEDTRONIC™ Mk V software. Once the unit attains full speed, no mode below AUTO may be selected unless a unit STOP has been initiated.

“CABLE REMOTE” OPERATING MODE

Selecting the “CABLE REMOTE” mode allows the plant’s central control system (DCS or SCADA) to send certain commands to the SPEEDTRONIC Mark V panel. If “CABLE REMOTE” has not been selected, the plant control may only monitor the Mark V, not issue commands. Information displayed in the status message field will be the same as that for AUTO mode operation. The CABLE REMOTE mode may be selected at any time and operation may be switched back and forth from CABLE REMOTE to AUTO while the unit is running. The switching from CABLE REMOTE to AUTO and back must be done from the local panel. Personnel must remember that when CABLE REMOTE is selected, the local <I> is still able to issue commands to the control panel; control does not transfer to the plant control.

COOLDOWN CYCLE COMMANDS

TURBINE COOLDOWN

COOLDOWN ON (RATCHET ON) COOLDOWN OFF (RATCHET OFF)

“COOLDOWN ON”

COOLDOWN ON or RATCHET ON is used during unit cooldown to prevent rotor bow. If the rotor was to remain stationary after being shutdown, the upper half of the rotor would tend to get warmer than the lower half and the rotor would bow. This could cause a vibration problem during a subsequent start-up or might prevent the rotor from turning at all. The larger units, Model Series 7 and 9, utilize the COOLDOWN ON command which puts the units on “slow roll”, a constant rotation at low rpm. Model Series 5 and 6 units utilize the RATCHET ON command which rotates the shaft 56° every three minutes. The major difference between the large and small Model



Series is the type of torque convertor used. The unit will be on COOLDOWN or RATCHET any time it is at zero speed, unless COOLDOWN OFF or RATCHET OFF has been selected. When the 14HR zero speed relay picks up after a unit shutdown, the unit goes on slow roll or ratchet automatically, no operator initiation required. While on slow roll or ratchet, the ac-powered lube oil pump will operate, providing both lubrication and the “muscle” needed for rotor rotation. A unit should remain on the cooldown cycle, slow roll or ratchet, for a minimum of 12 hours after a shutdown. It is preferable to leave the unit on the cooldown cycle continuously unless a lengthy shutdown is anticipated. It is suggested the unit be put on the cooldown cycle prior to a start-up after an extended period of no rotation.

“COOLDOWN OFF”

“COOLDOWN OFF” or “RATCHET OFF” will terminate the cooldown cycle. Model Series 7 and 9 will not accept a COOLDOWN OFF until 12–14 hours after the unit has been shutdown.

GAS TURBINE UNIT COMMANDS

UNIT START

START

FAST LOAD START

FAST START, FAST LOAD (MS5001, MS6001 OPTION)

UNIT STOP

STOP

“START” COMMAND

The START command is used to initiate the starting sequence when the CRANK, FIRE, AUTO, or REMOTE mode is selected. With auto-synch selected and the unit in AUTO mode, a START command will bring the unit from zero speed to Spinning Reserve with no other operator input; if BASE is selected, the unit will go from zero speed to base load with no other operator input. If the generator breaker has opened for some reason, automatic synchronization may be re-initiated by selecting START again.

“FAST LOAD START” COMMAND

When a FAST LOAD START is used to start the unit in AUTO with automatic synchronization selected at the generator panel, the unit will come up to full speed at its normal rate of acceleration, but once the generator breaker closes, the machine is loaded at a much higher rate than normal, approximately eight times the automatic loading rate. This makes megawatts available very quickly but subjects the unit to high levels of thermal stress. FAST LOAD START should be used only when necessary as it has a negative impact on the machine’s maintenance intervals. If FAST LOAD START has been selected mistakenly when initiating a start, it may de-selected by selecting the normal START command.

“FAST START, FAST LOAD” COMMAND

When a FAST START, FAST LOAD is used to start the unit in AUTO with automatic synchronization selected at the generator panel, the unit will come up to full speed at an accelerated rate and, when the breaker is closed, the machine will load at a higher rate. The fast start results from a shorter warm-up period from the diesel engine starting device, if so equipped, a shorter warm-up period for the gas turbine after firing and a steeper acceleration curve bringing the unit to full speed. The unit then loads at the fast load rate. The FAST START, FAST LOAD has even more of a negative impact on the machine’s

maintenance intervals than FAST LOAD START and should be used judiciously. If FAST START, FAST LOAD has been selected mistakenly when initiating a start, it may de-selected by selecting the normal START command. The FAST START, FAST LOAD is an option available only on Model Series 5 and 6 machines.

“STOP” COMMAND

A “STOP” command will initiate a unit shutdown sequence. The turbine speed reference will be reduced at the normal automatic loading, and, hence unloading, rate. This will unload the unit until, in the case of a generator drive application, the generator breaker opens on “reverse power”. The unit will then be at approximately 100% speed and a fired shutdown sequence will be initiated. A fired shutdown sequence reduces fuel flow at a set rate and causes the unit to decelerate. The unit is decelerated until the flame becomes unstable at which point fuel flow is stopped; this occurs at approximately 30% speed. The fired shutdown sequence reduces the thermal stresses on the unit which would be caused by stopping fuel flow abruptly. On machines equipped with the hydraulic ratchet cooldown, when the rotor reaches zero speed (14HR), the hydraulic ratchet sequence is automatically initiated. On machines equipped with the slow roll cooldown, when the rotor reaches approximately 30–50 rpm the slow roll sequence is automatically initiated. A STOP command may be aborted prior to high speed relay L14HS drop-out by giving a START command.

GAS TURBINE LOAD COMMANDS

In the absence of having selected either of the commands listed below, if the gas turbine is started in AUTO with automatic synchronization selected at the generator panel, the unit will automatically load to a point known as “SPINNING RESERVE”. This is usually a nominal megawatt setting, e.g., four me-

gawatts, that is used by the control system as a reference in the absence of any other setting. The unit will remain at SPINNING RESERVE until another load command is given or until a RAISE or LOWER load command is given. SPINNING RESERVE is a site-adjustable setting determined by control constant LK90SPIN.

LOAD SELECTION

PRE-SELECT

BASE

PEAK

PRESELECTED LOAD

When “PRESELECTED LOAD” is selected, the unit will automatically load or unload at the automatic loading rate until the preselected load output is attained. The preselected load is a megawatt setting that is site-adjustable by changing control constant LK90PSEL. Once the preselected load level is attained, fuel flow will be controlled to maintain that megawatt output until another load command is given or until a RAISE or LOWER load command is given.

BASE LOAD

When “BASE LOAD” is selected, the unit will load (or unload from PEAK) at the normal loading rate until the unit goes on exhaust temperature control; at this point, the unit is at its nominal rated power output for the ambient conditions. When the unit is on exhaust temperature control, fuel flow is regulated to provide the maximum power for the ambient conditions without “overfiring” the machine. It is important to note that as ambient conditions change, primarily compressor inlet temperature, the unit’s power output will change. Once at BASE LOAD, the unit will remain there until another load command is given or a LOWER load command is given. After selecting BASE LOAD, the automatic loading or unloading of the unit may be aborted by giving a RAISE or LOWER load command.



PEAK LOAD

“PEAK LOAD” is an option and, when selected, the unit will load at the normal loading rate until the unit goes on peak exhaust temperature control. Similar to operation on BASE, as ambient conditions change, primarily compressor inlet temperature, the unit’s power output will change. When operating on PEAK, the unit is operating at a firing temperature above its design limit; unit output is increased with a consequent reduction in the machine’s maintenance intervals. A rule of thumb is one hour of PEAK operation is equivalent to six hours of BASE operation. Once at PEAK LOAD, the unit will remain there until another load command is given or a LOWER load command is given. After selecting PEAK LOAD, the automatic loading or unloading of the unit may be aborted by giving a RAISE or LOWER load command.

SPEED/LOAD CONTROL COMMANDS

SPEED/LOAD CONTROL

RAISE
LOWER

RAISE SPEED/LOAD

When selected, a “RAISE” command will increment the turbine speed reference TNR. With the generator breaker open, selecting RAISE will increase the unit’s speed. With the generator breaker closed and the unit on droop control, selecting RAISE will increase the unit’s load. Selecting RAISE is the manual means of increasing the unit’s speed or load.

LOWER SPEED/LOAD

When selected, a “LOWER” command will decrement the turbine speed reference TNR. With the generator breaker open, selecting LOWER will decrease the unit’s speed. With the generator breaker closed and the unit on droop control, selecting LOWER will decrease the unit’s load. Selecting LOWER is the manual means of decreasing the unit’s speed or load.

GOVERNOR COMMANDS

GOVERNOR

DROOP
ISOCH

DROOP GOVERNOR

“DROOP” control is the usual governor command for most generators connected to a utility grid; this is a ‘load-sharing’ governor. Droop speed control is a proportional control, changing called-for fuel flow (FSR) in proportion to the difference between actual turbine speed and the speed reference. Any change in actual speed (grid frequency) will cause a proportional change in unit load. If the entire grid system tends to be overloaded, grid frequency (or speed) will decrease and cause an FSR increase in proportion to the droop setting. If all units have the same droop, all will share a load increase equally. Load sharing and system stability are the main advantages of this method of speed control.

ISOCHRONOUS GOVERNOR

Selecting “ISOCHRONOUS” will force the unit to maintain rated speed/frequency and provide as much power as required up to the turbine’s firing temperature limit (temperature control). The isochronous governor setpoint is fixed at 100% speed; any deviation will integrate the fuel command in a

direction to reduce the speed error to exactly zero. If there were two isochronous governor machines on the same system, they would have a tendency to fight each other as each would attempt to hold a slightly different speed. The isochronous governor is a proportional plus reset, or integrating, controller. The reset action allows it to integrate out any steady state speed error, providing a steady state droop of 0 percent.

FUEL COMMANDS

FUEL SELECTION

GAS
DIST
MIX
HEAVY

For single fuel applications, there is obviously no fuel selection needed. However, many machines come equipped for dual fuel operation, the dual fuels primarily being natural gas and liquid fuel. The liquid fuel is usually a distillate known as Number 2 burner fuel, 2-D diesel fuel, 2-GT gas turbine fuel, high speed diesel, etc. These are the fuels specified by “GAS” and “DIST”, respectively.

Some applications may use heavier liquid fuels known as crudes and/or residuals, e.g., 3-GT gas turbine fuel, 4-D diesel fuel, marine diesel fuel (low speed diesel), No. 4 burner fuel, light residual oil, No. 6 burner fuel, bunker C, etc. These heavier fuels require special fuel handling equipment such as heaters and water wash skids to make the fuel easy to handle and suitable for use in a gas turbine. Generally, the higher the fuel number, the less volatile the fuel and the more on-site processing it needs before it is suitable for use. Heavy liquid fuels usually require that start-up of the gas turbine be done on another fuel and transfer to “HEAVY” after full speed has been attained.

There are also applications that use lighter liquid fuels such as kerosene or naphtha. Kerosene is also known as 1-D diesel fuel, 1-GT gas turbine fuel or JP5, Jet A and is generally more expensive than the number 2 distillates. Naphtha may also be known as O-GI gas turbine fuel or JP-4, Jet B and is more volatile than the number 1 and 2 distillates. Naphtha fuel generally requires forwarding equipment or an additive due to its low lubricity.

Some gas fuel applications may be dual gas applications, using some sort of gas generated by an on-site process as the secondary gas fuel. These applications are usually in processing plants such as refineries or chemical plants.

When running a dual-fuel gas/distillate machine, the machine is able to start on either fuel and switch to the alternate fuel after full speed has been attained. If running on gas and the gas supply pressure falls below a pre-set level, the control system will automatically switch to the liquid fuel; the transfer from liquid to gas must always be initiated by the operator. Many dual-fuel machines can run at “MIX”, a combination of the two fuels. This must be done within certain parameters such as being above a minimum load and minimum flow requirements for either fuel.

BACKUP OPERATOR INTERFACE COMMANDS

STARTING PROCEDURE

Step 1: Mode Select To “AUTO”

- Press function key “F1” for MODE SELECT options.
- Use the arrow (< >) keys to point to “AUTO”.
- Press the “ENTER” key. An asterisk (*) will appear beside “AUTO”.



Step 2: Master Control “START” Signal

- Press function key “F2” for MASTER CONTROL options.
- Use arrow (< >) key to point to “START”.
- Press “ENTER”. An asterisk (*) will appear beside “START”.
- Press the “RAISE” key. The signal “L1X” will change to a “1”, indicating the start sequence is in progress.
- Press the “NORMAL” key. Check “TNH” to confirm that turbine speed is increasing, indicating shaft rotation.

Step 3: Load Selection To Base Load

- Press function key “F5”.
- Use arrow (< >) keys to point to “BASE”.
- Press the “ENTER” key. An asterisk (*) will appear beside “BASE”.

STOP PROCEDURE

Normal Stop Command

- Press the function key “F2”.
- Use arrow (< >) keys to point to “STOP”.
- Press the “ENTER” key. An asterisk (*) will appear beside “STOP”.
- Press the “RAISE” key. The signal L94X will change to a “1”, indicating the stop sequence is in progress.

The STOP sequence is fully automatic from this point. No other commands are required. The STOP procedure may be aborted by initiating a START.

AUXILIARIES CONTROL

Cooldown On

- Press function key “F15” (press down on the “SHIFT” and “F5” keys simultaneously).
- Use the arrow (< >) keys to point to “CD_ON”.
- Press the “ENTER” key. An asterisk (*) will appear beside “CD_ON”.
- Press the “RAISE” key. The cooldown sequence has been initiated. At the appropriate time the necessary systems (lube oil, hydraulic oil and starting means systems) will be activated to support rotor cooldown activities.

Cooldown Off

- Press function key “F15” (press down on the “SHIFT” and “F5” keys simultaneously).
- Use the arrow (< >) keys to point to “CD_OFF”.
- Press the “ENTER” key. An asterisk (*) will appear beside “CD_OFF”.
- Press the “RAISE” key. Rotor cooldown operation will now stop and the support systems for this cooldown will be shut down automatically. This includes the lube oil going to the bearings.



GE Power Systems Training

*General Electric Company
One River Road
Schenectady, NY 12345*



FUNDAMENTALS OF SPEEDTRONIC™ MARK V CONTROL SYSTEM

SPEEDTRONIC™ Mark V Control contains a number of control, protection and sequencing systems designed for reliable and safe operation of the gas turbine. It is the objective of this chapter to describe how the gas turbine control requirements are met, using simplified block diagrams and one-line diagrams of the SPEEDTRONIC Mark V control, protection, and sequencing systems. A generator drive gas turbine is used as the reference.

CONTROL SYSTEM

Basic Design

Control of the gas turbine is done by the startup, ac-

celeration, speed, temperature, shutdown, and manual control functions illustrated in Figure 1. Sensors monitor turbine speed, exhaust temperature, compressor discharge pressure, and other parameters to determine the operating conditions of the unit. When it is necessary to alter the turbine operating conditions because of changes in load or ambient conditions, the control modulates the flow of fuel to the gas turbine. For example, if the exhaust temperature tends to exceed its allowable value for a given operating condition, the temperature control system reduces the fuel supplied to the turbine and thereby limits the exhaust temperature.

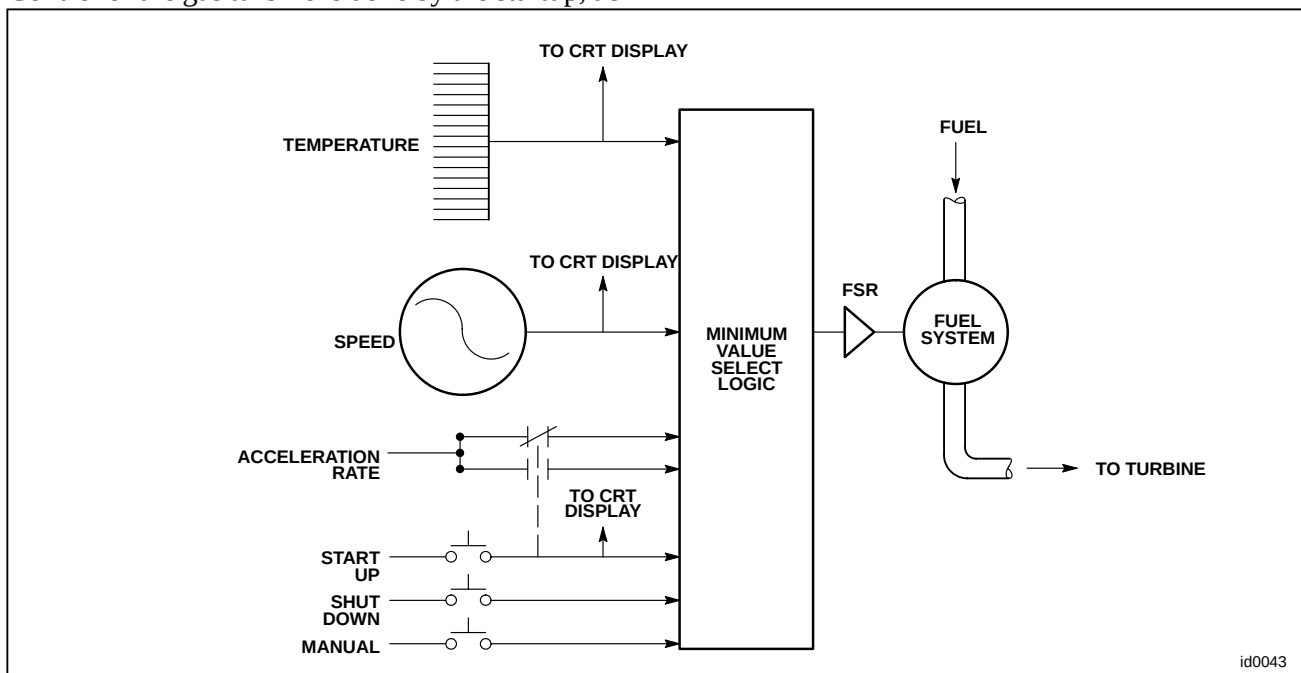
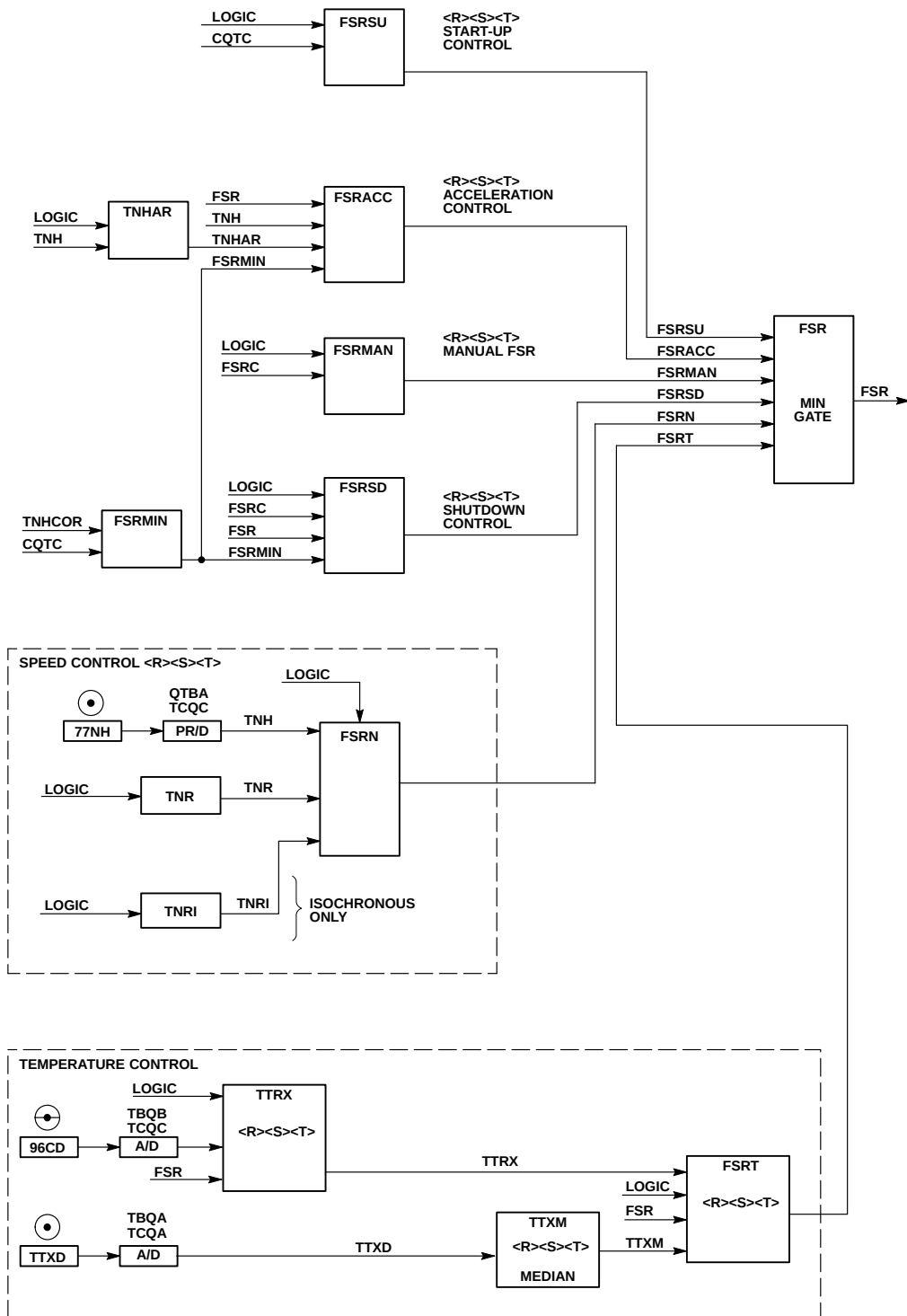


Figure 1 Simplified Control Schematic

Operating conditions of the turbine are sensed and utilized as feedback signals to the SPEEDTRONIC control system. There are three major control loops – startup, speed, and temperature – which may be in control during turbine operation. The output of these control loops is connected to a minimum value gate circuit as shown in Figure 1. The secondary control

modes of acceleration, manual FSR, and shutdown operate in a similar manner.

Fuel Stroke Reference (FSR) is the command signal for fuel flow. The minimum value select gate connects the output signals of the six control modes to the FSR controller; the lowest FSR output of the six



id0038V

Figure 2 Block Diagram – Control Schematic



control loops is allowed to pass through the gate to the fuel control system as the controlling FSR. The controlling FSR will establish the fuel input to the turbine at the rate required by the system which is in control. Only one control loop will be in control at any particular time and the control loop which is controlling FSR will be displayed on the CRT.

Figure 2 shows a more detailed schematic of the control loops. This can be referenced during the explanation of each loop to show the interfacing.

Start-up/Shutdown Sequence and Control

Start-up control brings the gas turbine from zero speed up to operating speed safely by providing proper fuel to establish flame, accelerate the turbine, and to do it in such a manner as to minimize the low cycle fatigue of the hot gas path parts during the sequence. This involves proper sequencing of command signals to the accessories, starting device and fuel control system. Since a safe and successful start-up depends on proper functioning of the gas turbine equipment, it is important to verify the state of selected devices in the sequence. Much of the control logic circuitry is associated not only with actuating control devices, but enabling protective circuits and obtaining permissive conditions before proceeding.

General values for control settings are given in this description to help in the understanding of the operating system. Actual values for control settings are given in the Control Specifications for a particular machine.

Speed Detectors

An important part of the start-up/shutdown sequence control of the gas turbine is proper speed sensing. Turbine speed is measured by magnetic pickups and will be discussed under speed control. The following speed detectors and speed relays are typically used:

–L14HR Zero-Speed (approx. 0% speed)

–L14HM Minimum Speed (approx. 16% speed)

–L14HA Accelerating Speed (approx. 50% speed)

–L14HS Operating Speed (approx. 95% speed)

The zero-speed detector, L14HR, provides the signal when the turbine shaft starts or stops rotating. When the shaft speed is below 14HR, or at zero-speed, L14HR picks-up (fail safe) and the permissive logic initiates ratchet or slow-roll operation during the automatic start-up/cooldown sequence of the turbine.

The minimum speed detector L14HM indicates that the turbine has reached the minimum firing speed and initiates the purge cycle prior to the introduction of fuel and ignition. The dropout of the L14HM minimum speed relay provides several permissive functions in the restarting of the gas turbine after shutdown.

The accelerating speed relay L14HA pickup indicates when the turbine has reached approximately 50 percent speed; this indicates that turbine start-up is progressing and keys certain protective features.

The high-speed sensor L14HS pickup indicates when the turbine is at speed and that the accelerating sequence is almost complete. This signal provides the logic for various control sequences such as stopping auxiliary lube oil pumps and starting turbine shell/exhaust frame blowers.

Should the turbine and generator slow during an underfrequency situation, L14HS will drop out at the under-frequency speed setting. After L14HS drops out the generator breaker will trip open and the Turbine Speed Reference (TNR) will be reset to 100.3%. As the turbine accelerates, L14HS will again pick up; the turbine will then require another start signal before the generator will attempt to auto-synchronize to the system again.

The actual settings of the speed relays are listed in the Control Specification and are programmed in the <RST> processors as EEPROM control constants.



START-UP CONTROL

The start-up control operates as an open loop control using preset levels of the fuel command signal FSR. The levels are: “ZERO”, “FIRE”, “WARM-UP”, “ACCELERATE” and “MAX”. The Control Specifications provide proper settings calculated for the fuel anticipated at the site. The FSR levels are set as Control Constants in the SPEEDTRONIC Mark V start-up control.

Start-up control FSR signals operate through the minimum value gate to ensure that other control functions can limit FSR as required.

The fuel command signals are generated by the SPEEDTRONIC control start-up software. In addition to the three active start-up levels, the software sets maximum and minimum FSR and provides for manual control of FSR. Clicking on the targets for “MAN FSR CONTROL” and “FSR GAG RAISE OR LOWER” allows manual adjustment of FSR setting between FSRMIN and FSRMAX.

While the turbine is at rest, electronic checks are made of the fuel system stop and control valves, the accessories, and the voltage supplies. At this time, “SHUTDOWN STATUS” will be displayed on the CRT. Activating the Master Operation Switch (L43) from “OFF” to an operating mode will activate the ready circuit. If all protective circuits and trip latches are reset, the “STARTUP STATUS” and “READY TO START” messages will be displayed, indicating that the turbine will accept a start signal. Clicking on the “START” Master Control Switch (L1S) and “EXECUTE” will introduce the start signal to the logic sequence.

The start signal energizes the Master Control and Protection circuit (the “L4” circuit) and starts the necessary auxiliary equipment. The “L4” circuit permits pressurization of the trip oil system and engages the starting clutch if applicable. With the “L4” circuit permissive and the starting clutch engaged, the starting device starts turning. Startup status message “STARTING” will be displayed on the CRT. See point “A” on the Typical Start-up Curve Figure 3.

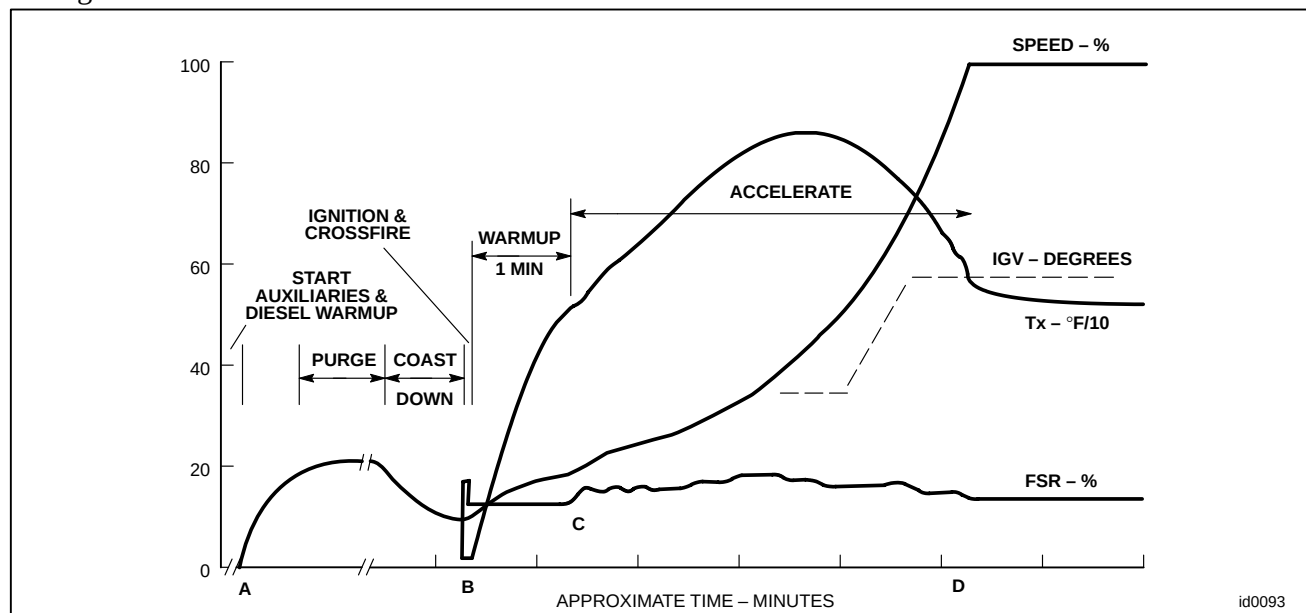


Figure 3 Mark V Start-up Curve

When the turbine ‘breaks away’ (starts to rotate), the L14HR signal de-energizes starting clutch solenoid 20CS and shuts down the hydraulic ratchet. The

clutch then requires torque from the starting device to maintain engagement. The turbine speed relay L14HM indicates that the turbine is turning at the



speed required for proper purging and ignition in the combustors. Gas fired units that have exhaust configurations which can trap gas leakage (i.e., boilers) have a purge timer, L2TV, which is initiated with the L14HM signal. The purge time is set to allow three to four changes of air through the unit to ensure that any combustible mixture has been purged from the system. The starting means will hold speed until L2TV has completed its cycle. Units which do not have extensive exhaust systems may not have a purge timer, but rely on the starting cycle and natural draft to purge the system.

The L14HM signal or completion of the purge cycle (L2TVX) ‘enables’ fuel flow, ignition, sets firing level FSR, and initiates the firing timer L2F. See point “B” on Figure 3. When the flame detector output signals indicate flame has been established in the combustors (L28FD), the warm-up timer L2W starts and the fuel command signal is reduced to the “WARM-UP” FSR level. The warm-up time is provided to minimize the thermal stresses of the hot gas path parts during the initial part of the start-up.

If flame is not established by the time the L2F timer times out, typically 60 seconds, fuel flow is halted. The unit can be given another start signal, but firing will be delayed by the L2TV timer to avoid fuel accumulation in successive attempts. This sequence occurs even on units not requiring initial L2TV purge.

At the completion of the warm-up period (L2WX), the start-up control ramps FSR at a predetermined rate to the setting for “ACCELERATE LIMIT”. The start-up cycle has been designed to moderate the highest firing temperature produced during acceleration. This is done by programming a slow rise in FSR. See point “C” on Figure 3. As fuel is increased, the turbine begins the acceleration phase of start-up. The clutch is held in as long as the starting device provides torque to the gas turbine. When the turbine overruns the starting device, the clutch will disengage, shutting down the starting device. Speed relay L14HA indicates the turbine is accelerating.

The start-up phase ends when the unit attains full-speed-no-load (see point “D” on Figure 3). FSR is

then controlled by the speed loop and the auxiliary systems are automatically shut down.

The start-up control software establishes the maximum allowable levels of FSR signals during start-up. As stated before, other control circuits are able to reduce and modulate FSR to perform their control functions. In the acceleration phase of the start-up, FSR control usually passes to acceleration control, which monitors the rate of rotor acceleration. It is possible, but not normal, to reach the temperature control limit. The CRT display will show which parameter is limiting or controlling FSR.

Fired Shutdown

A normal shutdown is initiated by clicking on the “STOP” target (L1STOP) and “EXECUTE”; this will produce the L94X signal. If the generator breaker is closed when the stop signal is initiated, the Turbine Speed Reference (TNR) counts down to reduce load at the normal loading rate until the reverse power relay operates to open the generator breaker; TNR then continues to count down to reduce speed. When the STOP signal is given, shutdown Fuel Stroke Reference FSRSD is set equal to FSR.

When the generator breaker opens, FSRSD ramps from existing FSR down to a value equal to FSRMIN, the minimum fuel required to keep the turbine fired. FSRSD latches onto FSRMIN and decreases with corrected speed. When turbine speed drops below a defined threshold (Control Constant K60RB) FSRSD ramps to a blowout of one flame detector. The sequencing logic remembers which flame detectors were functional when the breaker opened. When any of the functional flame detectors senses a loss of flame, FSRMIN/FSRSD decreases at a higher rate until flame-out occurs, after which fuel flow is stopped.

During coastdown on units having motor driven atomizing air booster compressors, the booster is started at L14HS drop out to prevent exhaust smoke during the shut down. Units not having motor driven boosters may require higher fuel shut off speed to avoid smoke.

Fired shut down is an improvement over the former fuel shut off at L14HS drop out. By maintaining



flame down to a lower speed there is significant reduction in the strain developed on the hot gas path parts at the time of fuel shut off.

SPEED CONTROL

The Speed Control System controls the speed and load of the gas turbine generator in response to the actual turbine speed signal and the called-for speed reference. While on speed control the control mode message “SPEED CTRL” will be displayed.

Speed Signal

Three magnetic sensors are used to measure the speed of the turbine. These magnetic pickup sensors (77NH-1,-2,-3) are high output devices consisting of a permanent magnet surrounded by a hermetically sealed case. The pickups are mounted in a ring around a 60-toothed wheel on the gas turbine compressor rotor. With the 60-tooth wheel, the frequency of the voltage output in Hertz is exactly equal to the speed of the turbine in revolutions per minute.

The voltage output is affected by the clearance between the teeth of the wheel and the tip of the magnetic pickup. Clearance between the outside diameter of the toothed wheel and the tip of the magnetic pickup should be kept within the limits specified in the Control Specifications (approx. 50 mils). If the clearance is not maintained within the specified limits, the pulse signal can be distorted. Turbine speed control would then operate in response to the incorrect speed feedback signal.

The signal from the magnetic pickups is brought into the Mark V panel, one mag pickup to each controller <RST>, where it is monitored by the speed control software.

Speed/Load Reference

The speed control software will change FSR in proportion to the difference between the actual turbine-

generator speed (TNH) and the called-for speed reference (TNR).

The called-for-speed, TNR, determines the load of the turbine. The range for generator drive turbines is normally from 95% (min.) to 107% (max.) speed. The start-up speed reference is 100.3% and is preset when a “START” signal is given.

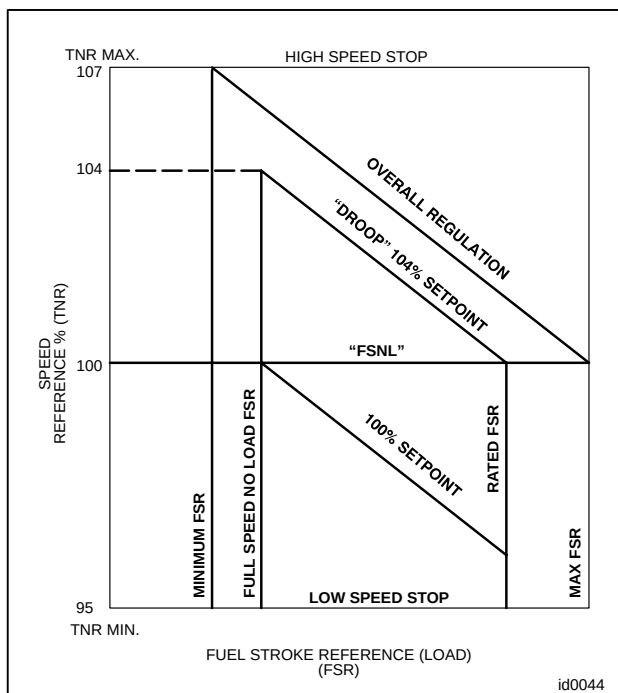


Figure 4 Droop Control Curve

The turbine follows to 100.3% TNH for synchronization. At this point the operator can raise or lower TNR, in turn raising or lowering TNH, via the 70R4CS switch on the generator control panel or by clicking on the targets on the CRT, if required. Refer to Figure 4. Once the generator breaker is closed onto the power grid, the speed is held constant by the grid frequency. Fuel flow in excess of that necessary to maintain full speed no load will result in increased power produced by the generator. Thus the speed control loop becomes a load control loop and the speed reference is a convenient control of the desired amount of load to be applied to the turbine-generator unit.

Droop speed control is a proportional control, changing FSR in proportion to the difference be-



tween actual turbine speed and the speed reference. Any change in actual speed (grid frequency) will cause a proportional change in unit load. This proportionality is adjustable to the desired regulation or “Droop”. The speed vs. FSR relationship is shown on Figure 4.

If the entire grid system tends to be overloaded, grid frequency (or speed) will decrease and cause an FSR increase in proportion to the droop setting. If all units have the same droop, all will share a load increase equally. Load sharing and system stability are the main advantages of this method of speed control.

Normally 4% droop is selected and the setpoint is calibrated such that 104% setpoint will generate a speed reference which will produce an FSR resulting in base load at design ambient temperature. If the unit has “PEAK” capability, 104% TNR will produce an FSR resulting in peak load.

When operating on droop control, the full-speed-no-load FSR setting calls for a fuel flow which is sufficient to maintain full speed with no generator load. By closing the generator breaker and raising TNR via raise/lower, the error between speed and reference is increased. This error is multiplied by a gain constant dependent on the desired droop setting

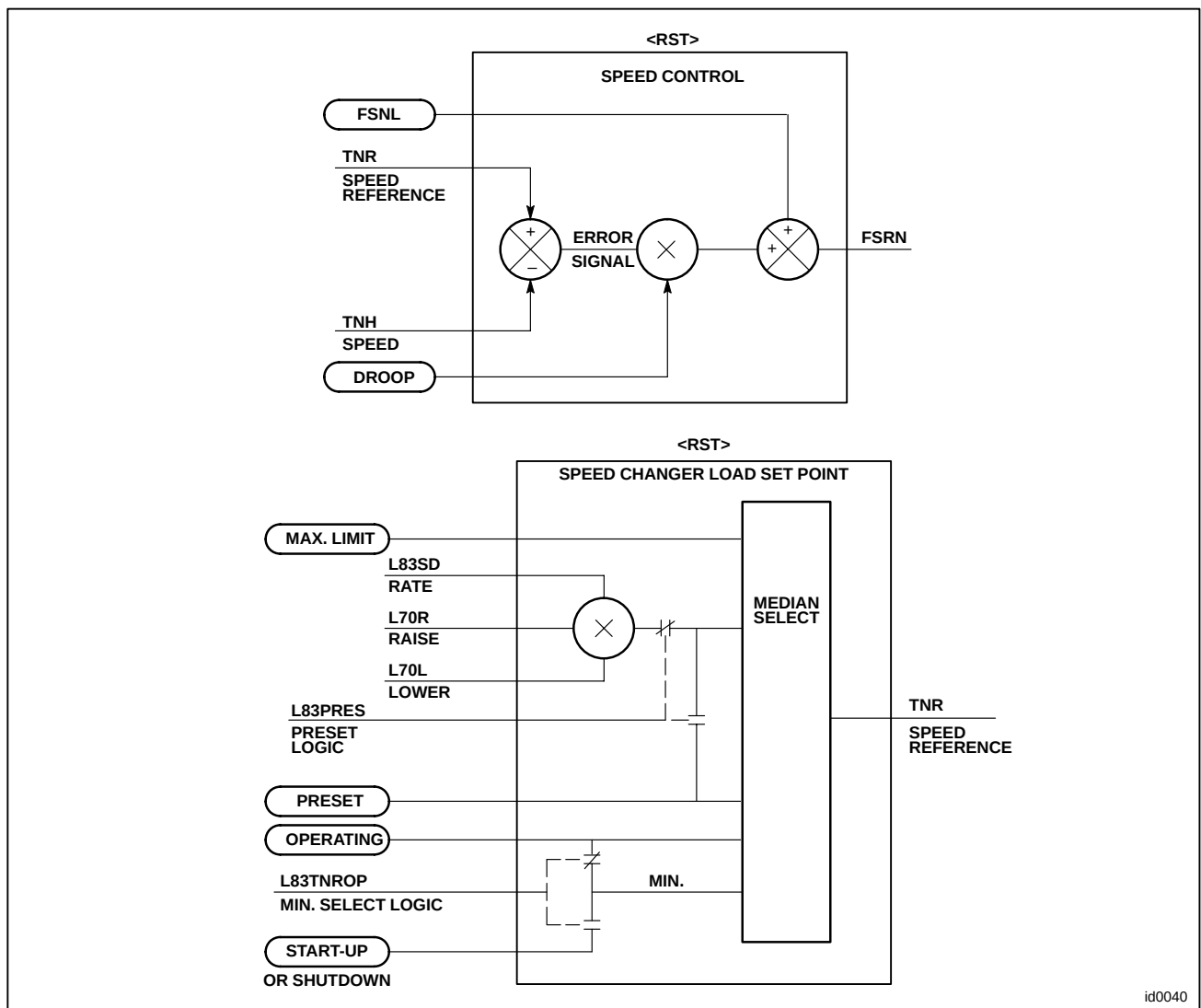


Figure 5 Speed Control Schematic



and added to the FSNL FSR setting to produce the required FSR to take more load and thus assist in holding the system frequency. Refer to Figures 4 and 5.

The minimum FSR limit (FSRMIN) in the SPEEDTRONIC Mark V system prevents the speed control circuits from driving the FSR below the value which would cause flameout during a transient condition. For example, with a sudden rejection of load on the turbine, the speed control system loop would want to drive the FSR signal to zero, but the minimum FSR setting establishes the minimum fuel level that prevents a flameout. Temperature and/or start-up con-

trol can drive FSR to zero and are not influenced by FSRMIN.

Synchronizing

Automatic synchronizing is accomplished using synchronizing algorithms programmed into <RST> and <P> software. Bus and generator voltage signals are input to the <P> core which contains isolation transformers, and are then paralleled to <RST>. <RST> software drives the synch check and synch permissive relays, while <P> provides the actual breaker close command. See Figure 6.

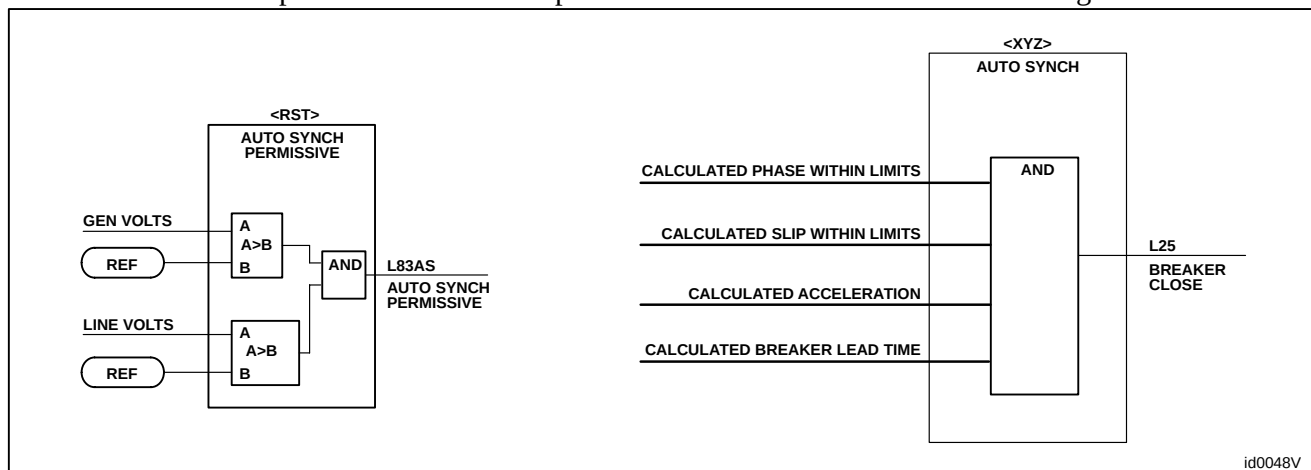


Figure 6 Synchronizing Control Schematic

There are three basic synchronizing modes. These may be selected from external contacts, i.e., generator panel selector switch, or from the SPEEDTRONIC Mark V CRT.

1. OFF – Breaker will not be closed by SPEEDTRONIC Mark V control
2. MANUAL – Operator initiated breaker closure when permissive synch check relay 25X is satisfied
3. AUTO – System will automatically match voltage and speed and then close the breaker at the appropriate time to hit top dead center on the synchroscope

For synchronizing, the unit is brought to 100.3% speed to keep the generator “faster” than the grid, assuring load pick-up upon breaker closure. If the sys-

tem frequency has varied enough to cause an unacceptable slip frequency (difference between generator frequency and grid frequency), the speed matching circuit adjusts TNR to maintain turbine speed 0.20% to 0.40% faster than the grid to assure the correct slip frequency and permit synchronizing.

For added protection a synchronizing check relay is provided in the generator panel. It is used in series with both the auto synchronizing relay and the manual breaker close switch to prevent large out-of-phase breaker closures.

ACCELERATION CONTROL

Acceleration control compares the present value of the speed signal with the value at the last sample time. The difference between these two numbers is a



measure of the acceleration. If the actual acceleration is greater than the acceleration reference, FSRACC is reduced, which will reduce FSR, and consequently the fuel to the gas turbine. During start-up the acceleration reference is a function of turbine speed; acceleration control usually takes over from speed control shortly after the warm-up period and brings the unit to speed. At “Complete Sequence”, which is normally 14HS pick-up, the acceleration reference is a Control Constant, normally 1% speed/second. After the unit has reached 100% TNH, acceleration control usually serves only to contain the unit’s speed if the generator breaker should open while under load.

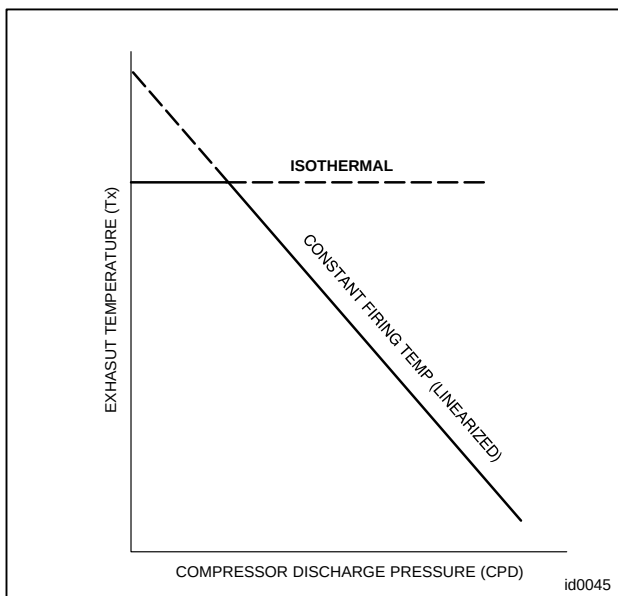


**Figure 7 Exhaust Temperature vs.
Compressor Discharge Pressure**

TEMPERATURE CONTROL

The Temperature Control System will limit fuel flow to the gas turbine to maintain internal operating temperatures within design limitations of turbine hot gas path parts. The highest temperature in the gas turbine occurs in the flame zone of the combustion chambers. The combustion gas in that zone is diluted by cooling air and flows into the turbine section through the first stage nozzle. The temperature of that gas as it exits the first stage nozzle is known as

the “firing temperature” of the gas turbine; it is this temperature that must be limited by the control system. From thermodynamic relationships, gas turbine cycle performance calculations, and known site conditions, firing temperature can be determined as a function of exhaust temperature and the pressure ratio across the turbine; the latter is determined from the measured compressor discharge pressure (CPD). The temperature control system is designed to measure and control turbine exhaust temperature rather than firing temperature because it is impractical to measure temperatures directly in the combustion chambers or at the turbine inlet. This indirect control of turbine firing temperature is made practical by utilizing known gas turbine aero- and thermo-dynamic characteristics and using those to bias the exhaust temperature signal, since the exhaust temperature alone is not a true indication of firing temperature.

Firing temperature can also be approximated as a function of exhaust temperature and fuel flow (FSR) and as a function of exhaust temperature and generator output (DWATT). Either FSR or megawatt exhaust temperature control curves are used as back-up to the primary CPD-biased temperature control curve.

These relationships are shown on Figures 7 and 8. The lines of constant firing temperature are used in the control system to limit gas turbine operating temperatures, while the constant exhaust temperature limit protects the exhaust system during start-up.

Exhaust Temperature Control Hardware

Chromel–Alumel exhaust temperature thermocouples are used and, depending on the gas turbine model, there may be 13 to 27. These thermocouples are mounted in the exhaust plenum in an axial direction circumferentially around the exhaust diffuser. They have individual radiation shields that allow the radial outward diffuser flow to pass over these 1/16” diameter (1.6mm) stainless steel sheathed thermocouples at high velocity, minimizing the cooling effect of the longer time constant, cooler plenum

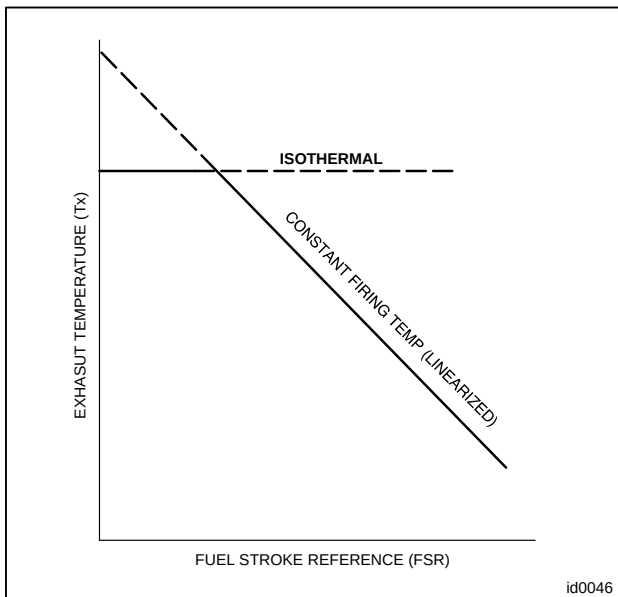


Figure 8 Exhaust Temperature vs. Fuel Control Command Signal

walls. The signals from these individual, ungrounded detectors are sent to the SPEEDTRONIC Mark V control panel through shielded thermocouple cables and are divided amongst controllers <RST>.

Exhaust Temperature Control Software

The software contains a series of application programs written to perform the exhaust temperature control and monitoring functions such as digital and analog input scan. A major function is the exhaust temperature control, which consists of the following programs:

1. Temperature control command
2. Temperature control bias calculations
3. Temperature reference selection

The temperature control software determines the cold junction compensated thermocouple readings, selects the temperature control setpoint, calculates the control setpoint value, calculates the representative exhaust temperature value, compares this value with the setpoint, and then generates a fuel com-

mand signal to the analog control system to limit exhaust temperature.

Temperature Control Command Program

The temperature control command program compares the exhaust temperature control setpoint with the measured gas turbine exhaust temperature as obtained from the thermocouples mounted in the exhaust plenum; these thermocouples are scanned and cold junction corrected by programs described later. These signals are accessed by <RST> as well as <C>. The temperature control command program in <RST> (Figure 9) reads the exhaust thermocouple temperature values and sorts them from the highest to the lowest. This array (TTXD2) is used in the combustion monitor program as well as in the Temperature Control Program. In the Temperature Control Program all exhaust thermocouple inputs are monitored and if any are reading too low as compared to a constant, they will be rejected. The highest and lowest values are then rejected and the remaining values are averaged, that average being the TTXM signal.

If a Controller should fail, this program will ignore the readings from the failed Controller. The TTXM signal will be based on the remaining Controllers' thermocouples and an alarm will be generated.

The TTXM value is used as the feedback for the exhaust temperature comparator because the value is not affected by extremes that may be the result of faulty instrumentation. The temperature-control-command program in <RST> compares the exhaust temperature control setpoint (calculated in the temperature-control-bias program and stored in the computer memory) TTRXB to the TTXM value to determine the temperature error. The software program converts the temperature error to a fuel stroke reference signal, FSRT.

Temperature Control Bias Program

Gas turbine firing temperature is determined by the measured parameters of exhaust temperature and compressor discharge pressure (CPD) or exhaust

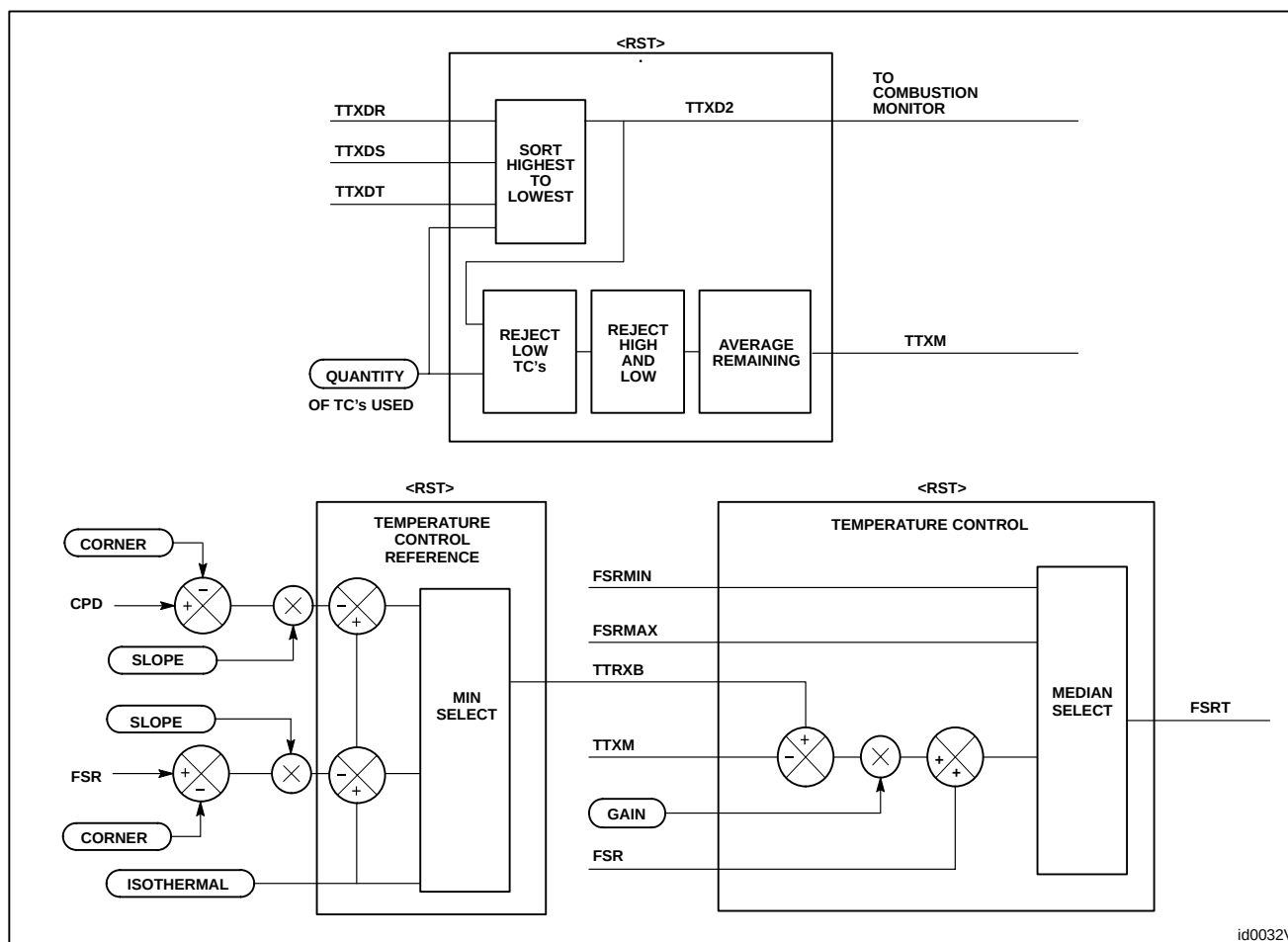


Figure 9 Temperature Control Schematic

temperature and fuel consumption (proportional to FSR). In the computer, firing temperature is limited by a linearized function of exhaust temperature and CPD backed up by a linearized function of exhaust temperature and FSR (See Figure 8). The temperature control bias program (Figure 10) calculates the exhaust temperature control setpoint TTRXB based on the CPD data stored in computer memory and constants from the selected temperature-reference table. The program calculates another setpoint based on FSR and constants from another temperature-reference table.

Figure 11 is a graphical illustration of the control setpoints. The constants TTKn_C (CPD bias corner) and TTKn_S (CPD bias slope) are used with the CPD data to determine the CPD bias exhaust temperature setpoint. The constants TTKn_K (FSR bias

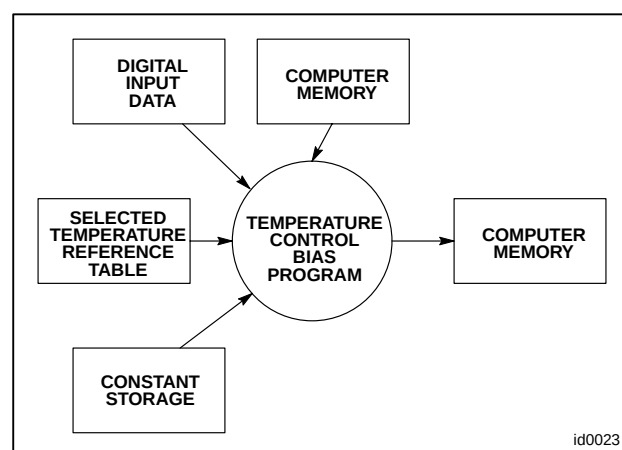


Figure 10 Temperature Control Bias corner) and TTKn_M (FSR bias slope) are used with the FSR data to determine the FSR bias exhaust temperature setpoint. The values for these constants are given in the Control Specifications–Control System



Settings drawing. The temperature-control-bias program also selects the isothermal setpoint TTKn_I. The program selects the minimum of the three setpoints, CPD bias, FSR bias, or isothermal for the final exhaust temperature control reference. During normal operation with gas or light distillate fuels, this selection results in a CPD bias control with an isothermal limit, as shown by the heavy lines on Figure 11. The CPD bias setpoint is compared with the FSR bias setpoint by the program and an alarm occurs when the CPD setpoint is higher. For units operating with heavy fuel, FSR bias control will be selected to minimize the effect of turbine nozzle plugging on firing temperature. The FSR bias setpoint will then be compared with the CPD bias setpoint and an alarm will occur when the FSR setpoint exceeds the CPD setpoint. A ramp function is provided in the program to limit the rate at which the setpoint can change. The maximum and minimum change in ramp rates (slope) are programmed in constants TTKRXR1 and TTKRXR2. Consult the Control Sequence Program (CSP) and the Control Specifications drawing for the block diagram illustration of this function and the value of the constants. Typical rate change limit is 1.5°F per second. The output of the ramp function is the exhaust temperature control setpoint which is stored in the computer memory.

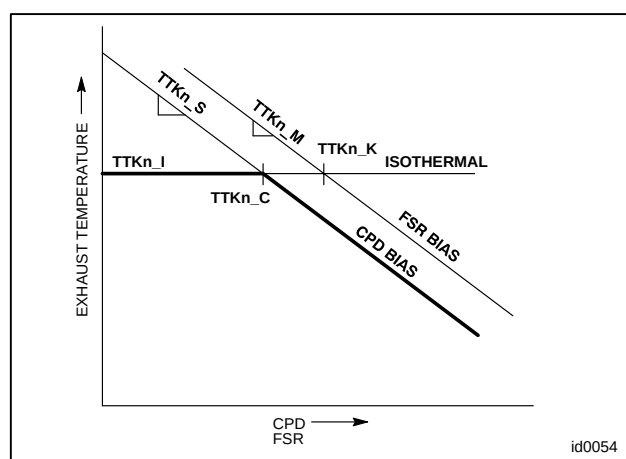


Figure 11 Exhaust Temperature Control Setpoints

Temperature Reference Select Program

The exhaust temperature control function selects control setpoints to allow gas turbine operation at various firing temperatures. The temperature-reference-select program (Figure 12) determines the operational level for control setpoints based on digital input information representing temperature control requirements. Three digital input signals are decoded to select one set of constants which define the control setpoints necessary to meet those requirements. Typical digital signals are “BASE SELECT”, “PEAK SELECT” and “HEAVY FUEL SELECT” and are selected by clicking on the appropriate target on the operator interface CRT. For example, the “PEAK SELECT” signal determines operation at PEAK (vs. BASE) firing temperature. When the appropriate set of constants are selected, they are stored in the selected-temperature-reference memory.

FUEL CONTROL SYSTEM

The gas turbine fuel control system will change fuel flow to the combustors in response to the fuel stroke reference signal (FSR). FSR actually consists of two separate signals added together, FSR1 being the called-for liquid fuel flow and FSR2 being the called-for gas fuel flow; normally, FSR1 + FSR2 = FSR. Standard fuel systems are designed for operation with liquid fuel and/or gas fuel. This chapter will describe a dual fuel system. It starts with the servo drive system, where the setpoint is compared with the feedback signal and converted to a valve

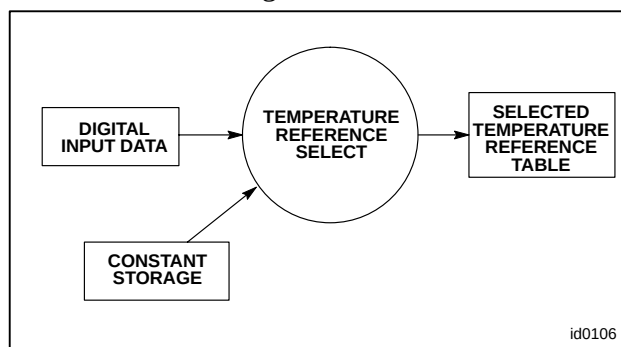


Figure 12 Temperature Reference Select Program



position. It will describe liquid, gas and dual fuel operation and how the FSR from the control systems previously described is conditioned and sent as a set point to the servo system.

Servo Drive System

The heart of the fuel system is a three coil electro-hydraulic servovalve (servo) as shown in Figure 13. The servovalve is the interface between the electrical and mechanical systems and controls the direction and rate of motion of a hydraulic actuator based on the input current to the servo.

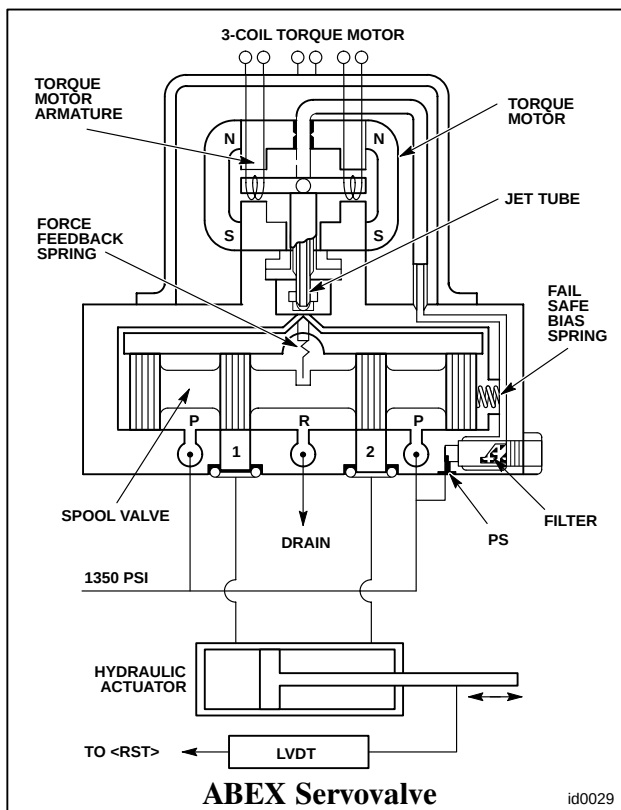


Figure 13 Electrohydraulic Servovalve

The servovalve contains three electrically isolated coils on the torque motor. Each coil is connected to one of the three Controllers <RST>. This provides redundancy should one of the Controllers or coils fail. There is a null-bias spring which positions the servo so that the actuator will go to the fail safe position should ALL power and/or control signals be lost.

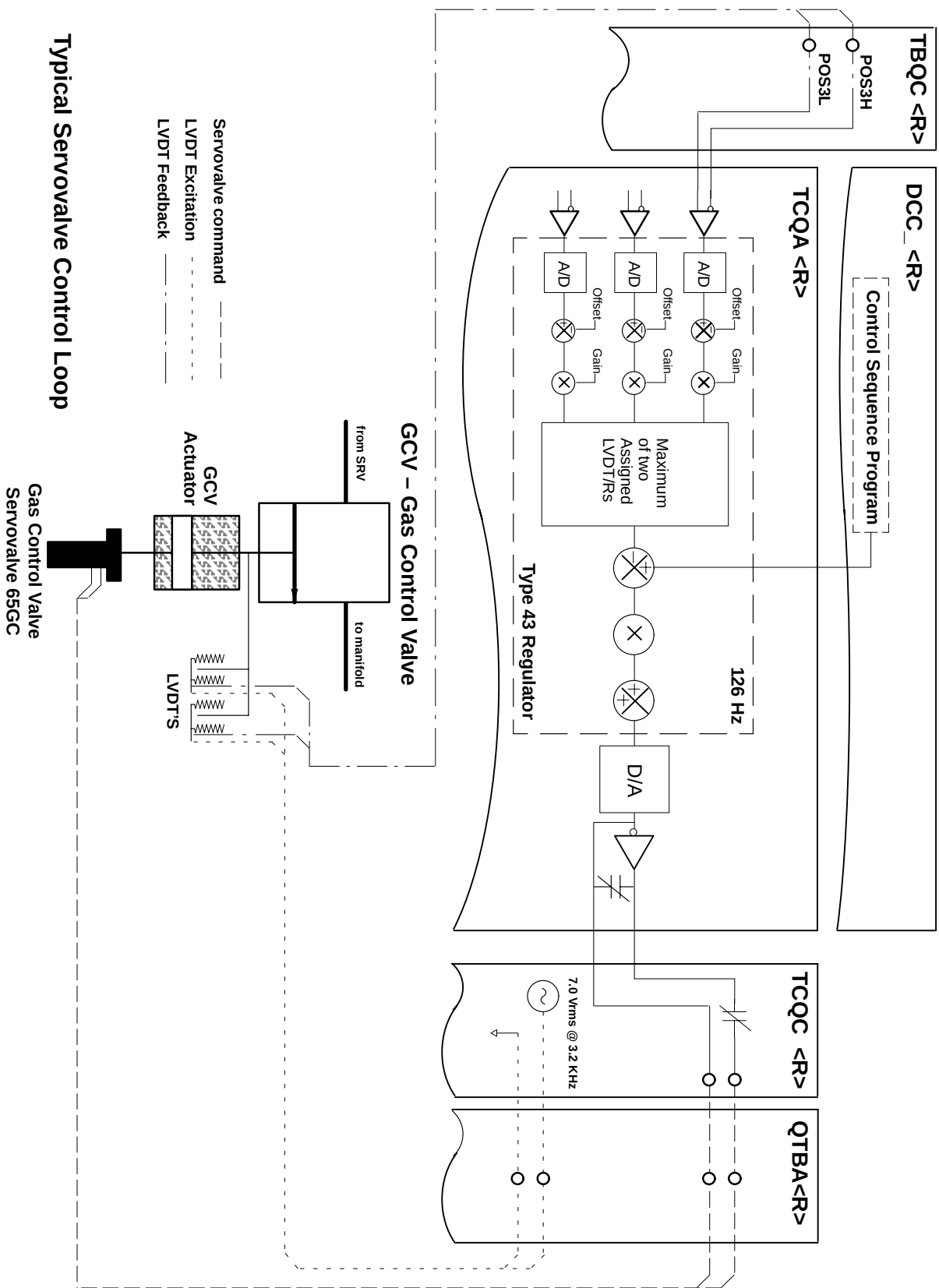
If the hydraulic actuator is a double-action piston, the control signal positions the servovalve so that it ports high-pressure oil to either side of the hydraulic actuator. If the hydraulic actuator has spring return, hydraulic oil will be ported to one side of the cylinder and the other to drain. A feedback signal provided by a linear variable differential transformer (LVDT, Figure 13) will tell the control whether or not it is in the required position. The LVDT outputs an AC voltage which is proportional to the position of the core of the LVDT. This core in turn is connected to the valve whose position is being controlled; as the valve moves, the feedback voltage changes. The LVDT requires an exciter voltage which is provided by the TCQC card.

Figure 14 shows the major components of the servo positioning loops. The digital (microprocessor signal) to analog conversion is done on the TCQA card; this represents called-for fuel flow. The called-for fuel flow signal is then compared to a feedback representing actual fuel flow. The difference is amplified on the TCQC card and sent through the QTBA card to the servo. This output to the servos is monitored and there will be an alarm on loss of any one of the three signals from <RST>.

Liquid Fuel Control

The liquid fuel system consists of fuel handling components and electrical control components. Some of the fuel handling components are: primary fuel oil filter (low pressure), fuel oil stop valve, fuel pump, fuel bypass valve, fuel pump pressure relief valve, secondary fuel oil filter (high pressure), flow divider, combined selector valve/pressure gauge assembly, false start drain valve, fuel lines, and fuel nozzles. The electrical control components are: liquid fuel pressure switch (upstream) 63FL-2, fuel oil stop valve limit switch 33FL, fuel pump clutch solenoid 20CF, liquid fuel pump bypass valve servovalve 65FP, flow divider magnetic speed pickups 77FD-1, -2, -3 and SPEEDTRONIC control cards TCQC and TCQA. A diagram of the system showing major components is shown in Figure 15.

The fuel bypass valve is a hydraulically actuated valve with a linear flow characteristic. Located





between the inlet (low pressure) and discharge (high pressure) sides of the fuel pump, this valve bypasses excess fuel delivered by the fuel pump back to the fuel pump inlet, delivering to the flow divider the

fuel necessary to meet the control system fuel demand. It is positioned by servo valve 65FP, which receives its signal from the controllers.

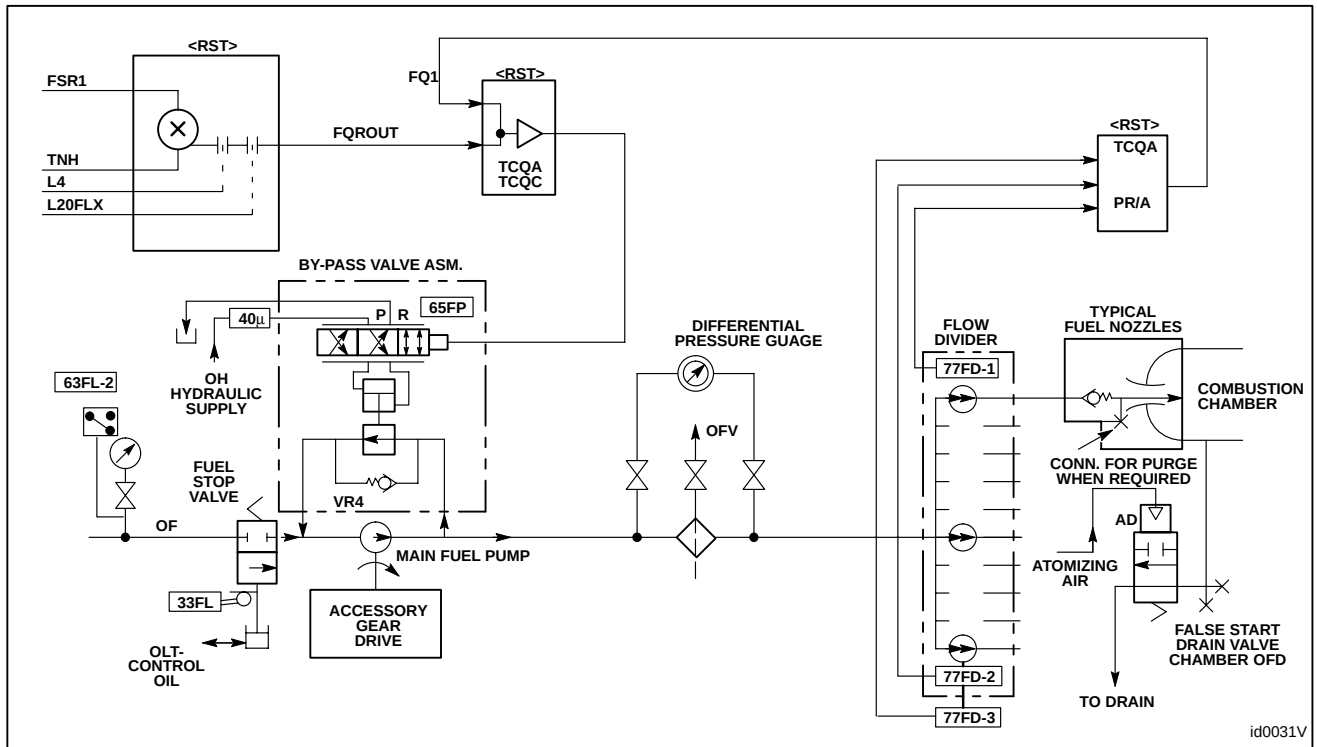


Figure 15 Liquid Fuel Control Schematic

The flow divider divides the single stream of fuel from the pump into several streams, one for each combustor. It consists of a number of matched high volumetric efficiency positive displacement gear pumps, again one per combustor. The flow divider is driven by the small pressure differential between the inlet and outlet. The gear pumps are mechanically connected so that they all run at the same speed, making the discharge flow from each pump equal. Fuel flow is represented by the output from the flow divider magnetic pickups (77FD-1, -2 & -3). These are non-contacting magnetic pickups, giving a pulse signal frequency proportional to flow divider speed, which is proportional to the fuel flow delivered to the combustion chambers.

The TCQA card receives the pulse rate signals from 77FD-1, -2, and -3 and outputs an analog signal which is proportional to the pulse rate input. The

TCQC card modulates servovalve 65FP based on inputs of turbine speed, FSR1 (called-for liquid fuel flow), and flow divider speed (FQ1).

Fuel Oil Control – Software

When the turbine is run on liquid fuel oil, the control system checks the permissives L4 and L20FLX and does not allow FSR1 to close the bypass valve unless they are ‘true’ (closing the bypass valve sends fuel to the combustors). The L4 permissive comes from the Master Protective System (to be discussed later) and L20FLX becomes ‘true’ after the turbine vent timer times out. These signals control the opening and closing of the fuel oil stop valve. The fuel pump clutch solenoid (20CF) is energized to drive the pump when the stop valve opens.

The FSR signal from the controlling system goes through the fuel splitter where the liquid fuel re-



quirement becomes FSR1. The FSR1 signal is multiplied by TNH, so fuel flow becomes a function of speed – an important feature, particularly while the unit is starting. This enables the system to have better resolution at the lower, more critical speeds where air flow is very low. This produces the FQROUT signal, which is the digital liquid fuel flow command. At full speed TNH does not change, therefore FQROUT is directly proportional to FSR.

FQROUT then goes to the TCQA card where it is changed to an analog signal to be compared to the feedback signal from the flow divider. As the fuel flows into the turbine, speed sensors 77FD-1, -2, and -3 send a signal to the TCQA card, which in turn outputs the fuel flow rate signal (FQ1) to the TCQC card. When the fuel flow rate is equal to the called-for rate ($FQ1 = FSR1$), the servovalve 65FP is moved to the null position and the bypass valve remains “stationary” until some input to the system changes. If the feedback is in error with FQROUT, the operational amplifier on the TCQC card will change the signal to servovalve 65FP to drive the bypass valve in a direction to decrease the error.

The flow divider feedback signal is also used for system checks. This analog signal is converted to digital counts and is used in the controller’s software to compare to certain limits as well as to display fuel flow on the CRT. The checks made are as follows:

1. L60FFLH: Excessive fuel flow on start-up
2. L3LFLT1: Loss of LVDT position feedback (MS7-1 & MS9-1)
3. L3LFBSQ: Bypass valve is not fully open when the stop valve is closed.
4. L3LFBSC: Servo current is detected when the stop valve is closed.
5. L3LFT: Loss of flow divider feedback

If L60FFLH is true for a specified time period (nominally 2 seconds), the unit will trip; if L3LFLT1 through L3LFT are true, these faults will trip the unit during start-up and require manual reset.

Gas Fuel Control

Fuel gas is controlled by the gas speed ratio/stop valve (SRV) and gas control valve (GCV) assembly. In all but the F-series machines, two valves are combined in this assembly as shown on Figure 16; the two valves are physically separate on the F-series machines. Both are servo controlled by signals from the SPEEDTRONIC control panel and actuated by single-acting hydraulic cylinders moving against spring-loaded valve plugs.

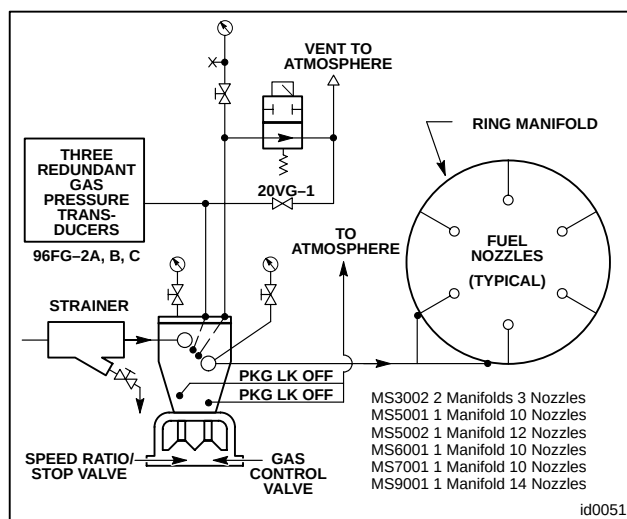


Figure 16 Gas Fuel System

It is the gas control valve which controls the desired gas fuel flow in response to the command signal FSR. To enable it to do this in a predictable manner, the speed ratio valve is designed to maintain a predetermined pressure (P_2) at the inlet of the gas control valve as a function of gas turbine speed.

The fuel gas control system consists primarily of the following components: gas strainer, gas supply pressure switch 63FG, speed ratio/stop valve assembly, fuel gas pressure transducer(s) 96FG, gas fuel vent solenoid valve 20VG, control valve assembly, LVDT’s 96GC-1, -2 and 96SR-1, -2, electro-hydraulic servovalves 90SR and 65GC, dump valve(s) VH-5, three pressure gauges, gas manifold with ‘pigtailed’ to respective fuel nozzles, and SPEEDTRONIC control cards TBQB and TCQC. The components are shown interconnected schematically in Figure 17. A functional explanation of each subsystem is contained in subsequent paragraphs.

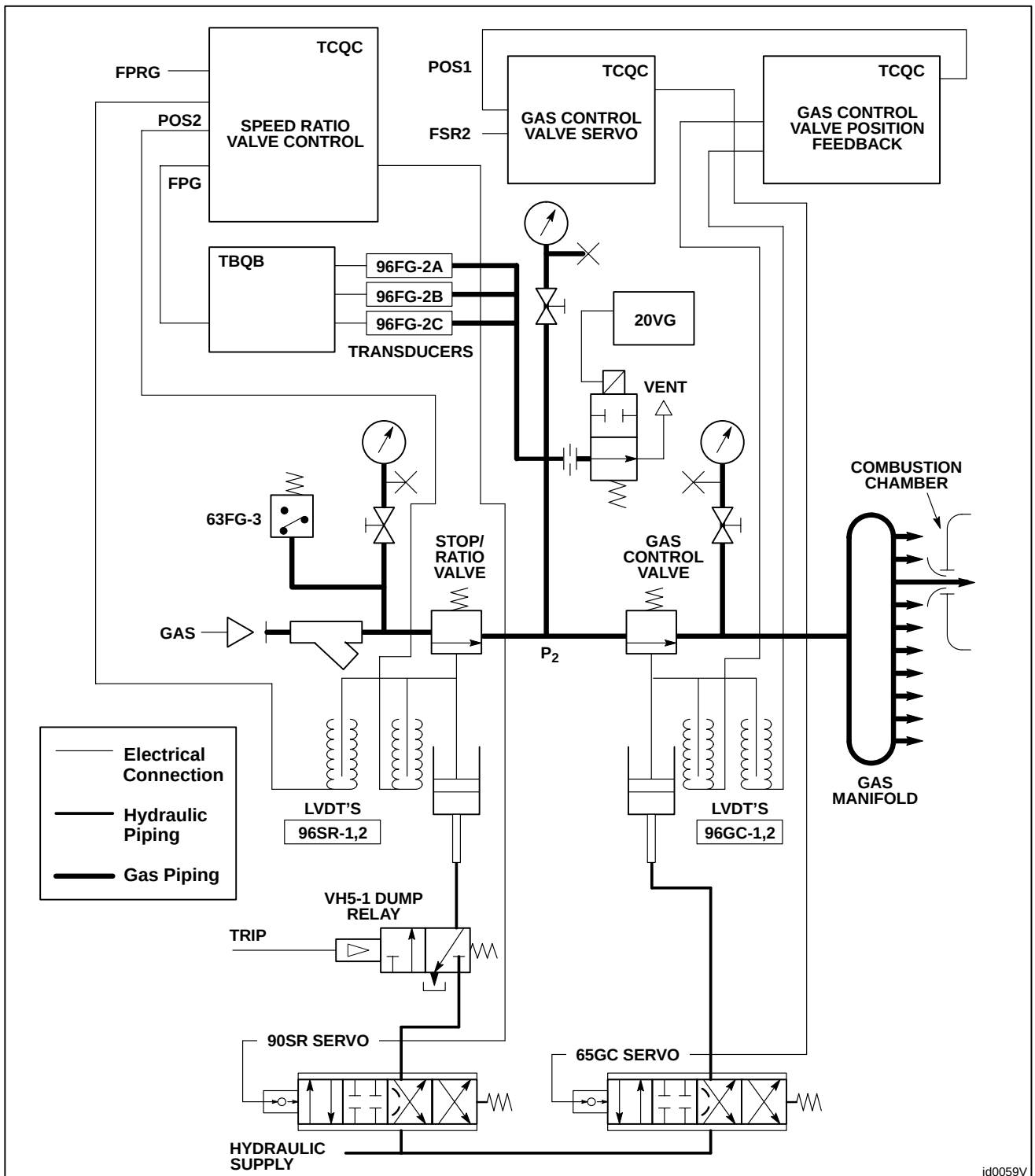


Figure 17 Gas Fuel Control System



Gas Control Valve

The position of the gas control valve plug is intended to be proportional to FSR2 which represents called-for gas fuel flow. Actuation of the spring-loaded gas control valve is by a hydraulic cylinder controlled by an electro-hydraulic servovalve.

When the turbine is to run on gas fuel the permissives L4, L20FGX and L2TVX (turbine purge complete) must be 'true', similar to the liquid system. This allows the Gas Control Valve to open. The stroke of the valve will be proportional to FSR.

FSR goes through the fuel splitter (to be discussed in the dual fuel section) where the gas fuel requirement becomes FSR2, which is then conditioned for offset and gain. This signal, FSROUT, goes to the TCQC

card where it is converted to an analog signal. The gas control valve stem position is sensed by the output of a linear variable differential transformer (LVDT) and fed back to an operational amplifier on the TCQC card where it is compared to the FSROUT input signal at a summing junction. There are two LVDTs providing feedback; two of the three controllers are dedicated to one LVDT each, while the third selects the highest feedback through a high-select diode gate. If the feedback is in error with FSROUT, the operational amplifier on the TCQC card will change the signal to the hydraulic servovalve to drive the gas control valve in a direction to decrease the error. In this way the desired relationship between position and FSR2 is maintained and the control valve correctly meters the gas fuel. See Figure 18.

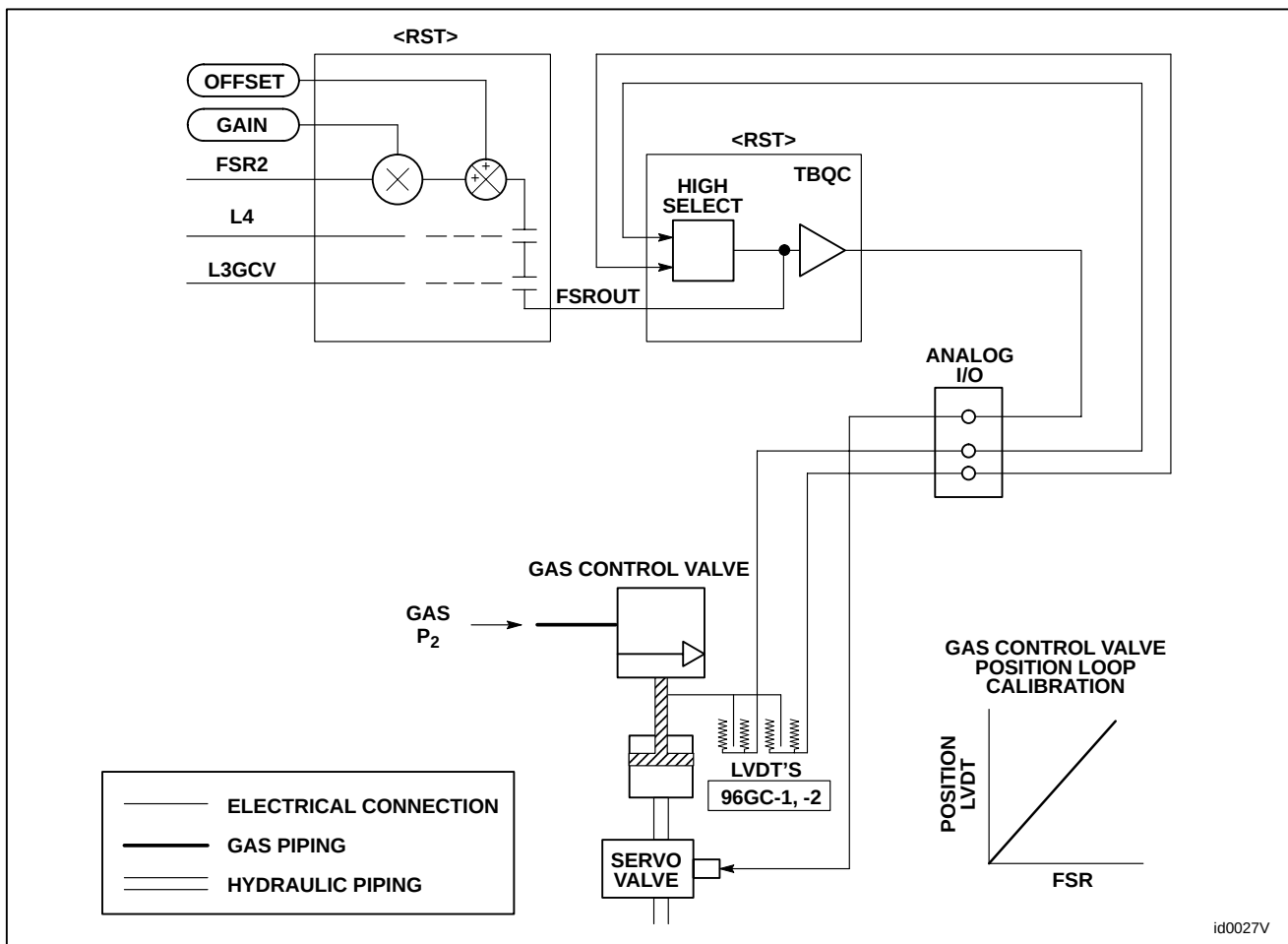
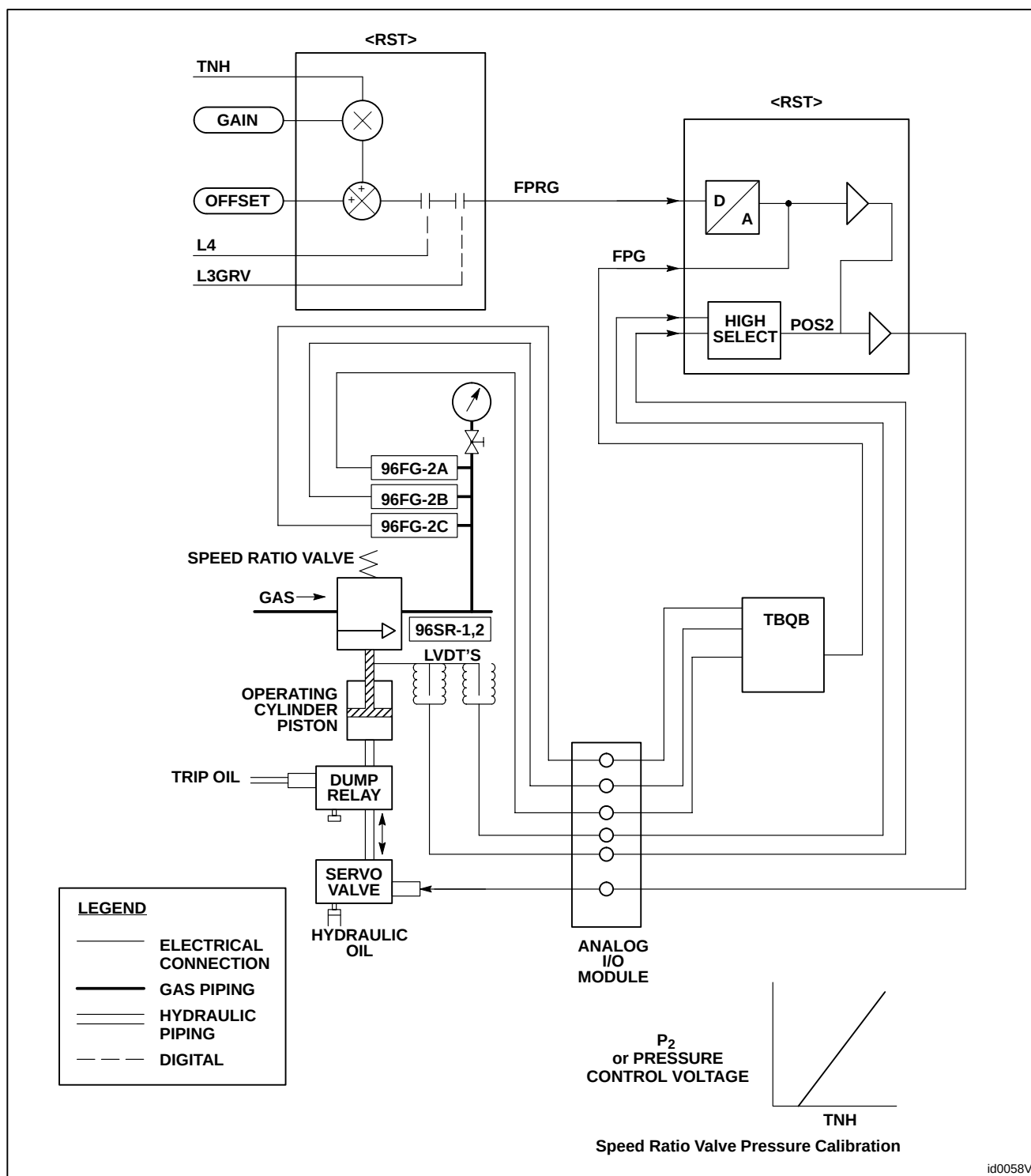


Figure 18 Gas Control Valve Control Schematic



id0058V

Figure 19 Speed Ratio/Stop Valve Control Schematic



The plug in the gas control valve is contoured to provide the proper flow area in relation to valve stroke. The gas control valve uses a skirted valve disc and venturi seat to obtain adequate pressure recovery. High pressure recovery occurs at overall valve pressure ratios substantially less than the critical pressure ratio. The net result is that flow through the control valve is independent of valve pressure drop. Gas flow then is a function of valve inlet pressure P_2 and valve area only.

As before, an open or a short circuit in one of the servo coils or in the signal to one coil does not cause a trip. The GCV has two LVDTs and can run correctly on one.

Speed Ratio/Stop Valve

The speed ratio/stop valve is a dual function valve. It serves as a pressure regulating valve to hold a desired fuel gas pressure ahead of the gas control valve and it also serves as a stop valve. As a stop valve it is an integral part of the protection system. Any emergency trip or normal shutdown will move the valve to its closed position shutting off gas fuel flow to the turbine. This is done either by dumping hydraulic oil from the Speed Ratio Valve VH-5 hydraulic trip relay or driving the position control closed electrically.

The speed ratio/stop valve has two control loops. There is a position loop similar to that for the gas control valve and there is a pressure control loop. See Figure 19. Fuel gas pressure P_2 at the inlet to the gas control valve is controlled by the pressure loop as a function of turbine speed. This is done by proportioning it to turbine speed signal TNH, with an offset and gain, which then becomes Gas Fuel Pressure Reference FPRG. FPRG then goes to the TCQC card to be converted to an analog signal. P_2 pressure is measured by 96FG which outputs a voltage proportional to P_2 pressure. This P_2 signal (FPG) is compared to the FPRG and the error signal (if any) is in turn compared with the 96SR LVDT feedback to reposition the valve as in the GCV loop.

The speed ratio/stop valve provides a positive stop to fuel gas flow when required by a normal shutdown, emergency trip, or a no-run condition. Hydraulic trip dump valve VH-5 is located between the electro-hydraulic servovalve 90SR and the hydraulic actuating cylinder. This dump valve is operated by the low pressure control oil trip system. If permissives L4 and L3GRV are 'true' the trip oil (OLT) is at normal pressure and the dump valve is maintained in a position that allows servovalve 90SR to control the cylinder position. When the trip oil pressure is low (as in the case of normal or emergency shutdown), the dump valve spring shifts a spool valve to a position which dumps the high pressure hydraulic oil (OH) in the speed ratio/stop valve actuating cylinder to the lube oil reservoir. The closing spring atop the valve plug instantly shuts the valve, thereby shutting off fuel flow to the combustors.

In addition to being displayed, the feedback signals and the control signals of both valves are compared to normal operating limits, and if they go outside of these limits there will be an alarm. The following are typical alarms:

1. L60FSGH: Excessive fuel flow on start-up
2. L3GRVFB: Loss of LVDT feedback on the SRV
3. L3GRVO: SRV open prior to permissive to open
4. L3GRVSC: Servo current to SRV detected prior to permissive to open
5. L3GCVFB: Loss of LVDT feedback on the GCV
6. L3GCVO: GCV open prior to permissive to open
7. L3GCVSC: Servo current to GCV detected prior to permissive to open
8. L3GFIVP: Intervall (P₂) pressure low

The servovalves are furnished with a mechanical null offset bias to cause the gas control valve or speed ratio valve to go to the zero stroke position (fail safe condition) should the servovalve signals or power be lost. During a trip or no-run condition, a positive voltage bias is placed on the servo coils holding them in the 'valve closed' position.



Dual Fuel Control

Turbines that are designed to operate on both liquid and gaseous fuel are equipped with controls to provide the following features:

1. Transfer from one fuel to the other on command.
2. Allow time for filling the lines with the type of fuel to which turbine operation is being transferred.
3. Mixed fuel operation.
4. Operation of liquid fuel nozzle purge when operating totally on gas fuel.

The software diagram for the fuel splitter is shown in Figure 20.

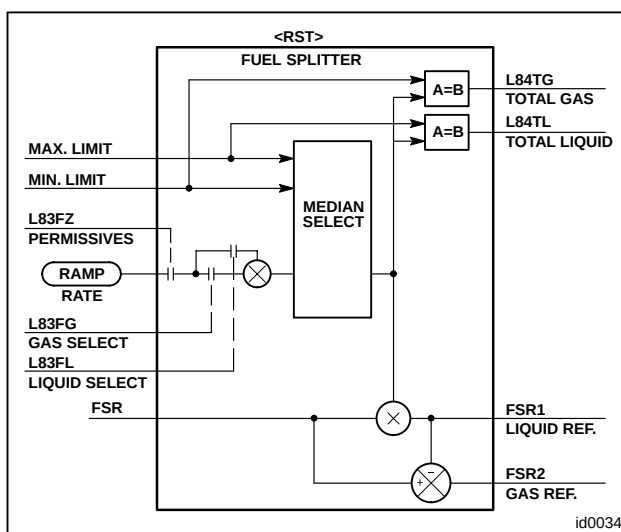


Figure 20 Fuel Splitter Schematic

Fuel Splitter

As stated before FSR is divided into two signals, FSR1 and FSR2, to provide dual fuel operation. See Figure 20.

FSR is multiplied by the liquid fuel fraction FX1 to produce the FSR1 signal. FSR1 is then subtracted from the FSR signal resulting in FSR2, the control signal for the secondary fuel.

Fuel Transfer – Liquid to Gas

If the unit is running on liquid fuel (FSR1) and the “GAS” membrane switch is pressed to select gas fuel, the following sequence of events will take place, providing the transfer and fuel gas permissives are true (refer to Figure 21):

FSR1 will remain at its initial value, but FSR2 will step to a value slightly greater than zero, usually 0.5%. This will open the gas control valve slightly to bleed down the intervalve volume. This is done in case a high pressure has been entrained. The presence of a higher pressure than that required by the speed/ratio controller would cause slow response in initiating gas flow.

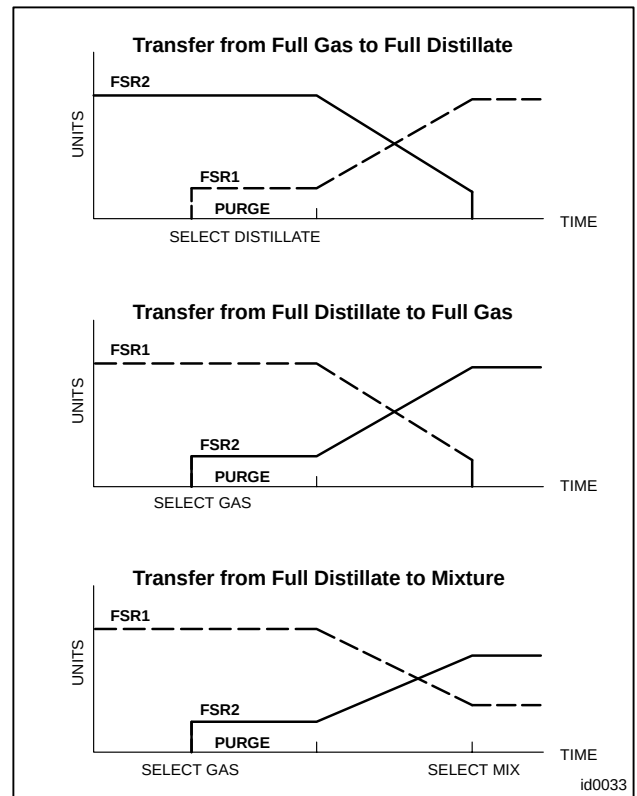


Figure 21 Fuel Transfer

After a typical time delay of thirty seconds to bleed down the P₂ pressure and fill the gas supply line, the software program ramps the fuel commands, FSR2 to increase and FSR1 to decrease, at a programmed rate through the median select gate. This is complete in thirty seconds.



When the transfer is complete logic signal L84TG (Total Gas) will disengage the fuel pump clutch 20CF, close the fuel oil stop valve by de-energizing the liquid fuel dump valve 20FL, and initiate the purge sequence.

Liquid Fuel Purge

To prevent coking of the liquid fuel nozzles while operating on gas fuel, some atomizing air is diverted through the liquid fuel nozzles. See Figure 22. The following sequence of events occurs when transfer from liquid to gas is complete.

The atomizing air bypass valve VA18 is opened by energizing 20AA. This results in a purge pressure ratio across the fuel nozzles of 1:1, resulting in a small volume of liquid fuel flow being purged into the combustors.

After a 10 second time delay which permits reaching steady state nozzle pressure ratio, purge valve VA19-1 is actuated by energizing solenoid valve 20PL-1. This results in a higher cooling/purging air flow through the liquid fuel nozzles.

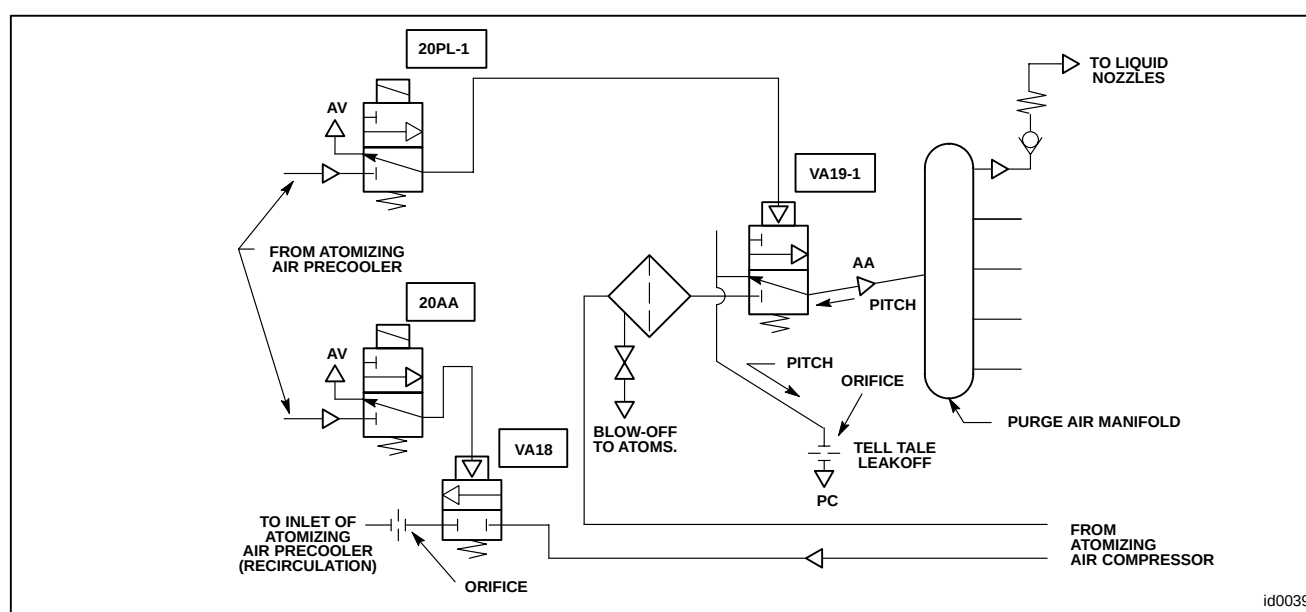


Figure 22 Dual Fuel Liquid Fuel Nozzle Purge System

The time delay is needed to reduce the load spike which occurs when the liquid fuel is purged into the combustion chamber.

Fuel Transfer – Gas to Liquid

Transfer from gas to liquid is essentially the same sequence as previously described, except that gas and liquid fuel command signals are interchanged. For instance, at the beginning of a transfer, FSR2 remains at its initial value, but FSR1 steps to a value slightly greater than zero. This will command a small liquid fuel flow. If there has been any fuel leakage out past the check valves, this will fill the liquid

fuel piping and avoid any delay in delivery at the beginning of the FSR1 increase.

The rest of the sequence is the same as liquid-to-gas, except that there is usually no purging sequence.

Mixed Fuel Operation

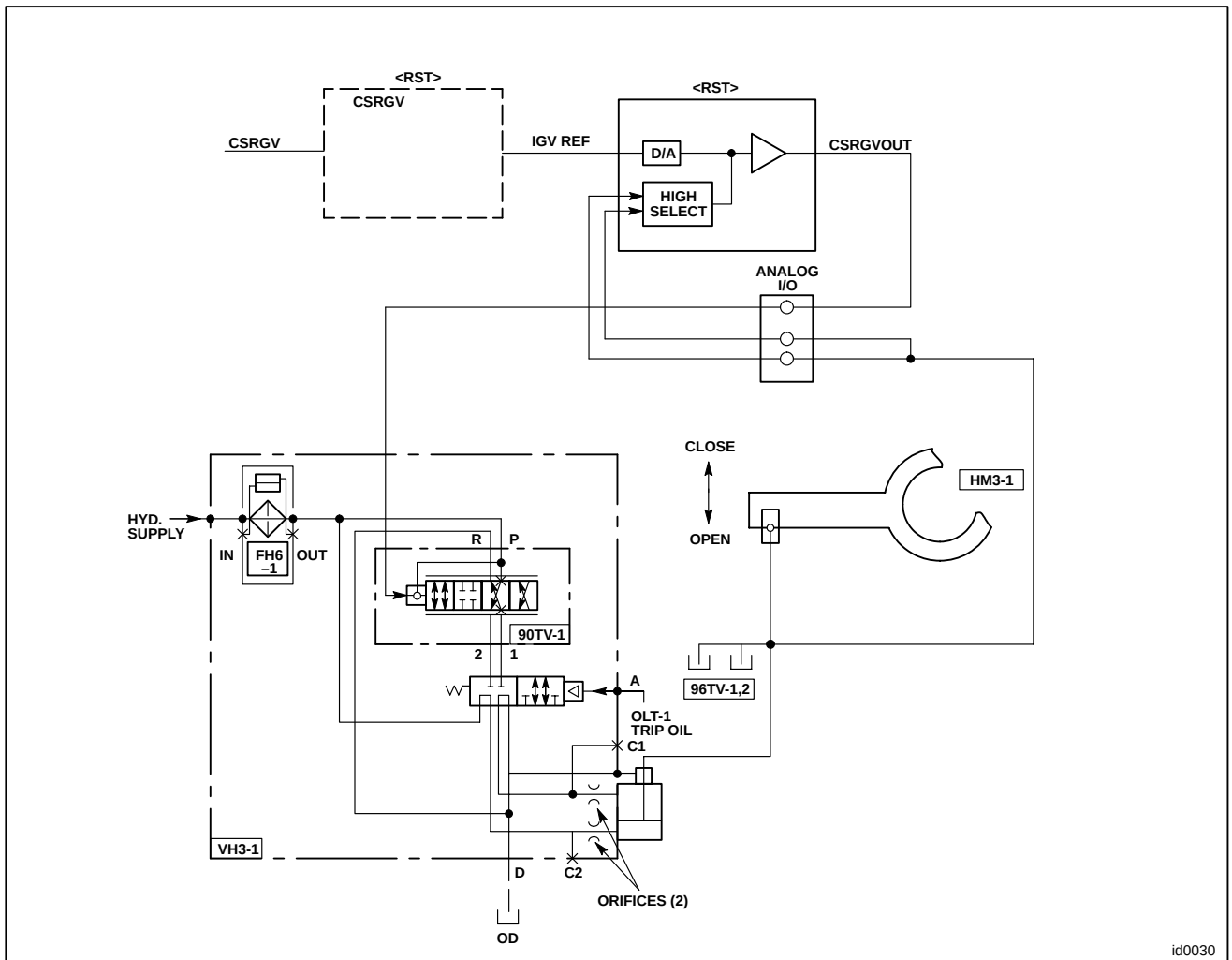
Gas turbines may be operated on a mixture of liquid and gas fuel. Operation on a selected mixture is obtained by entering the desired mixture at the operator interface and then selecting 'MIX'.

Limits on the fuel mixture are required to ensure proper combustion, gas fuel distribution, and gas nozzle flow velocities. Percentage of gas flow must



ing and unloading of the generator, and deceleration of the gas turbine. This IGV modulation maintains proper flows and pressures, and thus stresses, in the compressor, maintains a minimum pressure drop across the fuel nozzles, and, when used in a combined cycle application, maintains high exhaust temperatures at low loads.

The Inlet Guide Vanes (IGVs) modulate during the acceleration of the gas turbine to rated speed, load-



The modulated inlet guide vane actuating system is comprised of the following components: servovalve 90TV, LVDT position sensors 96TV-1 and

96TV-2, and, in some instances, solenoid valve 20TV and hydraulic dump valve VH3. Control of 90TV will port hydraulic pressure to operate the variable inlet guide vane actuator. If used, 20TV and VH3 can prevent hydraulic oil pressure from flowing to 90TV. See Figure 23.



Operation

During start-up, the inlet guide vanes are held fully closed, a nominal 34 degree angle, from zero to 83.5% corrected speed. Turbine speed is corrected to reflect air conditions at 80° F; this compensates for changes in air density as ambient conditions change. At ambient temperatures greater than 80° F, corrected speed TNHCR is less than actual speed TNH; at ambients less than 80° F, TNHCR is greater than TNH. After attaining a speed of approximately 83.5%, the guide vanes will modulate open at about 6.7 degrees per percent increase in corrected speed. When the guide vanes reach the minimum full speed angle, nominally 57°, they stop opening; this is usually at approximately 91% TNH. By not allowing the guide vanes to close to an angle less than the minimum full speed angle at 100% TNH, a minimum pressure drop is maintained across the fuel nozzles, thereby lessening combustion system resonance. Solenoid valve 20CB is usually opened when the generator breaker is closed; this in turn closes the compressor bleed valves.

As the unit is loaded and exhaust temperature increases, the inlet guide vanes will go to the full open position when the exhaust temperature reaches one of two points, depending on the operation mode selected. For simple cycle operation, the IGVs move to the full open position at a pre-selected exhaust temperature, usually 700° F. For combined cycle operation, the IGVs begin to move to the full open position as exhaust temperature approaches the temperature control reference temperature; normally, the IGVs begin to open when exhaust temperature is within 30° F of the temperature control reference.

During a normal shutdown, as the exhaust temperature decreases the IGVs move to the minimum full speed angle; as the turbine decelerates from 100% TNH, the inlet guide vanes are modulated to the fully closed position. When the generator breaker opens, the compressor bleed valves will be opened.

In the event of a turbine trip, the compressor bleed valves are opened and the inlet guide vanes go to the

fully closed position. The inlet guide vanes remain fully closed as the turbine continues to coast down.

For underspeed operation, if TNHCR decreases below approximately 91%, the inlet guide vanes modulate closed at 6.7 degrees per percent decrease in corrected speed. In most cases, the MS5001 being an exception, if the actual speed decreases below 95% TNH, the generator breaker will open and the turbine speed setpoint will be reset to 100.3%. The IGVs will then go to the minimum full speed angle. See Figure 24.

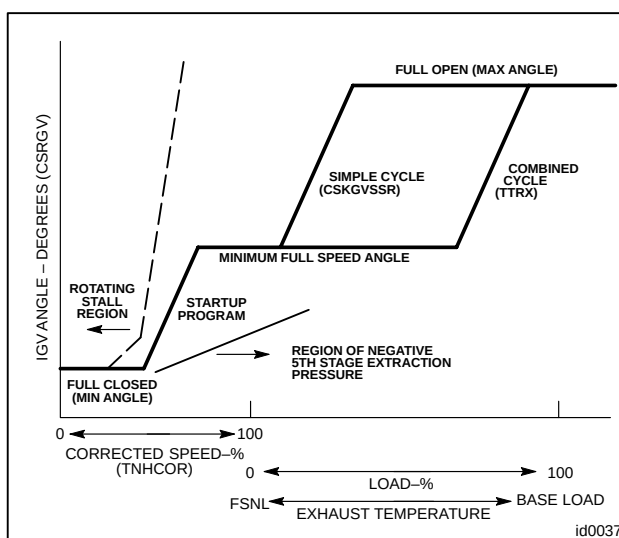


Figure 24 Variable Inlet Guide Vane Schedule

PROTECTION SYSTEMS

The gas turbine protection system is comprised of a number of sub-systems, several of which operate during each normal start-up and shutdown. The other systems and components function strictly during emergency and abnormal operating conditions. The most common kind of failure on a gas turbine is the failure of a sensor or sensor wiring; the protection systems are set up to detect and alarm such a failure. If the condition is serious enough to disable the protection completely, the turbine will be tripped.

Protective systems respond to the simple trip signals such as pressure switches used for low lube oil pressure, high gas compressor discharge pressure, or similar indications. They also respond to more com-



plex parameters such as overspeed, overtemperature, high vibration, combustion monitor, and loss of flame. To do this, some of these protection systems and their components operate through the master control and protection circuit in the SPEEDTRONIC control system, while other totally mechanical systems operate directly on the components of the

turbine. In each case there are two essentially independent paths for stopping fuel flow, making use of both the fuel control valve (FCV) and the fuel stop valve (FSV). Each protective system is designed independent of the control system to avoid the possibility of a control system failure disabling the protective devices. See Figure 25.

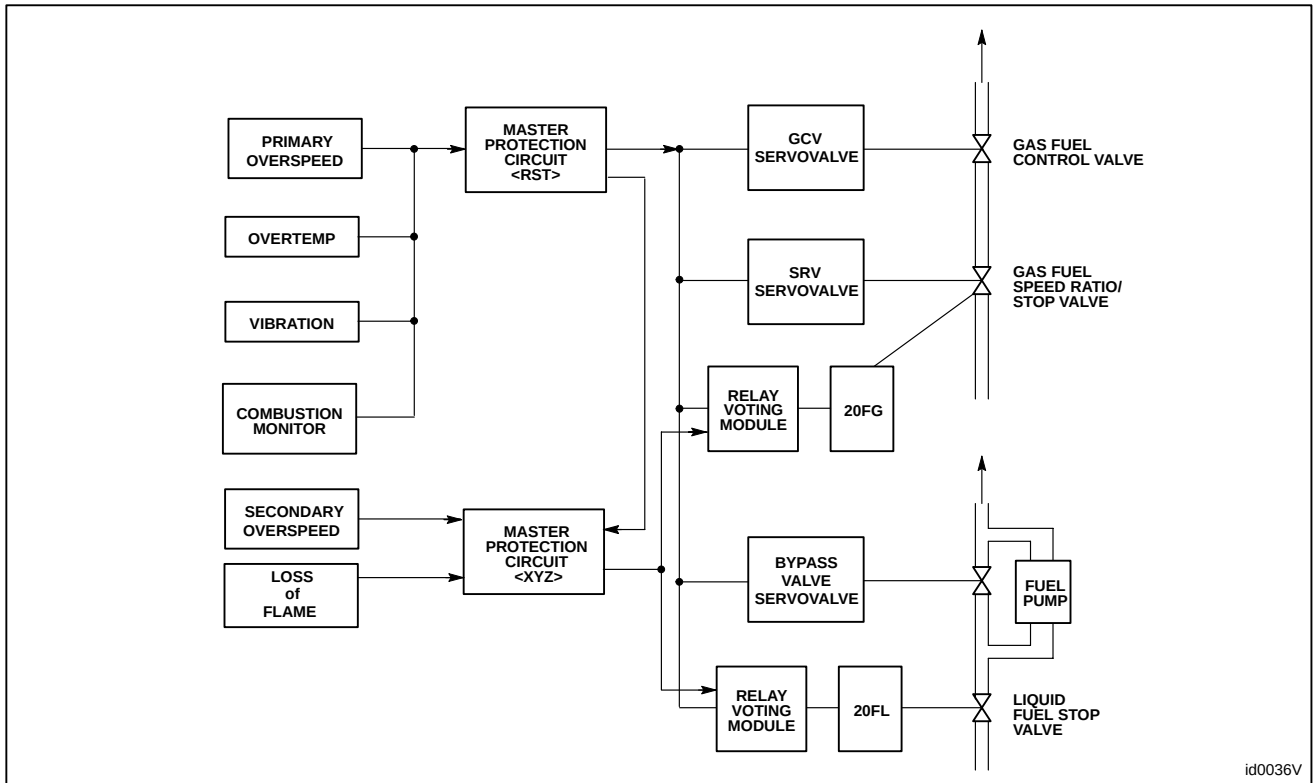


Figure 25 Protective Systems Schematic

Trip Oil

A hydraulic trip system called Trip Oil is the primary protection interface between the turbine control and protection system and the components on the turbine which admit, or shut-off, fuel. The system contains devices which are electrically operated by SPEEDTRONIC control signals as well as some totally mechanical devices.

Besides the tripping functions, trip oil also provides a hydraulic signal to the fuel stop valves for normal start-up and shutdown sequences. On gas turbines equipped for dual fuel (gas and oil) operation the

system is used to selectively isolate the fuel system not required.

Significant components of the Hydraulic Trip Circuit are described below.

Mechanical Overspeed Trip

This is a totally mechanical device located in the accessory gearbox and is actuated automatically by the overspeed bolt if the unit's speed exceeds the bolt's setting. The result is a rapid decay of trip oil pressure which stops all fuel flow to the unit. See Figure 26 and the Overspeed Protection System.



Inlet Orifice

An orifice is located in the line running from the bearing header supply to the trip oil system. This orifice is sized to limit the flow of oil from the lube oil system into the trip oil system. It must ensure adequate capacity for all tripping devices, yet prevent reduction of lube oil flow to the gas turbine and other equipment when the trip system is in the tripped state.

Dump Valve

Each individual fuel branch in the trip oil system has a solenoid dump valve (20FL for liquid, 20FG for gas). This device is a solenoid-operated spring-return spool valve which will relieve trip oil pressure only in the branch that it controls. These valves are normally energized-to-run, deenergized-to-trip. This philosophy protects the turbine during all normal situations as well as that time when loss of dc power occurs.

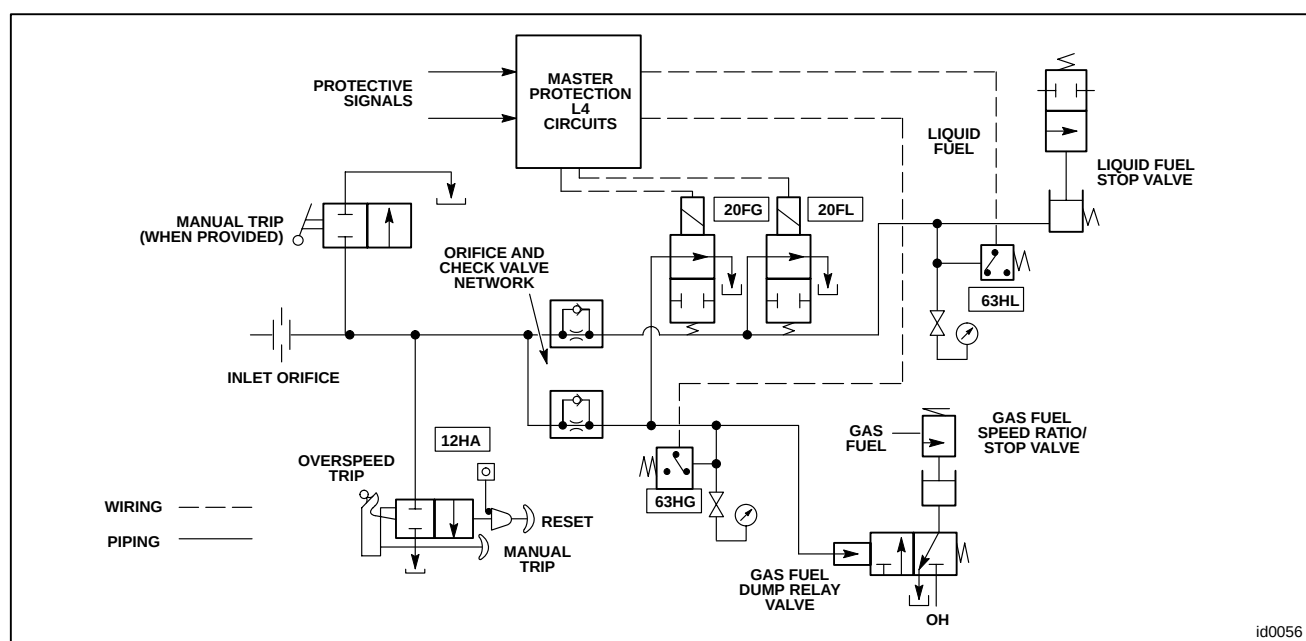


Figure 26 Trip Oil Schematic – Dual Fuel

Check Valve & Orifice Network

At the inlet of each individual fuel branch is a check valve and orifice network which limits flow out of that branch. This network limits flow into each branch, thus allowing individual fuel control without total system pressure decay. However, when one of the trip devices located in the main artery of the system, e.g., the overspeed trip, is actuated, the check valve will open and result in decay of all trip pressures.

Pressure Switches

Each individual fuel branch contains pressure switches (63HL-1,-2,-3 for liquid, 63HG-1,-2,-3

for gas) which will ensure tripping of the turbine if the trip oil pressure becomes too low for reliable operation while operating on that fuel.

Operation

The tripping devices which cause unit shutdown or selective fuel system shutdown do so by dumping the low pressure trip oil (OLT). See Figure 26. An individual fuel stop valve may be selectively closed by dumping the flow of trip oil going to it. Solenoid valve 20FL can cause the trip valve on the liquid fuel stop valve to go to the trip state, which permits closure of the liquid fuel stop valve by its spring return mechanism. Solenoid valve 20FG can cause the trip valve on the gas fuel speed ratio/stop valve to go to



the trip state, permitting its spring–returned closure. The orifice in the check valve and orifice network permits independent dumping of each fuel branch of the trip oil system without affecting the other branch. Tripping all devices other than the individual dump valves will result in dumping the total trip oil system, which will shut the unit down.

During start–up or fuel transfer, the SPEEDTRON-IC control system will close the appropriate dump valve to activate the desired fuel system(s). Both dump valves will be closed only during fuel transfer or mixed fuel operation.

The dump valves are de–energized on a “2–out–of–3 voted” trip signal from the relay module. This helps prevent trips caused by faulty sensors or the failure of one controller.

The signal to the fuel system servovalves will also be a “close” command should a trip occur. This is done by clamping FSR to zero. Should one controller fail, the FSR from that controller will be zero. The output of the other two controllers is sufficient to continue to control the servovalve.

By pushing the Emergency Trip Button, 5E P/B, the P28 vdc power supply is cut off to the relays controlling solenoid valves 20FL and 20FG, thus de–energizing the dump valves.

Overspeed Protection

The SPEEDTRONIC Mark V overspeed system is designed to protect the gas turbine against possible damage caused by overspeeding the turbine rotor. Under normal operation, the speed of the rotor is controlled by speed control. The overspeed system would not be called on except after the failure of other systems.

The overspeed protection system consists of a primary and secondary electronic overspeed system. The primary electronic overspeed protection system resides in the <RST> controllers. The secondary electronic overspeed protection system resides in the <XYZ> controllers. Both systems consist of magnetic pickups to sense turbine speed, speed

detection software, and associated logic circuits and are set to trip the unit at 110% rated speed.

There is also a mechanical overspeed protection system on all units except for F–model heavy–duty and aero–derivatives. This consists of the overspeed bolt assembly in an accessory gear shaft and the overspeed trip mechanism. This system should be set to trip the unit at 112.5% rated speed. All systems operate to trip the fuel stop valves and, redundantly, drive the FSR command to zero.

Electronic Overspeed Protection System

The electronic overspeed protection function is performed in both <RST> and <XYZ> as shown in Figure 27. The turbine speed signal (TNH) derived from the magnetic pickup sensors (77NH–1, –2, and –3) is compared to an overspeed setpoint (TNKHOS). When TNH exceeds the setpoint, the overspeed trip signal (L12H) is transmitted to the master protective circuit to trip the turbine and the “ELECTRICAL OVERSPEED TRIP” message will be displayed on the CRT. This trip will latch and must be reset by the master reset signal L86MR.

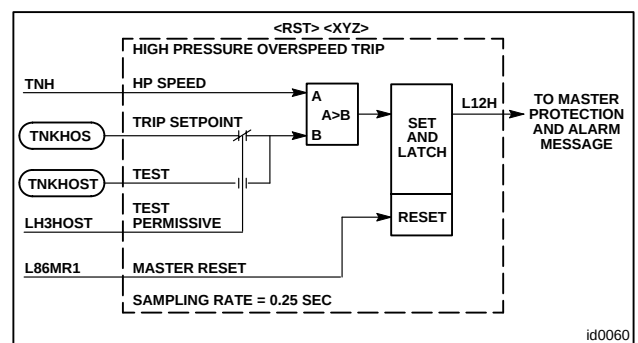


Figure 27 Electronic Overspeed Trip

Mechanical Overspeed Protection System

The mechanical overspeed protection system consists of the following principal components:

1. Overspeed bolt assembly in the accessory gear shaft
2. Overspeed trip mechanism in the accessory gear
3. Position limit switch 12HA

The mechanical overspeed protection system is the backup for the electronic overspeed protection sys-



tem. As the backup system, the trip speed setting is higher than the primary or electronic overspeed protection setting. For the most part the mechanical overspeed protection system is an integral part of the gas turbine unit and will trip the fuel stop valves closed when the turbine speed is at, or exceeds, the trip setting of the overspeed bolt assembly. This trip action is totally independent of the electronic connections in the turbine control panel. Whenever this trip is actuated an alarm will occur.

Overspeed Bolt Assembly

An overspeed bolt assembly mounted in an accessory gear shaft is used to sense the overspeed of the gas turbine. It is a spring-loaded, eccentrically located bolt assembled in a cartridge and designed so that the spring force holds the bolt in the seated position until the trip speed is reached. As the shaft speed increases, centrifugal force acting on the bolt is balanced by the spring force within the bolt assembly and the bolt remains seated. Further increase of the shaft speed causes the centrifugal force on the bolt to exceed the spring force and the bolt moves outward in less than one shaft revolution where it contacts and trips the overspeed trip mechanism. The spring force can be adjusted so that the overspeed bolt will trip at a specified shaft speed.

Overspeed Trip Mechanism

The overspeed trip mechanism for the turbine shaft is also mounted in the accessory gear, adjacent to the overspeed bolt assembly. When actuated, the overspeed bolt assembly trips the latching trip finger of the overspeed trip mechanism. This action releases the trip valve in the mechanism and dumps the trip oil system pressure to drain, which in turn closes the trip valves controlling the fuel stop valves. This in turn dumps the hydraulic control oil from the stop valve actuating cylinders to drain, thus closing the valves. This also prevents hydraulic pressure from re-opening the valves. See Figure 28.

The overspeed trip mechanism may be tripped manually and must be reset manually. The trip button and the reset handle are mounted with the over-

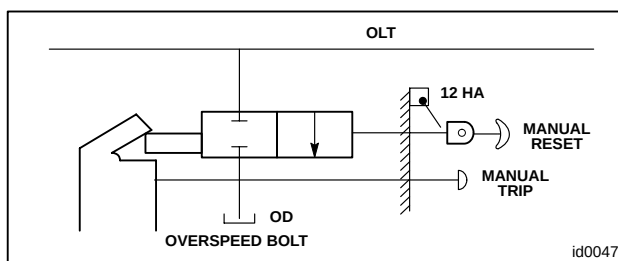


Figure 28 Mechanical Overspeed Trip
speed trip mechanism limit switch 12HA on the outside of the accessory gear.

Overtemperature Protection

The overtemperature system protects the gas turbine against possible damage caused by overfiring. It is a backup system, operating only after the failure of the temperature control system.

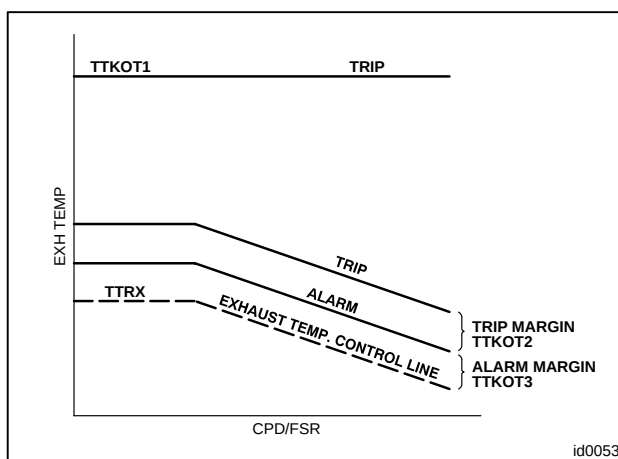


Figure 29 Overtemperature Protection

Under normal operating conditions, the exhaust temperature control system acts to control fuel flow when the firing temperature limit is reached. In certain failure modes however, exhaust temperature and fuel flow can exceed control limits. Under such circumstances the overtemperature protection system provides an overtemperature alarm about 25° F above the temperature control reference. To avoid further temperature increase, it starts unloading the gas turbine. If the temperature should increase further to a point about 40° F above the temperature control reference, the gas turbine is tripped. For the actual alarm and trip overtemperature setpoints refer to the Control Specifications. See Figure 29.



Overtemperature trip and alarm setpoints are determined from the temperature control setpoints derived by the Exhaust Temperature Control software. See Figure 30.

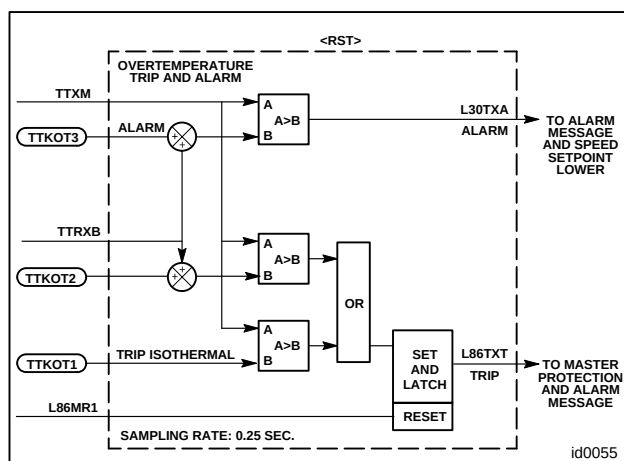


Figure 30 Overtemperature Trip and Alarm

Overtemperature Protection Software

Overtemperature Alarm (L30TXA)

The representative value of the exhaust temperature thermocouples (TTXM) is compared with alarm and trip temperature setpoints. The “EXHAUST TEMPERATURE HIGH” alarm message will be displayed when the exhaust temperature (TTXM) exceeds the temperature control reference (TTRXB) plus the alarm margin (TTKOT3) programmed as a Control Constant in the software. The alarm will automatically reset if the temperature decreases below the setpoint.

Overtemperature Trip (L86TXT)

An overtemperature trip will occur if the exhaust temperature (TTXM) exceeds the temperature control reference (TTRXB) plus the trip margin (TTKOT2), or if it exceeds the isothermal trip setpoint (TTKOT1). The overtemperature trip will latch, the “EXHAUST OVERTEMPERATURE TRIP” message will be displayed, and the turbine will be tripped through the master protection circuit. The trip function will be latched in and the master re-

set signal L86MR1 must be true to reset and unlatch the trip.

Flame Detection and Protection System

The SPEEDTRONIC Mark V flame detectors perform two functions, one in the sequencing system and the other in the protective system. During a normal start-up the flame detectors indicate when a flame has been established in the combustion chambers and allow the start-up sequence to continue. Most units have four flame detectors, some have two, and a very few have eight. Generally speaking, if half of the flame detectors indicate flame and half (or less) indicate no-flame, there will be an alarm but the unit will continue to run. If more than half indicate loss-of-flame, the unit will trip on “LOSS OF FLAME.” This avoids possible accumulation of an explosive mixture in the turbine and any exhaust heat recovery equipment which may be installed. The flame detector system used with the SPEEDTRONIC Mark V system detects flame by sensing ultraviolet (UV) radiation. Such radiation results from the combustion of hydrocarbon fuels and is more reliably detected than visible light, which varies in color and intensity.

The flame sensor is a copper cathode detector designed to detect the presence of ultraviolet radiation. The SPEEDTRONIC control will furnish up to +350Vdc to drive the ultraviolet detector tube. In the presence of ultraviolet radiation, the gas in the detector tube ionizes and conducts current. The current through the detector will discharge through circuitry in the SPEEDTRONIC control until the driving voltage decreases to the point where the gas is no longer ionized. This cycle continues as long as there is ultraviolet radiation. The SPEEDTRONIC counts the number of current pulses per second through the ultraviolet sensor. If the number of pulses per second exceeds a set threshold value, the SPEEDTRONIC generates a logic signal to indicate “FLAME DETECTED” by the sensor. Typically, there will be about 300 pulses/second when a strong ultraviolet signal is present.

The flame detector system is similar to other protective systems, in that it is self-monitoring. For exam-



ple, when the gas turbine is below L14HM all channels must indicate “NO FLAME.” If this condition is not met, the condition is annunciated as a “FLAME DETECTOR TROUBLE” alarm and the turbine cannot be started. After firing speed has been reached and fuel introduced to the machine, if at least half the flame detectors see flame the starting sequence is allowed to proceed. A failure of one detector will be annunciated as “FLAME DETECTOR TROUBLE” when complete sequence is reached

and the turbine will continue to run. More than half the flame detectors must indicate “NO FLAME” in order to trip the turbine.

Note that a short-circuited or open-circuited detector tube will result in a “NO FLAME” signal. The flame detection circuits are incorporated in the protective module <P> and is triple redundant, utilizing three channels called <X>, <Y>, and <Z>.

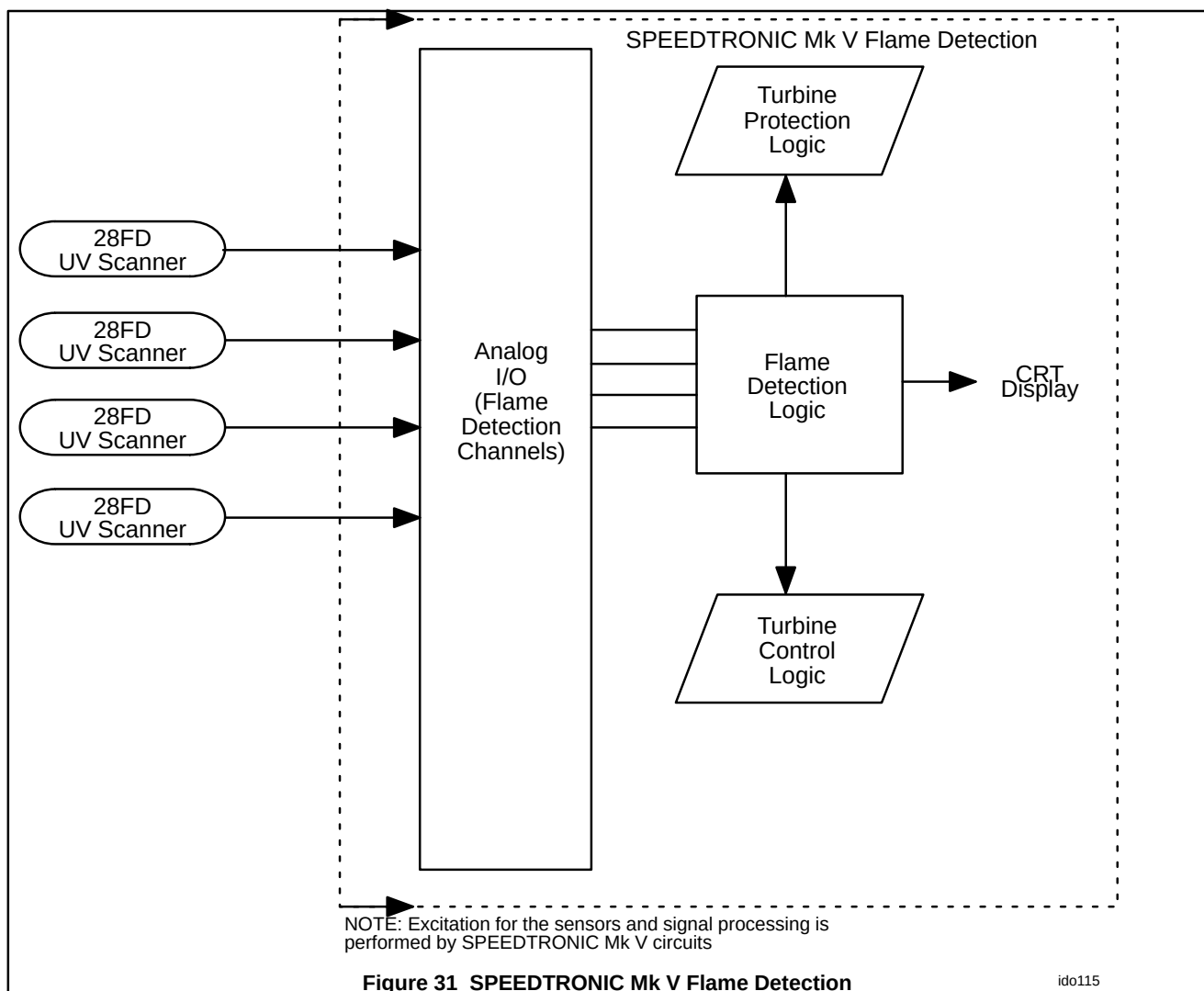


Figure 31 SPEEDTRONIC Mk V Flame Detection

ido115

Vibration Protection

The vibration protection system of a gas turbine unit is composed of several independent vibration chan-

nels. Each channel detects excessive vibration by means of a seismic pickup mounted on a bearing housing or similar location of the gas turbine and the driven load. If a predetermined vibration level is ex-



ceeded, the vibration protection system trips the turbine and annunciates to indicate the cause of the trip.

Each channel includes one vibration pickup (velocity type) and a SPEEDTRONIC Mark V amplifier circuit. The vibration detectors generate a relatively low voltage by the relative motion of a permanent magnet suspended in a coil and therefore no excitation is necessary. A twisted-pair shielded cable is used to connect the detector to the analog input/output module.

The pickup signal from the analog I/O module is inputted to the computer software where it is compared with the alarm and trip levels programmed as Control Constants. See Figure 32. When the vibration amplitude reaches the programmed trip set point, the channel will trigger a trip signal, the circuit will latch, and a “HIGH VIBRATION TRIP” message will be displayed. Removal of the latched trip condition can be accomplished only by depressing the master reset button (L86MR1) when vibration is not excessive.

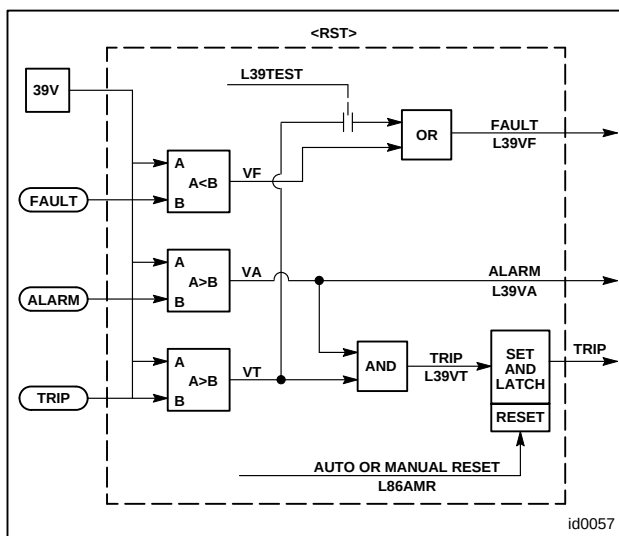


Figure 32 Vibration Protection

When the “VIBRATION TRANSDUCER FAULT” message is displayed and machine operation is not interrupted, either an open or shorted condition may be the cause. This message indicates that mainte-

nance or replacement action is required. By using the display keypad and CRT display, it is possible to monitor vibration levels of each channel while the turbine is running without interrupting operation.

Combustion Monitoring

The primary function of the combustion monitor is to reduce the likelihood of extensive damage to the gas turbine if the combustion system deteriorates. The monitor does this by examining the exhaust temperature thermocouples and compressor discharge temperature thermocouples. From changes that may occur in the pattern of the thermocouple readings, warning and protective signals are generated by the combustion monitor software to alarm and/or trip the gas turbine.

This means of detecting abnormalities in the combustion system is effective only when there is incomplete mixing as the gases pass through the turbine; an uneven turbine inlet pattern will cause an uneven exhaust pattern. The uneven inlet pattern could be caused by loss of fuel or flame in a combustor, a rupture in a transition piece, or some other combustion malfunction.

The usefulness and reliability of the combustion monitor depends on the condition of the exhaust thermocouples. It is important that each of the thermocouples is in good working condition.

Combustion Monitoring Software

The controllers contain a series of programs written to perform the monitoring tasks (See Combustion Monitoring Schematic Figure 33). The main monitor program is written to analyze the thermocouple readings and make appropriate decisions. Several different algorithms have been developed for this depending on the turbine model series and the type of thermocouples used. The significant program constants used with each algorithm are specified in the Control Specification for each unit.

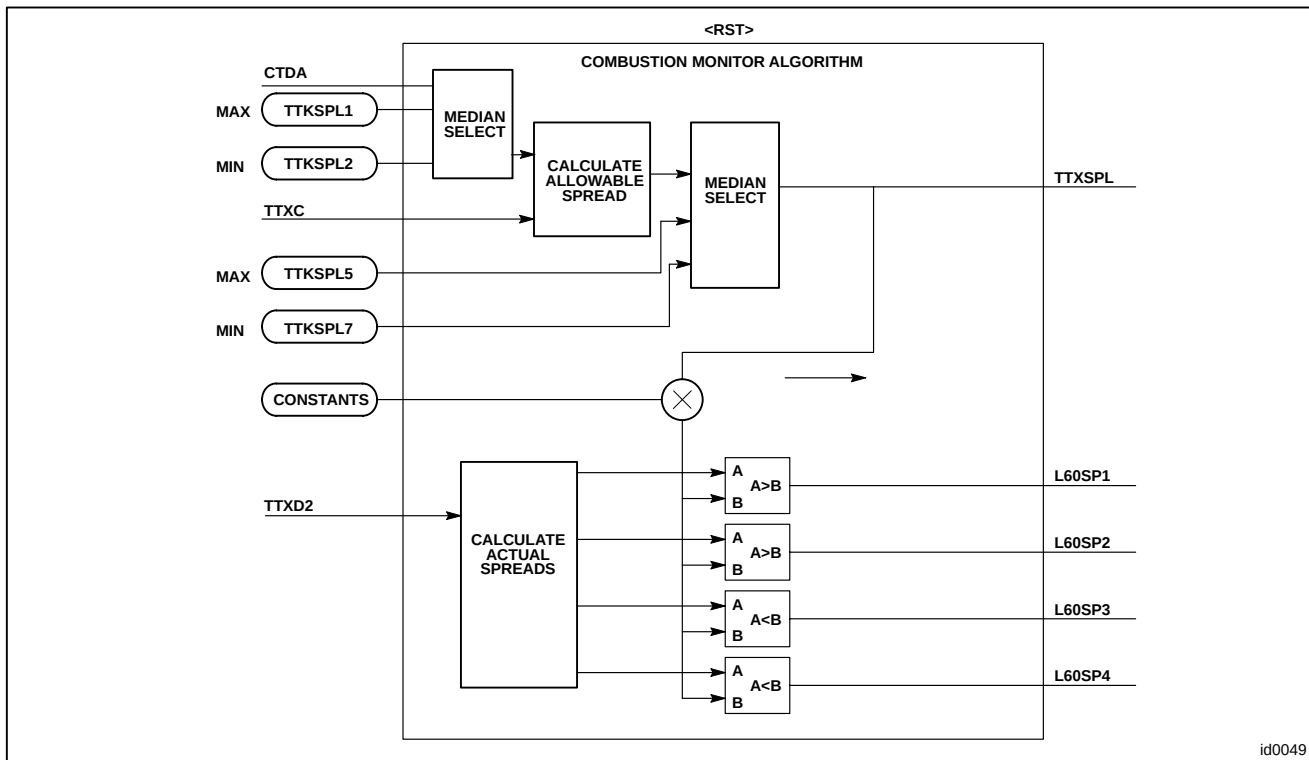


Figure 33 Combustion Monitoring Function Algorithm (Schematic)

The most advanced algorithm, which is standard for gas turbines with redundant sensors, makes use of the temperature spread and adjacency tests to differentiate between actual combustion problems and thermocouple failures. The behavior is summarized by the Venn diagram (Figure 34) where:

- SPREAD #1 (S_1): The difference between the highest and the lowest thermocouple reading
- SPREAD #2 (S_2): The difference between the highest and the 2nd lowest thermocouple reading
- SPREAD #3 (S_3): The difference between the highest and the 3rd lowest thermocouple reading

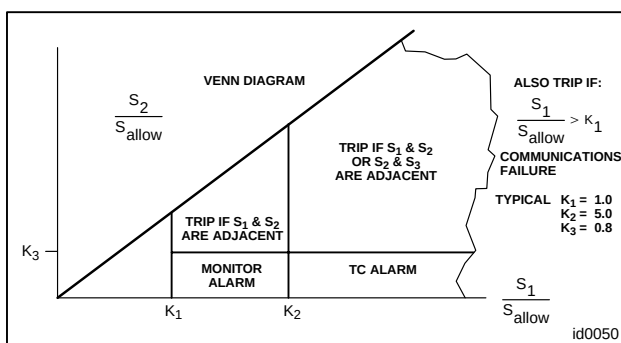


Figure 34 Exhaust Temperature Spread Limits

- S_{allow} is the “Allowable Spread”, based on average exhaust temperature and compressor discharge temperature.
- S_1 , S_2 and S_3 are defined as follows:

The allowable spread will be between the limits TTKSPL7 and TTKSPL6, usually 30° F and 125° F. The values of the combustion monitor program constants are listed in the Control Specifications.

The various <C> processor outputs to the CRT cause alarm message displays as well as appropriate control action. The combustion monitor outputs are:

Exhaust Thermocouple Trouble Alarm (L30SPTA)

If any thermocouple value causes the largest spread to exceed a constant (usually 5 times the allowable spread), a thermocouple alarm (L30SPTA) is pro-



duced. If this condition persists for four seconds, the alarm message “EXHAUST THERMOCOUPLE TROUBLE” will be displayed and will remain on until acknowledged and reset. This usually indicates a failed thermocouple, i.e., open circuit.

Combustion Trouble Alarm (L30SPA)

A combustion alarm can occur if a thermocouple value causes the largest spread to exceed a constant (usually the allowable spread). If this condition persists for three seconds, the alarm message “COMBUSTION TROUBLE” will be displayed and will remain on until it is acknowledged and reset.

High Exhaust Temperature Spread Trip (L30SPT)

A high exhaust temperature spread trip can occur if:

1. “COMBUSTION TROUBLE” alarm exists, the second largest spread exceeds a constant (usually 0.8 times the allowable spread), and the lowest and second lowest outputs are from adjacent thermocouples
2. “EXHAUST THERMOCOUPLE TROUBLE” alarm exists, the second largest spread exceeds a constant (usually 0.8 times the allowable spread), and the second and third lowest outputs are from adjacent thermocouples
3. the third largest spread exceeds a constant (usually the allowable spread) for a period of five minutes

If any of the trip conditions exist for 9 seconds, the trip will latch and “HIGH EXHAUST TEMPERATURE SPREAD TRIP” message will be displayed. The turbine will be tripped through the master protective circuit. The alarm and trip signals will be displayed until they are acknowledged and reset.

Monitor Enable (L83SPM)

The protective function of the monitor is enabled when the turbine is above 14HS and a shutdown signal has not been given. The purpose of the “enable” signal (L83SPM) is to prevent false action during normal start-up and shutdown transient conditions. When the monitor is not enabled, no new protective actions are taken. The combustion monitor will also be disabled during a high rate of change of FSR. This prevents false alarms and trips during large fuel and load transients.

The two main sources of alarm and trip signals being generated by the combustion monitor are failed thermocouples and combustion system problems. Other causes include poor fuel distribution due to plugged or worn fuel nozzles and combustor flameout due, for instance, to water injection.

The tests for combustion alarm and trip action have been designed to minimize false actions due to failed thermocouples. Should a controller fail, the thermocouples from the failed controller will be ignored (similar to temperature control) so as not to give a false trip.



GE Power Systems Training

*General Electric Company
One River Road
Schenectady, NY 12345*

SPEEDTRONIC™ MARK V GAS TURBINE CONTROL SYSTEM

D. Johnson and R.W. Miller
GE Drive Systems
Salem, VA

T. Ashley
GE Power Systems
Schenectady, NY

INTRODUCTION

The SPEEDTRONIC™ Mark V Gas Turbine Control System is the latest derivative in the highly successful SPEEDTRONIC™ series. Preceding systems were based on automated turbine control, protection and sequencing techniques dating back to the late 1940s, and have grown and developed with the available technology. Implementation of electronic turbine control, protection and sequencing originated with the Mark I system in 1968. The Mark V system is a digital implementation of the turbine automation techniques learned and refined in more than 40 years of successful experience, over 80% of which has been through the use of electronic control technology.

The SPEEDTRONIC™ Mark V Gas Turbine Control System employs current state-of-the-art technology, including triple-redundant 16-bit microprocessor controllers, two-out-of-three voting redundancy on critical control and protection parameters and Software-Implemented Fault Tolerance (SIFT). Critical control and protection sensors are triple redundant and voted by all three control processors. System output signals are voted at the contact level for critical solenoids, at the logic level for the remaining contact outputs and at three coil servo valves for analog control signals, thus maximizing both protective and running reliability. An independent protective module provides triple redundant hardwired detection and shutdown on overspeed along with detecting flame. This module also synchronizes the turbine generator to the power system. Synchronization is backed up by a check function in the three control processors.

The Mark V Control System is designed to fulfill all gas turbine control requirements. These include control of liquid, gas or both fuels in accordance with the requirements of the speed, load control under part-load conditions, temperature control under maximum capability conditions or during startup conditions. In addition, inlet guide vanes and water or steam injection are controlled to meet emissions and operating requirements. If emissions control uses

Dry Low NO_x techniques, fuel staging and combustion mode are controlled by the Mark V system, which also monitors the process. Sequencing of the auxiliaries to allow fully automated startup, shutdown and cooldown are also handled by the Mark V Control System. Turbine protection against adverse operating situations and annunciation of abnormal conditions are incorporated into the basic system.

The operator interface consists of a color graphic monitor and keyboard to provide feedback regarding current operating conditions. Input commands from the operator are entered using a cursor positioning device. An arm/execute sequence is used to prevent inadvertent turbine operation. Communication between the operator interface and the turbine control is through the Common Data Processor, or <C>, to the three control processors called <R>, <S> and <T>. The operator interface also handles communication functions with remote and external devices. An optional arrangement, using a redundant operator interface, is available for those applications where integrity of the external data link is considered essential to continued plant operations. SIFT technology protects against module failure and propagation of data errors. A panel mounted back-up operator display, directly connected to the control processors, allows continued gas turbine operation in the unlikely event of a failure of the primary operator interface or the <C> module.

Built-in diagnostics for troubleshooting purposes are extensive and include "power-up," background and manually initiated diagnostic routines capable of identifying both control panel and sensor faults. These faults are identified down to the board level for the panel and to the circuit level for the sensor or actuator components. The ability for on-line replacement of boards is built into the panel design and is available for those turbine sensors where physical access and system isolation are feasible. Set points, tuning parameters and control constants are adjustable during operation using a security password system to prevent unauthorized access. Minor modifications to sequencing and the addition of relatively simple algorithms can be

accomplished when the turbine is not operating. They are also protected by a security password.

A printer is included in the control system and is connected via the operator interface. The printer is capable of copying any alpha-numeric display shown on the monitor. One of these displays is an operator configurable demand display that can be automatically printed at a selectable interval. It provides an easy means to obtain periodic and shift logs. The printer automatically logs time-tagged alarms, as well as the clearance of alarms. In addition, the printer will print the historical trip log that is frozen in memory in the unlikely event of a protective trip. The log assists in identifying the cause of a trip for trouble shooting purposes.

The statistical measures of reliability and availability for SPEEDTRONIC™ Mark V systems have quickly established the effectiveness of the new control because it builds on the highly successful SPEEDTRONIC™ Mark IV system. Improvements in the new design have been made in microprocessors, I/O capacity, SIFT technology, diagnostics, standardization and operator information, along with continued application flexibility and careful design for maintainability. SPEEDTRONIC™ Mark V control is achieving greater reliability, faster mean-time-to-repair and improved control system availability than the SPEEDTRONIC™ Mark IV applications.

As of May 1994, almost 264 Mark V systems had entered commercial service and system operation has exceeded 1.4 million hours. The established Mark V level of system reliability, including sensors and actuators, exceeds 99.9 percent, and the fleet mean-time-between-forced-outages (MTBFO) stands at 28,000 hours. As of May 1994, there were 424 gas turbine Mark V systems and 106 steam turbine Mark V systems shipped or on order.

CONTROL SYSTEM HISTORY

The gas turbine was introduced as an industrial and utility prime mover in the late 1940s with initial applications in gas pipeline pumping and utility peaking. The early control systems were based on hydro-mechanical steam turbine governing practice, supplemented by a pneumatic temperature control, preset startup fuel limiting and manual sequencing. Independent devices provided protection against overspeed, overtemperature, fire, loss of flame, loss of lube oil and high vibration.

Through the early years of the industry, gas turbine control designs benefited from the

rapid growth in the field of control technology. The hydro-mechanical design culminated in the "fuel regulator" and automatic relay sequencing for automatic startup, shutdown and cooldown where appropriate for unattended installations. The automatic relay sequencing, in combination with rudimentary annunciator monitoring, also allowed interfacing with SCADA (Supervisory Control and Data Acquisition) systems for true continuous remote control operation.

This was the basis for introduction of the first electronic gas turbine control in 1968. This system, ultimately known as the SPEEDTRONIC™ Mark I Control, replaced the fuel regulator, pneumatic temperature control and electro-mechanical starting fuel control with an electronic equivalent. The automatic relay sequencing was retained and the independent protective functions were upgraded with electronic equivalents where appropriate. Because of its electrically dependent nature, emphasis was placed on integrity of the power supply system, leading to a DC-based system with AC- and shaft-powered back-ups. These early electronic systems provided an order of magnitude increase in running reliability and maintainability.

Once the changeover to electronics was achieved, the rapid advances in electronic system technology resulted in similar advances in gas turbine control technology (Table 1). Note that more than 40 years of gas turbine control experience has involved more than 5,400 units, while the 26 years of electronic control experience has been centered on more than 4,400 turbine installations. Throughout this time period, the control philosophy shown in Table 2 has developed and matured to match the capabilities of the existing technology. This philosophy emphasizes safety of operation, reliability, flexibility, maintainability and ease of use, in that order.

CONTROL SYSTEM FUNCTIONS

The SPEEDTRONIC™ Gas Turbine Control System performs many functions including fuel, air and emissions control; sequencing of turbine fuel and auxiliaries for startup, shutdown and cooldown; synchronization and voltage matching of the generator and system; monitoring of all turbine, control and auxiliary functions; and protection against unsafe and adverse operating conditions. All of these functions are performed in an integrated manner that is tailored to achieve the previously described philosophy in

Table 1
ADVANCES IN ELECTRONIC CONTROL CONCEPTS

System Type	Mark I	Mark II	Mark II ITS	Mark IV	Mark V
Introduced	1966	1973	1976	1982	1991
Total Shipped	850	1825	356	1080	530
Sequencing	Relays	Discrete Solid State Components		TMR Micro-processor	TMR Micro-processor
Control	Discrete Solid State	Integrated Circuits	I.C.s & Micro-processor	TMR Micro-processor	TMR Micro-processor
Protection	Relays	Relays & Solid State	I.C.s & Micro-processor	TMR Micro-processor	Independent TMR Micro-processor
Display	Analog Meters & Relay Annunciator	Analog and Digital Meters; Solid State Annunciator		CRT & LED Aux. Display	VGA Color Graphics
Input	Pushbuttons and Bat Handle Switches			Membrane Switches	Keyboard and/or CPD
Fault Tolerance	Manually Rejectable Failed Exhaust Thermocouples		Automatically Rejected Failed T.C.s	Hardware-based	SIFT

the stated priority.

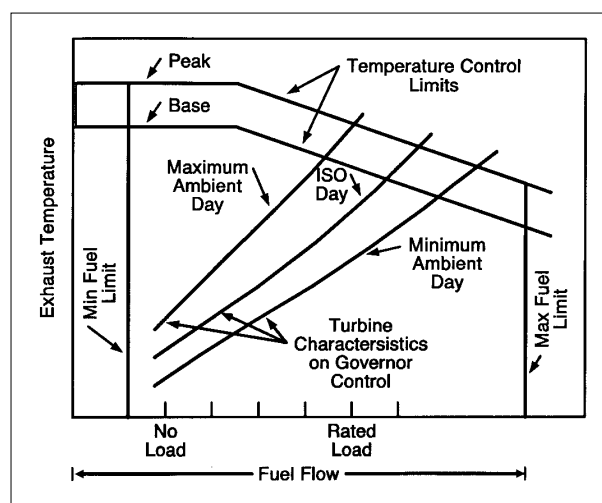
The speed and load control function acts to control the fuel flow under part-load conditions to satisfy the needs of the governor. Temperature control limits fuel flow to a maximum consistent with achieving rated firing temperatures and controls air flow via the inlet guide vanes to optimize part-load heat rates on heat recovery applications. The operating limits of the fuel control are shown in Figure 1. A block diagram of the fuel, air and emissions control systems is shown in Figure 2. The input to the system is the operator command for speed

(when separated from the grid) or load (when connected). The outputs are the commands to the gas and liquid fuel control systems, the inlet guide vane positioning system and the emissions control system. A more detailed discussion of the control functionality required by the gas turbine may be found in Reference 1.

The fuel command signal is passed to the gas and liquid fuel systems via the fuel signal divider in accordance with the operator's fuel selection. Startup can be on either fuel and transfers

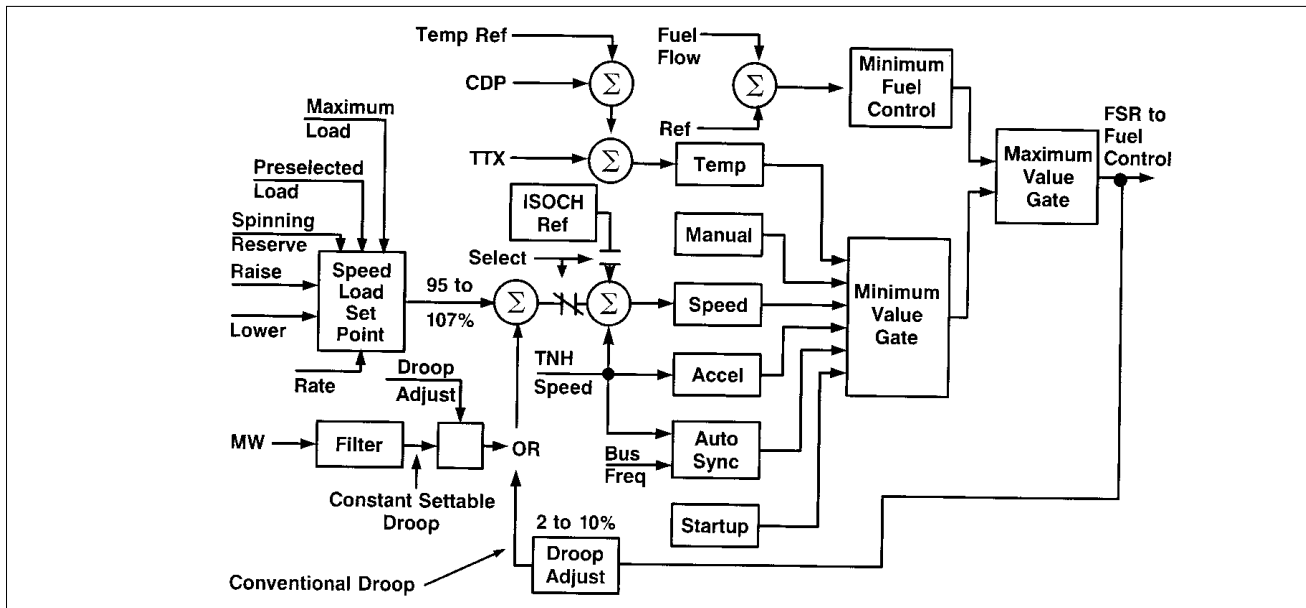
Table 2
GAS TURBINE CONTROL PHILOSOPHY

- Single control failure alarms when running or during startup
- Protection backs up control, thus independent
- Two independent means of shutdown will be available
- Double failure may cause shutdown, but will always result in safe shutdown
- Generator-drive turbines will tolerate full-load rejection without overspeeding
- Critical sensors are redundant
- Control is redundant
- Alarm any control system problems
- Standardize hardware and software to enhance reliability while maintaining flexibility



GT17610B

Figure 1. Gas turbine generator controls and limits



GT17603B

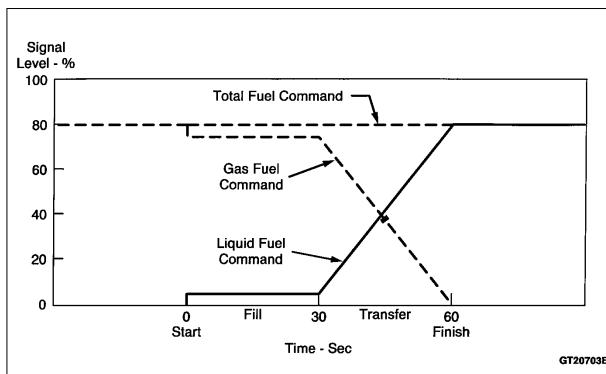
Figure 2. Gas turbine fuel control

under load are accomplished by transitioning from one system to the other after an appropriate fill time to minimize load excursions. System characteristics during a transfer from gas to liquid fuel are illustrated in Figure 3. Purging of the idle fuel system is automatic and continuously monitored to ensure proper operation. Transfer can be automatically initiated on loss of supply of the running fuel, which will be alarmed, and will proceed to completion without operator intervention. Return to the original fuel is manually initiated.

The gas fuel control system is shown schematically in Figure 4. It is a two-stage system, incorporating a pressure control proportional to speed and a flow control proportional to fuel command. Two stages provide a stable turn-down ratio in excess of 100:1, which is more than adequate for control under starting and

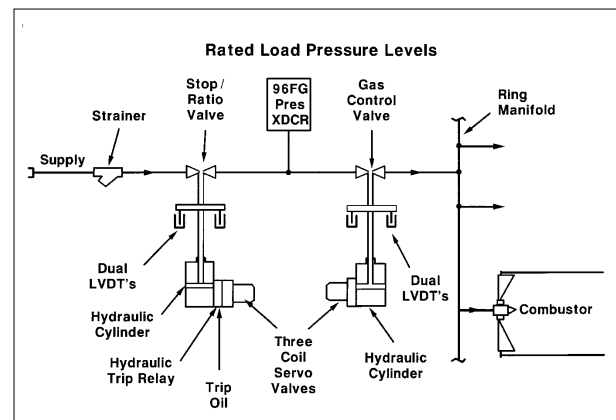
warm-up conditions, as well as maximum flow for peak output at minimum ambient temperature. The stop/speed ratio valve also acts as an independent stop valve. It is equipped with an interposed, hydraulically-actuated trip relay that can trip the valve closed independent of control signals to the servo valve. Both the stop ratio and control valves are hydraulically actuated, single-acting valves that will fail to the closed position on loss of either signal or hydraulic pressure. Fuel distribution to the gas fuel nozzles in the multiple combustors is accomplished by a ring manifold in conjunction with careful control of fuel nozzle flow areas.

The liquid fuel control system is shown schematically in Figure 5. Since the fuel pump is a positive displacement pump, the system achieves flow control by recirculating excess fuel



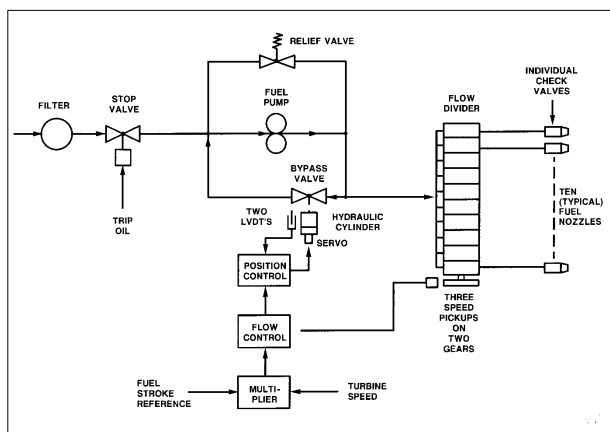
GT20703B

Figure 3. Dual fuel transfer characteristics gas to liquid



GT17599

Figure 4. Gas fuel control system



GT17604

Figure 5. Liquid fuel control system

from the discharge back to the pump suction. The required turndown ratio is achieved by multiplying the fuel command by a signal proportional to turbine speed. The resultant signal positions the pump recirculation, or bypass valve, as appropriate to make the actual fuel flow, as measured by the speed of the liquid fuel flow divider, equal the product of turbine speed and fuel command. This approach ensures a system in which both the liquid and gas fuel commands are essentially equal. Fuel distribution to the liquid fuel nozzles in the multiple combustors is achieved via the flow divider. This is a proven mechanical device that consists of carefully matched gear pumps for each combustor, all of which are mechanically connected to run at the same speed.

Control of nitrogen oxide emissions may be accomplished by the injection of water or steam into the combustors. The amount of water required is a function of the fuel flow, the fuel type, the ambient humidity and nitrogen oxide emissions levels required by the regulations in force at the turbine site. Steam flow requirements are generally about 40% higher than the equivalent water flow, but have a more beneficial effect on turbine performance. Accuracy of the flow measurement, control system and system monitoring meets or exceeds both EPA and all local code requirements. An independent, fast-acting shutoff valve is provided to ensure against loss of flame from over-watering on sudden load rejection.

Emissions control using Dry Low NO_x combustion techniques relies on multiple-combustion staging to optimize fuel/air ratios and achieve thorough premixing in various combinations, depending on desired operating temperature. The emissions fuel control system reg-

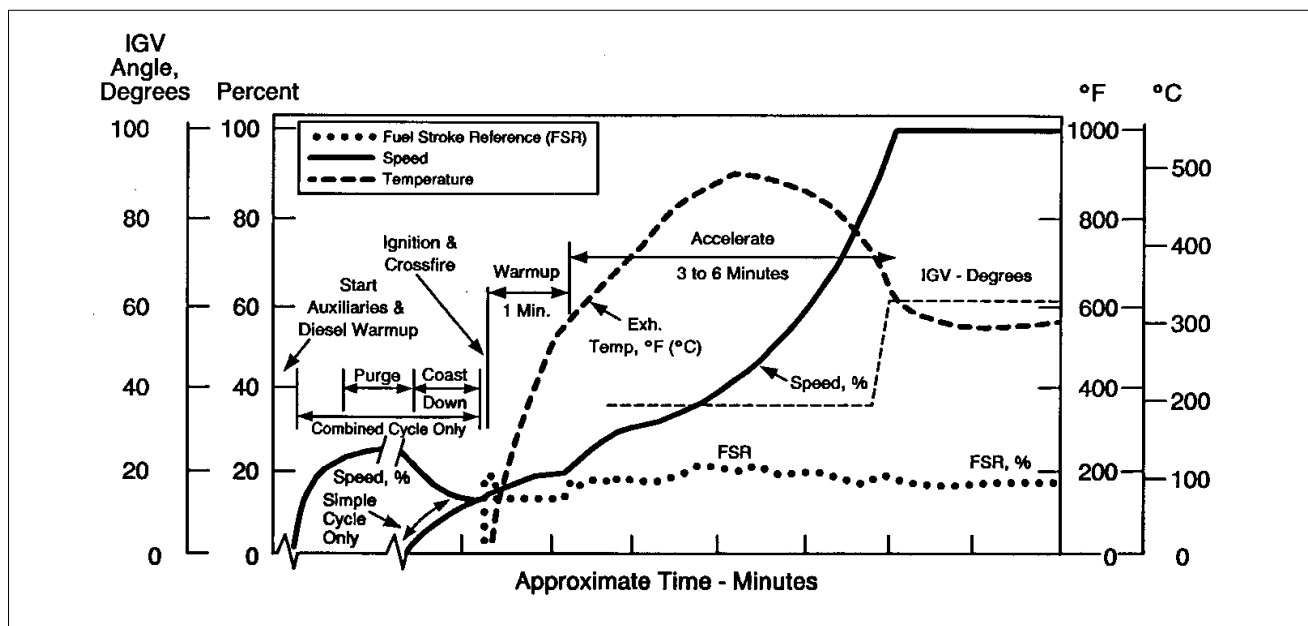
ulates the division of fuel among the multiple-combustion stages according to a schedule that is determined by a calculated value of the combustion reference temperature. The control system also monitors actual combustion system operation to ensure compliance with the required schedule. Special provisions are incorporated to accommodate off-normal situations such as load rejection.

The gas turbine, like any internal combustion engine, is not self-starting and requires an outside source of cranking power for startup. This is usually a diesel engine or electric motor combined with a torque converter, but could also be a steam turbine or gas expander if external steam or gas supplies are available. Startup via the generator, using variable frequency power supplies, is used on some of the larger gas turbines. Sufficient cranking power is provided to crank the unfired gas turbine at 25% to 30% speed, depending on the ambient temperature, even though ignition speed is 10% to 15%. This extra cranking power is used for gas path purging prior to ignition, for compressor water washing, and for accelerated cooldown.

A typical automatic starting sequence is shown in Figure 6. After automatic system checks have been successfully completed and lube oil pressure established, the cranking device is started and, for diesel engines, allowed to warm up. Simple-cycle gas turbines with conventional upward exhausts do not require purging prior to ignition and the ignition sequence can proceed as the rotor speed passes through firing speed. If ignition does not occur before the 60 second cross-firing timer times out, the controls will automatically enter a purge sequence, as described later, and then attempt to refire.

However, if there is heat recovery equipment, or if the exhaust ducting has pockets where combustibles can collect, gas path purging ensures a safe light-off. When the turbine reaches purge speed, this speed is held for the necessary purge period, usually sufficient to ensure three to five volume changes in the gas path. Purge times will vary from one minute to as long as 10 minutes in some heat recovery applications. When purging is completed, the turbine rotor is allowed to decelerate to ignition speed. This speed has been found to be optimum from the standpoint of both thermal fatigue duty on the hot gas path components, as well as offering reliable ignition and cross firing of the combustors.

The ignition sequence consists of turning on



GT17606D

Figure 6. Typical gas turbine starting characteristics

ignition power to the spark plugs and then setting firing fuel flow. When flame is detected by the flame detectors, which are on the opposite side of the turbine from the spark plugs, ignition and cross-firing are complete. Fuel is reduced to the warm-up value for one minute and the starting device power is brought to maximum. If successful ignition and cross firing are not achieved within an appropriate period of time, the control system automatically reverts back to the purge sequence, and will attempt a second firing sequence without operator intervention. In the unlikely event of incomplete cross firing, it will be detected by the combustion monitor as a high exhaust temperature spread prior to loading the gas turbine.

After completion of the warm-up period, fuel flow is allowed to increase and the gas turbine begins to accelerate faster. At a speed of about 30% to 50%, the gas turbine enters a predetermined program of acceleration rates, slower initially, and faster just before reaching running speed. The purpose of this is to reduce the thermal-fatigue duty associated with startup.

At about 40% to 85% speed, turbine efficiency has increased sufficiently so that the gas turbine becomes self sustaining and external cranking power is no longer required. At about 80% to 90% speed, the compressor inlet guide vanes, which were closed during startup to prevent compressor surge, are opened to the full-speed, no-load position.

As the turbine approaches running speed, synchronizing is initiated. This is a two or three

step process that consists of matching turbine generator speed, and sometimes voltage, to the bus, and then closing the breaker at the point where the two are in phase within predetermined limits.

Turbine speed is matched to the line frequency with a small positive differential to prevent the generator breaker from tripping on reverse power at breaker closure. In the protective module, triple-redundant microprocessor-based synchronizing methods are used to predict zero-phase angle difference and compensate for breaker closing time to provide true zero angle closure. Acceptable synchronizing conditions are independently verified by the triple-redundant control processors as a check function.

At the completion of synchronizing, the turbine will be at a spinning reserve load. The final step in the starting sequence consists of automatic loading of the gas turbine generator, at either the normal or fast rate, to either a preselected intermediate load, base load or peak load. Typical starting times to base load are shown in Table 3. Although the time to full-speed no-load applies to all simple cycle gas turbines, the loading rates shown are for standard combustion and may vary for some Dry Low NO_x systems.

Normal shutdown is initiated by the operator and is reversible until the breaker is opened and the turbine operating speed falls below 95%. The shutdown sequence begins with automatic unloading of the unit. The main generator breaker is opened by the reverse power relay at

Table 3
SIMPLE CYCLE PACKAGE POWER PLANT STARTING TIMES

Model Series	Type of Start	Starting Device	Minutes				Total Time to Base Load
			Diesel Warmup Time	+	Turbine Starting Time	= Time to Full Speed No Load	
LM6000	Normal	Hydraulic	NA		7.0	7.0	12.0
MS5001P	Normal	Diesel	2		7.17	9.17	13.17
	Fast Load	Diesel	1/2		7.17	7.67	9.67
	Emergency	Big Diesel	1/2		4.0	4.5	5.0
MS6001B	Normal	Diesel	2		10.0	12.0	16.0
	Fast Load	Diesel	1/2		6.67	7.17	9.17
MS7001EA	Normal	Motor	NA		7.5	7.5	19.5
	Fast Load	Motor	NA		7.5	7.5	9.0
MS7001FA	Normal	Motor/LCI	NA		9.0	9.0	21.0
MS9001E	Normal	Motor	NA		8.17	8.17	20.17
	Fast Load	Motor	NA		8.17	8.17	9.67
MS9001FA	Normal	Motor/LCI	NA		9.0	9.0	21.0

LCI = Load Commutating Inverter (Static Starter)

about 5% negative power, which drives the gas turbine fuel flow to a minimum value sufficient to maintain flame, but not turbine speed. The gas turbine then decelerates to about 40% to 25% speed, where fuel is completely shut off. As before, the purpose of this “fired shutdown” sequence is to reduce the thermal fatigue duty imposed on the hot gas path parts.

After fuel is shut off, the gas turbine coasts down to a point where the rotor turning system can be effective. The rotor should be turned periodically to prevent bowing from uneven cooldown, which would cause vibration on subsequent startups. Turning of the rotor for cooldown or maintenance is accomplished by a ratcheting mechanism on the smaller gas turbines, or by operation of a conventional turning gear on some larger gas turbines. Normal cooldown periods vary from five hours on the smaller turbines to as much as 48 hours on some of the larger units. Cool down sequences may be interrupted at any point for a restart if desired.

Gas turbines are capable of faster loading in the event of a system emergency. However, thermal fatigue duty for these fast load starts is substantially higher. Therefore, selection of a fast load start is by operator action with the normal start being the default case.

Gas turbine generators that are equipped with diesel engine starting devices are optionally capable of starting in a blacked out condition without outside electrical power. Lubricating oil for starting is supplied by the DC emergency pump powered from the unit battery. This battery also provides power to the DC fuel forwarding pump for black starts on distillate. The turbine and generator control panels on all units are powered from the battery. An inverter sup-

plies the AC power required for ignition and the local operator interface. Power for the cooling system fans is obtained from the main generator through the power potential transformer after the generator field is flashed from the battery at about 50% speed. The black start option uses a DC battery-powered turning device for rotor cooldown to ensure the integrity of the black start capability.

As mentioned, the protective function acts to trip the gas turbine independently from the fuel control in the event of overspeed, overtemperature, high rotor vibration, fire, loss of flame or loss of lube oil pressure. With the advent of microprocessors, additional protective features have been added with minimum impact on running reliability due to the redundancy of the microprocessors, sensors and signal processing. The added functions include combustion and thermocouple monitoring, high lube oil header temperature, low hydraulic supply pressure, multiple control computer faults and compressor surge for the aircraft-derivative gas turbines.

Because of their nature or criticality, some protective functions trip the stop valve through the hardwired, triple-redundant protective module. These functions are the hardwired overspeed detection system, which replaces the mechanical overspeed bolt on some units, the manual emergency trip buttons, and “customer process” trips. As previously mentioned, the protection model performs the synchronization function to close the breaker at the proper instant. It also receives signals from the flame detectors and determines if flame is on or off. A block diagram of the turbine protective system is shown in Figure 7. It shows how loss of lube oil, hydraulic supply, or manual hydraulic trip will

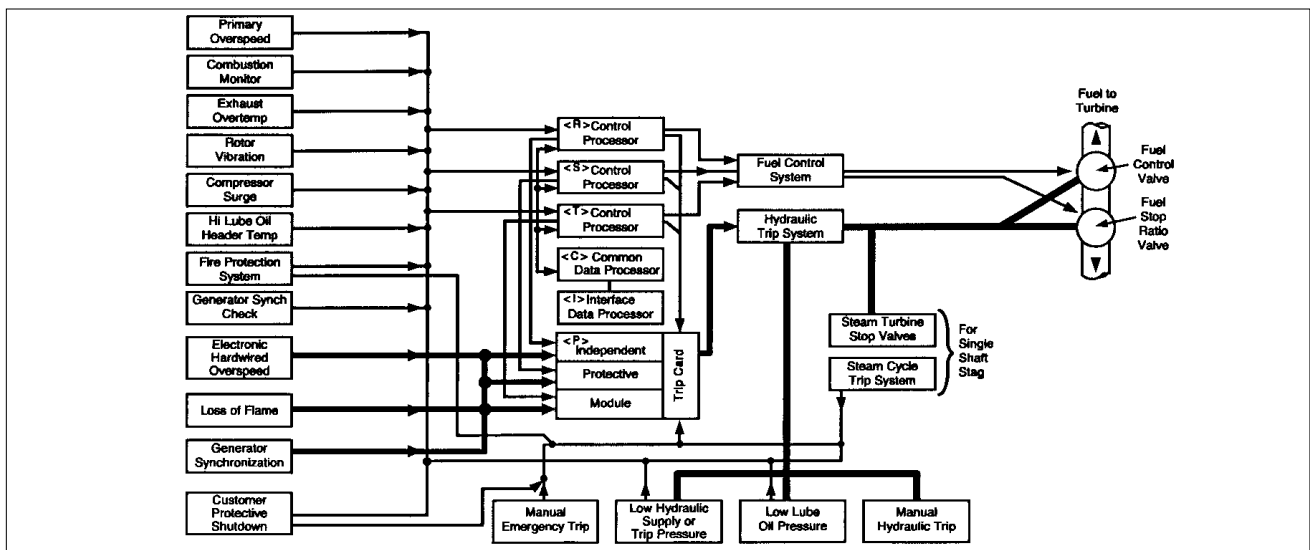


Figure 7. Protective system block diagram; SPEEDTRONIC™ Mark V turbine control

GT20784B

result in direct hydraulic actuation of the stop valves.

Interfacing to other application-specific trip functions is provided through the three control processors, the hardwired protection module or the hydraulic trip system. These trip functions include turbine shutdown for generator protective purposes and combined-cycle coordination with heat recovery steam generators and single-shaft STAG™ steam turbines. The latter is hydraulically integrated as shown in Figure 7. Other protective coordination is provided as required to meet the needs of specific applications.

SPEEDTRONIC™ MARK V CONTROL CONFIGURATION

The SPEEDTRONIC™ Mark V control system makes increased use of modern microprocessors and has an enhanced system configuration. It uses SIFT technology for the control, a new triple-redundant protective module and a significant increase in hardware diagnostics. Standardized modular construction enhances quality, speed of installation, reliability and ease of on-line maintenance. The operator interface has been improved with color graphic displays and standardized links to remote operator sta-

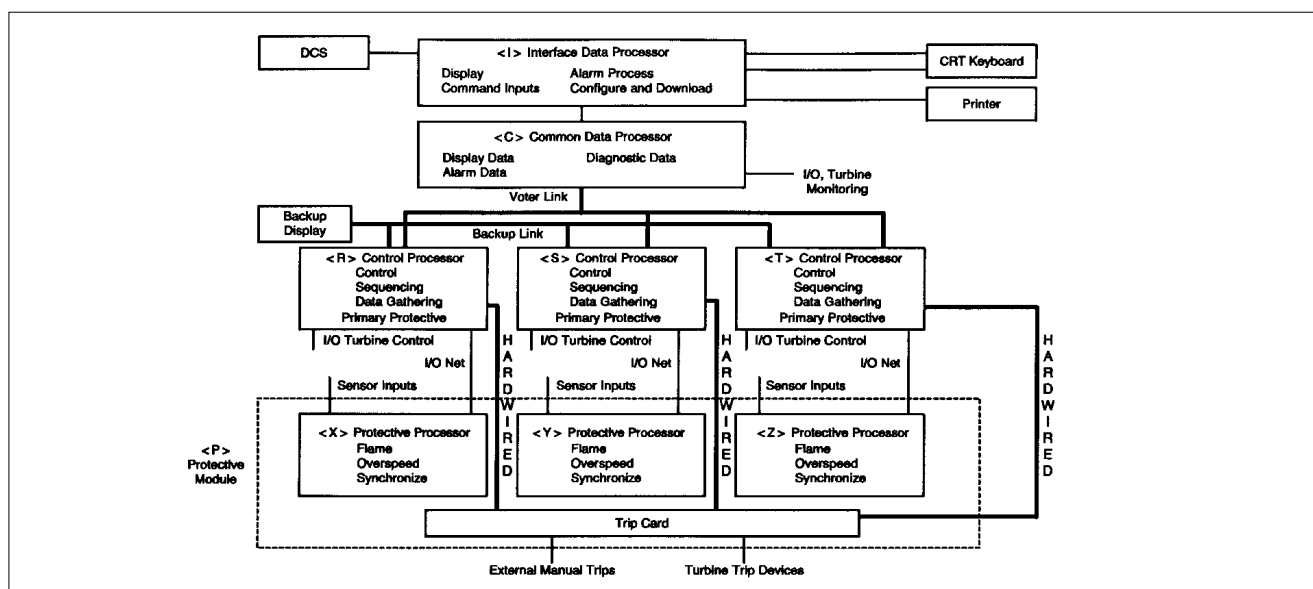


Figure 8. Standard control configuration

GT20781B

tions and distributed control systems (DCS).

Figure 8 shows the standard SPEEDTRONIC™ Mark V control system configuration. The top block in the diagram is the Interface Data Processor called <I>. It includes a monitor, keyboard, and printer. Its main functions are driving operator displays, managing the alarm process and handling operator commands. <I> also does system configuration and download, off-line diagnostics for maintenance, and implements interfaces to remote operator stations and plant distributed control systems.

The Common Data Processor, or <C>, collects data for display, maintains the alarm buffers, generates and keeps diagnostic data, and implements the common I/O for non-critical signals and control actions. Turbine supervisory sensors such as wheelspace thermocouples come directly to <C>. The <I> processor communicates with <C> using a peer-to-peer communication link which permits one or more <I> processors. <C> gathers data from the control processors by participating on the voting link.

At the core of SPEEDTRONIC™ Mark V control are the three identical control processors called <R> <S> and <T>. All critical control algorithms, turbine sequencing and primary protective functions are handled by these processors. They also gather data and generate most of the

alarms.

The three control processors accept input from various arrangements of redundant turbine and generator sensors. Table 4 lists typical redundant sensor arrangements. By extending the fault tolerance to include sensors, as with the Mark IV system, the overall control system availability is significantly increased. Some sensors are brought in to all three control processors, but many, like exhaust thermocouples, are divided among the control processors. The individual exhaust temperature measurements are exchanged on the voter link so that each control processor knows all exhaust thermocouple values. Voted sensor values are computed by each of the control processors. These voted values are used in control and sequencing algorithms that produce the required control actions.

One key output goes to the servo valves used in position loops as shown in Figure 9. These position loops are closed digitally. Redundant LVDTs (Linear Variable Differential Transformers, a position sensor) produce a signal proportional to actuator position. Each control processor measures both LVDT signals and chooses the higher of the two signals. This value is chosen because the LVDT is designed to have a strong failure preference for low voltage output. The signal is compared with the position

Table 4
CRITICAL REDUNDANT SENSORS

Parameter	Type	Function	Usage	Number
Speed	Mag. Pickup	CTL & PROT	Dedicated	3 to 6
Exhaust temperature	T.C.	CTL & PROT	Dedicated	13 to 27
Generator output	Transducer	Control	Dedicated	3
Liquid fuel flow	Mag. pickup	Control	Dedicated	3
Gas fuel flow	Transducer	Control	Dedicated	3
Water flow	Mag. pickup	Control	Dedicated	3
Actuator stroke	LVDT	Control	Shared	2/Actuator
Steam flow	Transducer	Control	Shared	1
Vibration	Seismic probe	Protection	Shared	8 to 11
Flame	Scanner	Protection	Shared	4 to 8
Fire	Switch	Protection	Shared	17 to 21
Control oil pressure	Switch	Protection	Shared	3
L.O. pressure	Switch	Protection	Shared	3
L.O. temperature	Switch	Protection	Shared	3
Exh. frame blwr.	Switch	Protection	Shared	2
Filter delta p.	Switch	Protection	Shared	3

Notes:

1. Dedicated sensors: one-third are connected to each processor
2. Shared sensors are shared by processors
3. Thee number of exhaust thermocouples is related to the number of combustors
4. Vibration and fire detectors are related to the physical arrangement
5. Generator output are redundant only for "constant settable droop" systems
6. Dry Low NO_x has four flame detectors in each of two zones

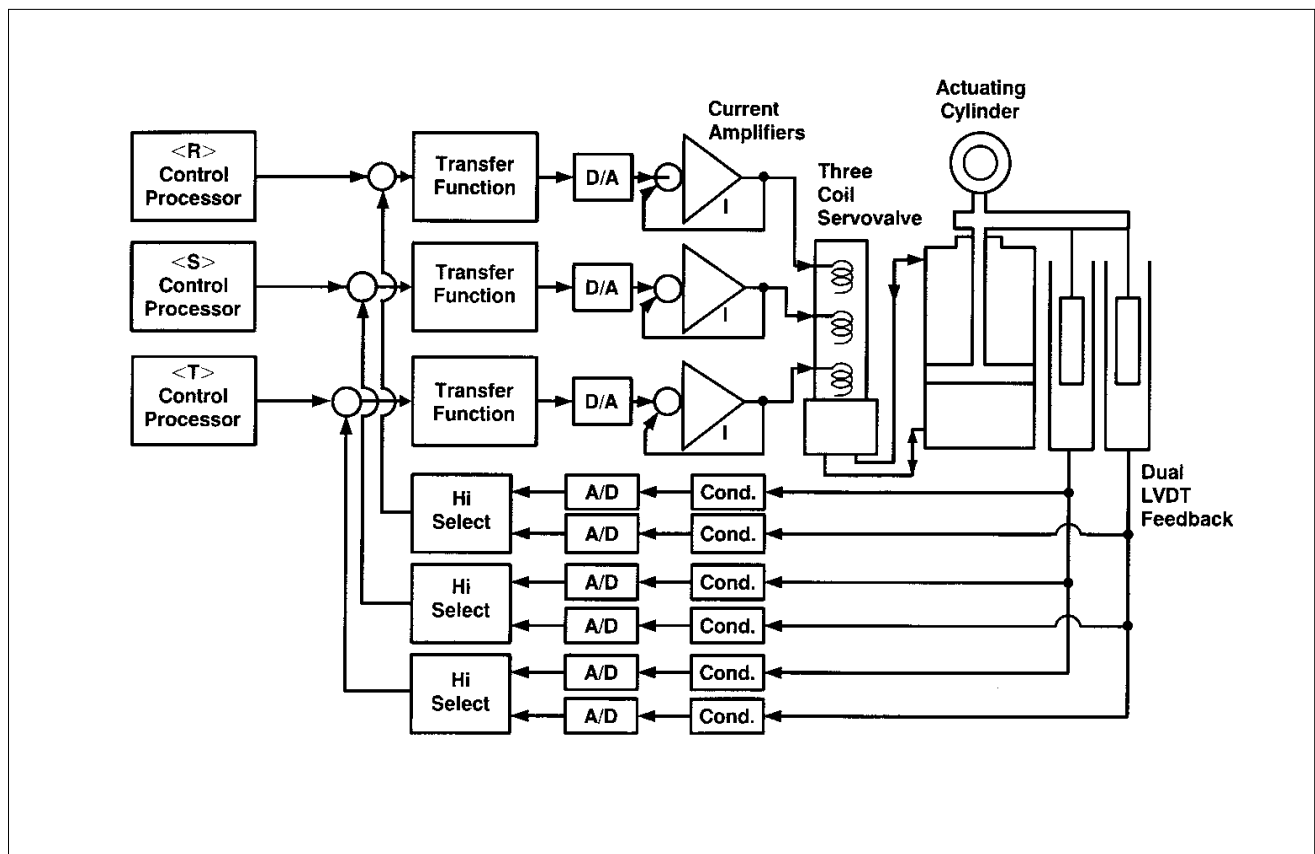


Figure 9. Digital servo position loops

GT20782A

command and the error signal passed through a transfer function and a D/A converter to a current amplifier. The current amplifier from each control processor drives one of the three coils. The servo valve acts on the sum of the ampere turns. If one of the three channels fails, the maximum current that one failed amplifier can deliver is overridden by the combined signals from the remaining two good amplifiers. The result is that the turbine continues running under control.

The SIFT system ensures that the output fuel command signals to the digital servo stay in step. As a result, almost all single failures will not cause an appreciable bump in the controlled turbine parameter. Diagnostics of LVDT excitation voltage, LVDT outputs that disagree, and current not equalling the commanded value make it easy to find a system problem, so that on-line repair can be initiated quickly.

An independent protective module <P> is internally triple redundant. It accepts speed sensors, flame detectors and potential transformer inputs to perform emergency electronic overspeed, flame detection and synchronizing functions. Hardware voting for <P> solenoid outputs

is accomplished on a trip card associated with the module. The trip card merges trip contact signals from the emergency overspeed, the main control processors, manual trip push buttons and other hardwired customer trips.

Overspeed and synchronization functions are independently performed in both the triple-redundant control and triple-redundant protective hardware, which reduces the probability of machine overspeed or out of phase synchronizing to the lowest achievable values.

SPEEDTRONIC™ Mark V control provides interfaces to DCS systems for plant control from the <I> processor. The two interfaces available are Modbus Slave Station and a standard ethernet link, which complies with the IEEE-802.3 specification for the physical and medium access control (MAC) layers. A GE protocol is available for use over the ethernet link. A hardwired interface is also available.

Table 5 lists signals and commands available on the interfacing links. The table includes an option for hard-wired contacts and 4-20 ma signals intended to interface with older systems such as SCADA remote dispatch terminal units. The wires are connected to the I/O module

Table 5
INTERFACING OPTIONS

Hardwired

- Connects to common "C" processor I/O
- Commands to turbine control
 - Turbine start/stop
 - Turbine fast load
 - Governor set point raise/lower
 - Base/Peak load selection
 - Gas/Distillate fuel selection
 - Generator voltage (VARS) raise/lower
 - Generator synchronizing inhibit/release
- Feedback from turbine control
 - Watts, VARS and volts (analog for meters)
 - Breaker status
 - Starting sequence status
 - Flame indication
 - On temperature control indication
- Alarm management
 - RS232C data transmission only, from <1>

Modbus link

- Turbine control is Modbus slave station
- Transmission on request by master, 300 to 19,200 baud
- Connects to interface processor (I)
- RS232C link layer
- Commands available
 - All allowable remote commands are available
 - Alarm management
- Feedback from turbine control
 - Most turbine data available in the I data base

associated with <C>.

The "stage link" that interconnects the <C> processor with the <I> processor is an extendible Arcnet link that allows daisy chaining multiple gas turbines with multiple <I> processors. Thus a single gas turbine can be controlled from multiple <I> processors, or a single <I> processor can control multiple gas and steam turbines. For multi-unit configurations, the <I> processor can be equipped with plant load control capability that will allow plant level management of all units for both real and reactive power. The <I> processor, or Operator Interface, is shown in Figure 10.

In process plants where maintaining the link to the DCS is essential to keeping the plant on-line, two <I> processors are used to obtain redundant links to the DCS system. For critical installations, a redundant <C> processor option, referred to as the <D> processor, is available that ensures that no single hardware failure can interrupt communications between the gas turbine and the DCS system.

A specially configured PC is available to act as a "historian," or <H> processor, for the gas turbine installation. All data available in the Mark V data base can be captured and stored by the historian. Analog data is stored when the values change beyond a settable deadband, and events and alarms are captured when they occur. In addition, data can be requested periodically or on demand in user definable lists. The historian is sized so that about a month's worth of data for a typical four unit plant can be stored on line, and provisions are included for both archiving and restoring older data. Display options include a full range of trending, cross-plotting and histogram screens.

Compliance with recognized standards is an important aspect of SPEEDTRONIC™ Mark V controls. It is designed to comply with several standards including:

- ETL — Approval has been obtained for labeling of the Mark V control panel, with ETL labeling of complete control cabs
- CSA/UL — Approval has been obtained for the complete SPEEDTRONIC™ Mark V control panel
- UBC — Seismic Code Section 2312 Zone 4
- ANSI — B133.4 Gas Turbine Control and Protection System
- ANSI — C37.90A Surge Withstand



GT22904

Figure 10. Mark V operator interface



RDC26449-2-5

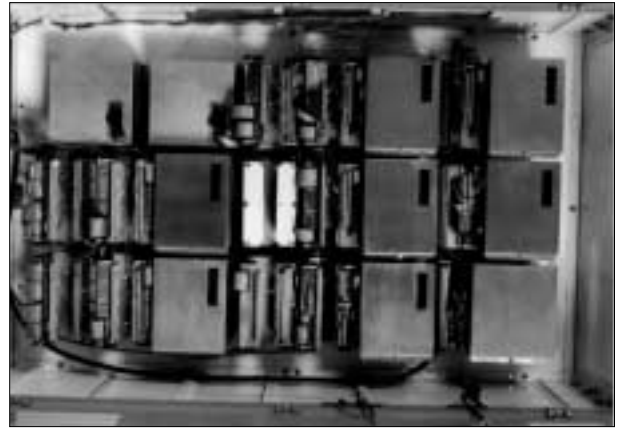
Figure 11. Mark V turbine control panel

HARDWARE CONFIGURATION

The SPEEDTRONIC™ Mark V gas turbine control system is specifically designed for GE gas and steam turbines, and uses a considerable number of CMOS and VLSI chips selected to minimize power dissipation and maximize functionality. The new design dissipates less power than previous generations for equivalent panels. Ambient air at the panel inlet vents should be between 32 F and 72 F (0 C and 40 C) with a humidity between 5 and 95%, non-condensing. The standard panel is a NEMA 1A panel that is 90 inches high, 54 inches wide, 20 inches deep, and weighs approximately 1,200 pounds. Figure 11 shows the panel with doors closed.

For gas turbines, the standard panel runs on 125 volt DC unit battery power, with AC auxiliary input at 120 volt, 50/60 Hz, used for the ignition transformer and the <I> processor. The typical standard panel will require 900 watts of DC and 300 watts of auxiliary AC power. Alternatively, the auxiliary power can be 240 volt AC 50 Hz, or it can be supplied from an optional black start inverter from the battery.

The power distribution module conditions the power and distributes it to the individual



RDC26449-2-8

Figure 12. Panel internal arrangement

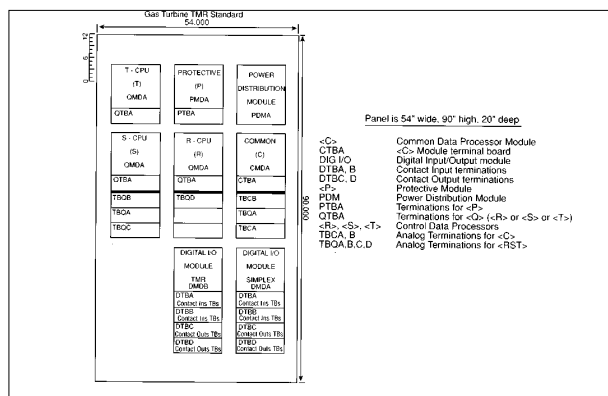
power supplies for the redundant processors through replaceable fuses. Each control module supplies its own regulated DC busses via AC/DC converters. These can accept an extremely wide range of incoming DC, which makes the control tolerant of significant battery voltage dips, such as those caused by starting a diesel cranking motor. All power sources and regulated busses are monitored. Individual power supplies can be replaced while the turbine is running.

The Interface Data Processor, particularly a remote <I>, can be powered by house power. This will normally be the case when the central control room has an Uninterruptible Power Supply (UPS) system. AC for the local <I> processor will normally be supplied via a cable from the SPEEDTRONIC™ Mark V panel or alternatively from house power.

The panel is constructed in a modular fashion and is quite standardized. A picture of the panel interior is shown in Figure 12, and the modules are identified by location in Figure 13. Each of these modules is also standardized, and a typical processor module is shown in Figure 14. They feature card racks that tilt out so cards can be individually accessed. Cards are connected by front-mounted ribbon cables which can be easily disconnected for service purposes. Tilting the card rack back in place and closing the front cover locks the cards in place.

Considerable thought has been given to the routing of incoming wires to minimize noise and crosstalk. The wiring has been made more accessible for ease of installation. Each wire is easily identified and the resulting installation is neat.

The panels are made in a highly standardized manufacturing process. Quality control is an integral part of the manufacturing; only thoroughly tested panels leave the factory. By having



GT20783A

Figure 13. Module map of panel interior



GT21533A

Figure 14. Typical processor module

a highly controlled process, the resulting modules and panels are very consistent and repeatable.

SOFTWARE CONFIGURATION

Improved methods of implementing the triple-modular redundant system center on SIFT technology and result in a more robust control. SIFT involves exchanging information on the voter link directly between <R>, <S>, <T> and <C> controllers. Each control processor measures all of its input sensors so that each sensor signal is represented by a number in the controller. The sensor numbers to be voted are gathered in a table of values. The values of all state outputs, such as integrators, for example, the load setpoint, are added to the table. Each control processor sends its table out on the voter link and receives tables from the other processors. Consider the <R> controller: it outputs its table to and receives the tables from the <S> and <T> controllers. Now all three controller tables will be in the <R> processor, which selects the

median value for each sensor and integrator output, and uses these voted outputs in all subsequent calculations. <S> and <T> follow the same procedure.

The basic SIFT concept brings one sensor of each kind into each of <R>, <S> and <T>. If a sensor fails, the controller with the failed transducer initially has a bad value. But it exchanges data with the other processors and when the voting takes place, the bad value is rejected. Therefore, a SIFT-based system can tolerate one failed transducer of each kind. In previous systems, one failed transducer was likely to cause one processor to vote to trip. A failure of a different kind of transducer on another controller could cause a turbine trip. This does not happen with SIFT because the input data is exchanged and voted.

<C> is also connected to the voter link. It eavesdrops while all three sets of variables are transmitted by the control processors and calculates the voted values for itself. If there are any significant disagreements, <C> reports them to <I> for operator attention and maintenance action. If one of the transducers has failed, its output will not be correct and there will be a disagreement with the two correct values. <C> will then diagnose that the transducer or parts immediately associated with it have failed and will post an alarm to <I>.

Voting is also performed on the outputs of all integrators and other state variables. By exchanging these variables, fewer bumps in output are caused when a failure or a repair takes place. For instance, if a turbine is set to run on isochronous speed control with an isolated load, an integrator compares the frequency of the generator with the nominal frequency reference (50 Hz or 60 Hz). Any error is integrated to produce the fuel command signal. If one computer calculates an erroneously high fuel command, nothing happens because the processors will exchange the fuel command and vote and all will use the correct value of fuel command. When the processor is repaired and put back in service, its fuel command will initially be set to zero. But as soon as the first data is exchanged on the voter link, the repaired control processor will output the voted value that will be from one of the running processors so no bump in fuel flow will occur. No special hardware or software is needed to keep integrated outputs in step.

Since only one turbine is connected to each panel, the triple-redundant control information must be recombined. This recombination is done in software or, for more critical signals, in

dedicated voting hardware. For critical outputs, such as the fuel command, the recombination of the signals is done by the servo valve on the turbine itself as previously explained.

For example, up to four critical 4 ma to 20 ma outputs are voted in a dedicated electronic circuit. The circuit selects the median signal for output. It takes control power for the electronics and the actual output current from all three sections such that any two control sections will sustain the correct output. Non-critical outputs are software voted and output by the I/O associated with <C>.

Logic outputs are voted by dedicated hardware relay driver circuits that require two or three "on" signals to pick up the output relay. Control power for the circuit and output relay is taken from all three control sections.

Protective functions are accomplished by the control processors and, for overspeed, independently by the Protective Module <P> as well. Primary speed pickups are wired to the control processors and used for both speed control and primary overspeed protection. The trip commands, generated by the primary overspeed protective function in the control processors, each activate a relay driver. The driver signals are sent to the trip card in the protective model where independent relays are actuated. Contacts from each of these three primary protective trip relays are voted to cause the trip solenoid to drop out. Separate overspeed pickups are brought to the independent protective module. Their relay contacts are wired in a voting arrangement to the other side of the trip solenoid and independently cause the trip solenoid to drop out on detection of overspeed.

The <I> processor is equipped with a hard disk which keeps the records that define the site software configuration. It comes from GE with the site-specific software properly configured. For most upgrades, the basic software configuration on the disk is replaced with new software from the GE factory. The software is quite flexible and most required alterations can be made on site by qualified personnel. Security codes limit access to the programs used to change constants and sequencing, do logic forcing, manual control and so forth. These codes are under the control of the owner so that if there is a need to change access codes, new ones can be established on site. Basic changes in configuration, such as an upgrade to turbine capability, requires that the new software be compiled in <I> and downloaded to the processor modules. The information for <C> is stored in EEPROM

there. The information for the control processors is passed through <C> and stored in EEPROM in <R>, <S> and <T>. Once the download is complete, the <I> processor can fail and the turbine will continue to run properly, accepting commands from the local backup display while <I> is being repaired.

Changes in control constants can be accomplished on-line in working memory. For example, a new set of tuning constants can be tried. If they are found to be satisfactory, they can be uploaded for storage in <I> where they will be retained for use in any subsequent software download. <I> also keeps a complete list of variables that can be displayed and printed.

The most critical algorithms for protection, control and sequencing have evolved over many years of GE gas turbine experience. These basic algorithms are in EPROM. They are tuned and adapted with constants that are field adjustable. By protecting these critical algorithms from inadvertent change, the performance and safety of the complete fleet of GE gas turbines is made more secure.

OPERATION AND MAINTENANCE

The operator interface is comprised of a VGA color graphics monitor, keyboard and printer. The functions available on the operator interface are shown in Table 6.

Displays for normal operation center around the unit control display. It shows the status of major selections and presents key turbine parameters in a table that includes the variable name, value and engineering units. A list of the oldest three unacknowledged alarms appears on this screen. The operator interface also supports an operator-entered list of variables, called a user defined display, where the operator can type in any turbine-generator variable and it will be added to the variable list. Commands that change the state of the turbine require an arm activate sequence to avoid accidental operation. The exception is setpoint incrementing commands, which are processed immediately and do not require an arm-activate sequence.

Alarm management screens list all the alarms in the chronological order of their time tags. The most recent alarm is added to the top of the display list. The line shows whether the alarm has been acknowledged or not, and whether the alarm is still active. When the alarm condition clears, the alarm can be reset. If reset is selected and the alarm has not cleared, the alarm does

Table 6
OPERATOR INTERFACE FUNCTIONS

- Control
 - Unit control
 - Generator control (or load control)
 - Alarm management
 - Manual control (examples)
 - Preselected load setpoint
 - Inlet guide vane control
 - Isochronous control
 - Fuel stroke reference
 - Auxiliary control
 - Water wash
 - Mechanical overspeed test
- Data (examples)
 - Exhaust temperatures
 - Lube oil temperatures
 - Wheel-space temperatures
 - Generator temperatures
 - Vibration
 - Timers and event counters
 - Emission control data
 - Logical status
 - Contracts in
 - Relay out
 - Internal logic
 - Demand display
 - Periodic logging
- Administrative–
 - Set time/date
 - Select scale units
 - Display identification numbers
 - Change security code
 - Maintenance/Diagnostics
 - Control reference
 - Configuration tools
 - Tuning tools
 - Constant change routines
 - Actuator auto-calibrate
 - Trip display
 - Rung display
 - Logic forcing
 - Diagnostic alarms
 - Diagnostic displays
 - Off-line
 - On-line
 - System memory access

not clear and the original time tag is retained.

The alarm log prints alarms in their arrival sequence, showing the time tags which are sent from the control modules with each alarm. Software is provided to allow printing of other information, such as copying of text screens, or

making a listing of the full text of all alarms or turbine variables. When the printer has been requested to make such an output, it will form feed, print the complete list and form feed again. Any alarms that happened during the time of printing were stored and are now printed. An optional alternative is to add a second printer, dedicating one to the alarm log.

Administrative displays help with various tasks such as setting processor real time clocks and the date. These displays will include the selection of engineering units and allow changing between English and metric units.

There are a number of diagnostic displays that provide information on the turbine and on the condition of the control system. A partial list of the diagnostics available is presented in Table 7. The trip diagnostic screen traps the actual signal condition that caused a turbine trip. This display gives detailed information about the actual logic signal path that caused any trip. It is accomplished by freezing information about the logic path when the trip occurs. This is particularly useful in identifying the original source of trouble if a spurious signal manages to cause one of the control processors to call for a trip and does not leave a normal diagnostic trail. In SPEEDTRONIC™ Mark V controls, all trips are annunciated and information about the actual logic path that caused the trip is captured. In addition to this information, contact inputs are resolved to one millisecond, which makes this sequence of events information more valuable.

The previously mentioned comparison of voting values is another powerful diagnostic tool. Normally these values will agree and significant disagreement means that something is wrong. Diagnostic alarms are generated whenever there is such a disagreement. Examination of these records can reveal what has gone wrong with the system. Many of these combinations have specific diagnostics associated with them and the software has many algorithms that infer what has gone wrong from a pattern of incoming diagnostic signals. In this way the diagnostic alarm will identify as nearly as possible what is wrong, such as a failed power supply, blown fuse, failed card, or open sensor circuit.

Some of the diagnostics are intended to enhance turbine-generator monitoring. For instance, reading and saving the actual closing time of the breaker is an excellent diagnostic on the health of the synchronizing system. An output from the flame detectors which shows the effective ultraviolet light level is another new diagnostic routine. It is an indicator of degrada-

Table 7
MONITORING AND DIAGNOSTICS

- Power
 - Incoming power sources
 - Power distribution
 - All control voltages
 - Battery ground, non-interfering with other ground detectors
- Sensors and actuators
 - Contact inputs circuits can force and interrogate
 - Open thermocouple
 - Open and short on seismic vibration transducers
 - LVDT excitation voltage
 - Servovalve current feedback loopback test
 - 4/20 MA control outputs — loopback testing
 - Relay driver; voting current monitor
 - RTD open and short
- Protective
 - Flame detector; UV light level count output
 - Synchronizer — phase angle at closure
 - Trip contact status monitor
- Voted data

tion in the ultraviolet flame detection system.

In another example, the contact input circuits can be forced to either state and then be interrogated to ensure that the circuit functions correctly without disturbing their normal operation. The extent of this kind of diagnostics has been greatly increased in SPEEDTRONIC™ Mark V control over previous generations. This level of monitoring and diagnostics makes maintenance easier and faster so that the control system stays in better repair. A properly maintained panel is highly fault-tolerant and makes systems starting and running reliability approach 100%.

Once the diagnostic routines have located a failed part, it may be replaced while the turbine continues to run. The most critical function of the diagnostics is to identify the proper control section where the problem exists. Wrong identification could lead to powering down a good section and result in a vote to trip. If the failed section is also voting to trip, the turbine will trip. A great deal of effort has been put into identifying the correct section. To affect the repair, the correct section is powered down. The module is opened and tilted out, the offending card located, cables disconnected, card replaced and cables reconnected. The rack is closed and power is reapplied to the module. The module will then join in with the others to control the turbine and the fault tolerance is restored.

Should the fault be in the <I> or <C> processor, it is likely that the operator display will stop or go blank and commands can no longer be sent by the operator to the turbine from <I>.

This upsets the operator much more than it disturbs the control processors or turbine. A back-up display is provided to handle this situation. It happens very infrequently, and repair of the normal operator interface will usually be accomplished in less than three hours. Optional redundant <I> processors make the use of the back-up display even more unlikely. The gas turbine control is completely automatic and needs little human intervention for starting, running, stopping or tripping once a sequence is initiated.

The back-up display provides for a minimum set of control commands: start, stop, raise load and lower load. It reports all process alarms by number. Since the alarm text can be altered on site in <I>, a provision is included to print the alarms with their internal alarm numbers. This list is used to look up the alarm name from the alarm number. The same is true for data points; however, a preselected list of key data points are programmed into the back-up panel that display the short symbol name, value and engineering units. The control ships from the factory with this limited list of key parameters established for the back-up display.

CONTROL SYSTEM EXPERIENCE

The SPEEDTRONIC™ Mark V Turbine Control System was initially put into service in May 1992 on one of three industrial generator drive MS9001B gas turbines. The system was subsequently put into utility service on two peaking gas turbines to obtain experience in daily starting service in order to develop a starting reliability assessment in addition to the continuous duty running reliability assessment. General product line shipments of the Mark V System on new unit production commenced early in 1993, with new installations starting up throughout the second half of that year.

Today, virtually all turbine shipments include Mark V Turbine Controls. This includes 424 new gas turbines and 106 new steam turbines either shipped or on order. In addition, almost 80 existing units have been committed to retrofitted SPEEDTRONIC™ Mark V Turbine Control Systems, however, the bulk of these are designed as Simplex rather than the triple-redundant systems associated with new units. This is due to the floor space available in retrofit applications. Reliability of the in service fleet, subsequent to commissioning and after accumulating more than 1.4 million powered opera-

tional hours on 264 units, has been as expected. Indicated MTBFO (mean time between force outages) is in excess of 28,000 hours for the system, which includes control panel, sensors, actuators and all intervening wiring and connectors. This performance is shown relative to the rest of the electronic control history in Figure 15.

Why is the Mark V system so much better than its predecessors? First, there are fewer components to fail and fewer types of components in the control panel. (This also means that there are fewer spares to stock.) Two-out-of-three redundancy on critical functions and components ensures that failures, which are less likely to begin with, are also less likely to cause a turbine trip. Extensive built-in diagnostics and the ability to replace almost any component while running further minimize exposure time, while running with a failed component when the potential to trip resulting from a double failure, is highest. Finally, the high degree of standardized, yet still flexible, software and hardware allowed a much greater degree of automated manufacturing and testing, substantially lowering the potential for human error, and increasing the repeatability of the process.

The Mark V system is a further improvement over the Mark IV system. Although the two-out-of-three voting philosophy is retained, its implementation is improved and made more robust through use of SIFT techniques. Components and types of components have been further reduced in number. Standardization of hard-

ware and software has been carried several steps further, but flexibility has also been increased. Greater degrees of automated manufacturing and testing have been complimented by greater use of computer-aided engineering to standardize the generation and testing of software and system configuration. Thus, it is fully expected the Mark V system will further advance the continuing growth of gas turbine control system starting and running reliability.

SUMMARY

The SPEEDTRONIC™ Mark V Gas Turbine Control System is based on a long history of successful gas turbine control experience, with a substantial portion using electronic and microprocessor techniques. Further advancements in the goals of starting and running reliability and system availability will be achieved by logical evolution of the unique architectural features developed and initially put into service with the Mark IV system. Flexibility of application and ease of operation will also grow to meet the needs of generator and mechanical drive systems, in process and utility operating environments, and in both peaking and base load service.

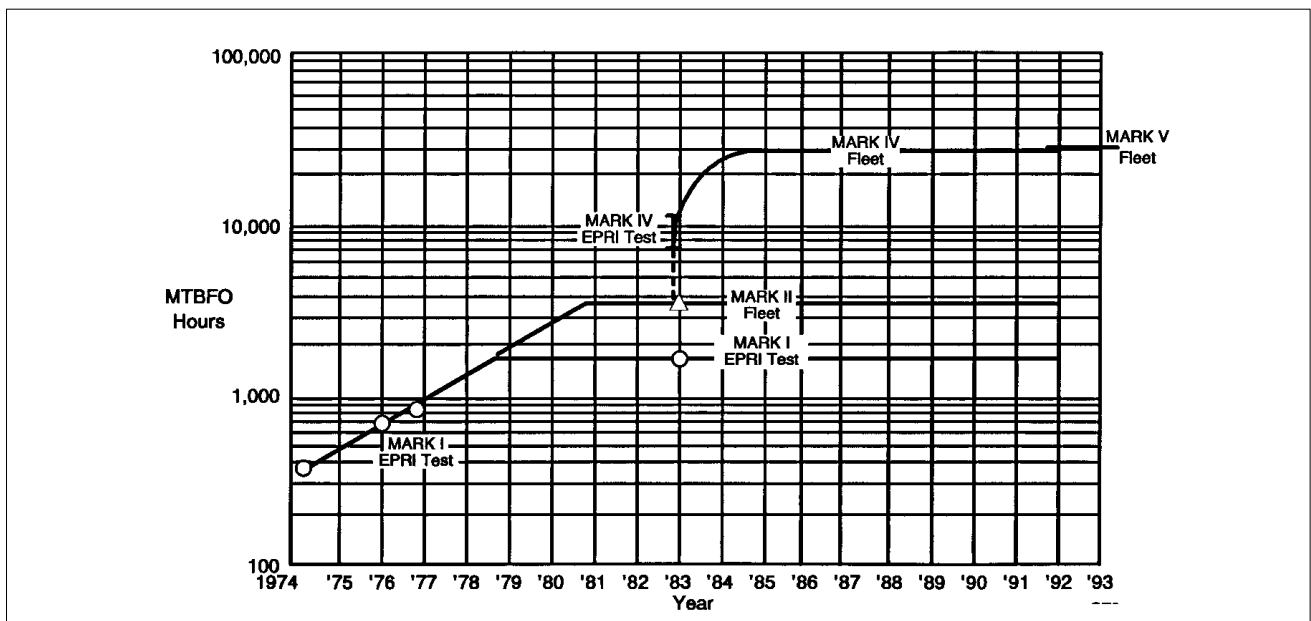


Figure 15. Control system reliability

GT21537B

REFERENCES

1. Rowen, W.I., "Operating Characteristics of Heavy-Duty Gas Turbines in Utility Service," ASME Paper No. 88-GT-150, presented at the Gas Turbine and Aeroengine Congress, Amsterdam, Netherlands, June 6-9, 1988.

LIST OF FIGURES

- Figure 1. Gas turbine generator controls and limits
- Figure 2. Gas turbine fuel control
- Figure 3. Dual fuel transfer characteristics gas to liquid
- Figure 4. Gas fuel control system
- Figure 5. Liquid fuel control system
- Figure 6. Typical gas turbine starting characteristics
- Figure 7. Protective system block diagram; SPEEDTRONIC™ Mark V turbine control
- Figure 8. Standard control configuration
- Figure 9. Digital servo position loops
- Figure 10. Mark V operator interface
- Figure 11. Mark V turbine control panel
- Figure 12. Panel internal arrangement
- Figure 13. Module map of panel interior
- Figure 14. Typical processor module
- Figure 15. Control system reliability

LIST OF TABLES

- Table 1. Advances in electronic control concepts
- Table 2. Gas turbine control philosophy
- Table 3. Simple cycle package power plant starting times
- Table 4. Critical redundant sensors
- Table 5. Interfacing options
- Table 6. Operator interface functions
- Table 7. Monitoring and diagnostics

SPEEDTRONICTM
Mark V
Turbine Control
User's Manual

SPEEDTRONICTM

Mark V

Turbine Control

User's Manual

GEH-5979D

Issue Date: December, 1991

Revision A: March, 1993

Revision B: June, 1994

Revision C: June, 1996

Revision D: February 1998

These instructions do not purport to cover all details or variations in equipment, nor to provide for every possible contingency to be met during installation, operation, and maintenance. If further information is desired or if particular problems arise that are not covered sufficiently for the purchaser's purpose, the matter should be referred to GE Industrial Control Systems.

This document contains proprietary information of General Electric Company, USA and is furnished to its customer solely to assist that customer in the installation, testing, operation, and/or maintenance of the equipment described. This document shall not be reproduced in whole or in part nor shall its contents be disclosed to any third party without the written approval of GE Industrial Control Systems.

Copyright© 1994 by General Electric Company, U.S.A.
All rights reserved.

Printed in the United States of America.
February 18, 1998

ARCNET is a registered trademark of Datapoint Corporation.
Ethernet is a trademark of Xerox Corporation.
HP is a trademark of Hewlett Packard Company.
MODBUS is a trademark of Gould Inc.
Proximity is a registered trademark of Bentley Nevada Corporation.
Speedtronic is a trademark of General Electric Company, USA.

SAFETY SYMBOL LEGEND



WARNING

Indicates a procedure, practice, condition, or statement that, if not strictly observed, could result in personal injury or death.



CAUTION

Indicates a procedure, practice, condition, or statement which, if not strictly observed, could result in damage to or destruction of equipment.

NOTE

Indicates an essential operation or important procedure, practice, condition, or statement.

WARNING

This equipment contains a potential hazard of electric shock or burn. Only personnel who are adequately trained and thoroughly familiar with the equipment and the instructions should install, operate, or maintain this equipment.

Isolation of test equipment from the equipment under test presents potential electrical hazards. If the test equipment cannot be grounded to the equipment under test, the test equipment's case must be shielded to prevent contact by personnel.

To minimize hazard of electrical shock or burn, approved grounding practices and procedures must be strictly followed.

To prevent personal injury or equipment damage caused by equipment malfunction, only adequately trained persons should modify any programmable machine.

Safety Symbol Legend (cont.)

Symbol	Publication	Description
	IEC 417, No. 5031	Direct current
	IEC 417, No. 5032	Alternating current
	IEC 417, No. 5033	Both direct and alternating current
	IEC 617-2, No. 02-02-06	Three-phase alternating current
	IEC 417, No. 5017	Earth (ground) TERMINAL
	IEC 417, No. 5019	PROTECTIVE CONDUCTOR TERMINAL
	IEC 417, No. 5020	Frame or chassis TERMINAL
	IEC 417, No. 5021	Equipotentiality
	IEC 417, No. 5007	On (Supply)
	IEC 417, No. 5008	Off (Supply)
	IEC 417, No. 5172	Equipment protected throughout by DOUBLE INSULATION or REINFORCED INSULATION (equivalent to Class II of IEC 536)
	ISO 3864, No. B.3.6	Caution, risk of electric shock
	ISO 3864, No. B.3.1	Caution

TABLE OF CONTENTS

CHAPTER 1 INTRODUCTION	
1-1. OVERVIEW	1-1
1-2. PRIMARY OPERATOR INTERFACE (<I>).....	1-1
1-3. BACKUP OPERATOR INTERFACE (<BOI>)	1-1
1-4. CONVENTIONS USED IN THIS MANUAL	1-2
1-4.1. Cursor Positioning Conventions	1-2
1-4.2. Keyboard Conventions	1-2
CHAPTER 2 THE PRIMARY OPERATOR INTERFACE	
2-1. INTRODUCTION.....	2-1
2-2. STARTING THE <I>.....	2-1
2-3. MAIN MENU.....	2-1
2-4. MAIN DISPLAY.....	2-3
2-5. MAIN MENU DISPLAYS AND FUNCTIONS	2-5
2-5.1. Password Administration	2-5
2-5.1.1. PASSWORD LEVELS AND THEIR PRIVILEGES.	2-6
2-5.1.2. ENABLING/DISABLING CURRENT STATUS.	2-7
2-5.1.3. SETTING OR CHANGING PASSWORDS.....	2-8
2-5.1.4. ENABLING/DISABLING THE BOOTUP STATUS.	2-8
2-5.1.5. EXAMPLES AND NOTES.	2-8
2-5.2. Time Set	2-9
2-5.3. Synonyms	2-9
2-5.3.1. HOW TO ENABLE/DISABLE SYNONYMS.	2-10
2-6. COMMON DISPLAY FIELDS	2-10
2-6.1. Display Message Field	2-10
2-6.2. Alarm Window	2-10
2-6.3. Display Target Field.....	2-10
2-6.4. Unit Command Targets	2-11
2-7. USER-DEFINED DISPLAYS.....	2-12
2-7.1. User-Defined Display Menu.....	2-12
2-7.2. User-Defined Display Body	2-12
2-7.3. User-Defined Display Modifications.....	2-13
2-7.3.1. ADDING A POINTNAME.....	2-13
2-7.3.2. DELETING A POINTNAME.....	2-14
2-7.3.3. ADDING A USER-DEFINED DISPLAY TO A MENU.	2-14
2-7.3.4. DELETING A USER-DEFINED DISPLAY FROM THE MENU.	2-14
2-7.3.5. MAKING MODIFICATIONS PERMANENT.	2-14
2-7.3.6. COPYING USER-DEFINED DISPLAYS TO MULTIPLE UNITS.	2-15
2-7.3.7. COMMAND TARGET ADDITIONS/DELETIONS	2-20
2-8. ALARM DISPLAY	2-22
2-8.1. Alarm Information.....	2-22
2-8.2. Silencing Annunciated Alarms.....	2-24
2-8.3. Acknowledging Alarms.....	2-24
2-8.4. Resetting Alarms	2-24
2-8.5. Locking Out Alarms	2-24
2-8.6. Unlocking Alarms	2-26
2-8.7. Printing The Alarm Display	2-26
2-8.8. Diagnostic Alarms	2-26
2-9. TRIP LOG DISPLAY	2-28
2-9.1. Display Header Information	2-28
2-9.2. First Displayed Screen (PAGE 2).....	2-28
2-9.3. Time vs. HIS_AGE CNTS	2-28

2-9.4. Control Signal Database Pointnames.....	2-29
2-9.5. Display Targets.....	2-30
2-9.5.1. CURRENT LOG/SAVED LOG.....	2-30
2-9.5.2. PRINT REPORT.....	2-31
2-9.5.3. PRINT IMAGE/SAVE IMAGE.....	2-31
2-9.7. Pre-Trip Screens.....	2-31
2-9.8. Alarms.....	2-32
2-9.9. Defining Control Signal Database Points.....	2-32
2-10. EPA DISPLAY.....	2-33
2-10.1. Example.....	2-33
2-11. PRINTING FUNCTIONS.....	2-35
2-11.1. Alarm Logging.....	2-35
2-11.2. Event Logger.....	2-36
2-11.2.1. POINTNAME.....	2-36
2-11.2.2. STATUS.....	2-36
2-11.3. Event Type.....	2-36
2-11.4. View Image/Save Image.....	2-37
 CHAPTER 3 USING THE BACKUP OPERATOR INTERFACE	
3-1. INTRODUCTION.....	3-1
3-2. MENU DISPLAY.....	3-2
3-3. ALARM DISPLAY.....	3-3
3-3.1. Alarm Management.....	3-4
3-3.1.1. Silence.....	3-4
3-3.1.2. Acknowledge.....	3-4
3-3.1.3. Reset.....	3-4
3-4. ENUMERATED SWITCH DISPLAYS.....	3-5
3-5. MAIN/NORMAL DISPLAYS.....	3-5
3-6. NORMAL DISPLAY.....	3-6
3-7. ALL POINTS DISPLAY.....	3-7
3-8. OPERATOR DEMAND DISPLAY.....	3-8
3-9. PROCESSOR SELECT DISPLAY (PROC).....	3-8
3-10. DESIGNATED PROCESSOR.....	3-9
 CHAPTER 4 CONTROL LOCATIONS	
4-1. Control Lockout.....	4-1
4-1.1. Implementing Control Lockout Using Password Administration.....	4-1
4-1.2. Control Lockout for Multi-Panel <I>s.....	4-1
4-2. CONTROL HIERARCHY.....	4-3

CHAPTER 1

INTRODUCTION

1-1. OVERVIEW

This manual provides information needed by an operator to use a SPEEDTRONIC™ Mark V Control Panel's operator interfaces to issue commands to the control panel and monitor the operation of a turbine and driven device. It discusses methods for selecting operating modes, controlling the turbine and driven device, viewing, acknowledging, and resetting alarms, modification and configuration of displays used primarily by operators, and log printouts associated with turbine system operation.

This manual is intended to supplement the Operator's Manual which is written for the overall turbine system. It does not cover maintenance displays nor specific operating details of each application or installation. Maintenance personnel should refer to the SPEEDTRONIC Mark V Turbine Control Maintenance Manual (GEH-5980) and the turbine and driven device associated drawings, specifications, schematics and diagrams.

1-2. PRIMARY OPERATOR INTERFACE (<I>)

The primary operator interface (<I>), consists of a color monitor, keyboard, cursor positioning device (CPD) (that is, a mouse, a trackball, or a touch-screen monitor), printer(s), and central processing unit (CPU). These items are collectively referred to as the <I>. These devices are connected to the Mark V Control Panel via an ARCNET cable. The devices can be located in the installation's central control room or a gas turbine's control compartment.

One <I> can be used to control as many as 8 gas and/or steam turbines; also more than one <I> may be used to control a turbine. The operator can thereby select the units he wishes to monitor or issue commands to. All <I>s are capable of issuing commands to a unit at any time while communicating with Mark V Control Panels. For the purposes of this manual, it is assumed that the <I> is controlling a single turbine and driven device.

Using the <I>, commands may be issued to the turbine and driven device (for example, START, STOP, COOLDOWN ON, AUTO, RAISE SPEED/LOAD, and so on) and displays may be accessed to view the status of the turbine and driven device (for example, ALARMS, WHEELSPACE TEMPERATURES, VIBRATION FEEDBACK, and so on). The associated printer(s) enable the operator to manually select and copy any display, to automatically log selected parameters, and to log alarms.

The <I> performs no control or protection functions of the turbine and driven device; it is a means of issuing commands to the Mark V Control Panel and monitoring unit operation. Turning the <I> off, turning the computer on, re-booting the computer, or disconnecting or reconnecting the ARCNET cable linking the Mark V Control Panel and the <I> (while the turbine and driven device are operating) will have no effect on the Mark V Control Panel or unit operation.

1-3. BACKUP OPERATOR INTERFACE (<BOI>)

A second means of issuing commands and monitoring turbine and driven device operation is supported through a Backup Operator Interface or <BOI>. The <BOI> is typically mounted on the door of the Mark V Control Panel enclosure where it may be implemented in the event of a loss of communication between the <I> and the Mark V Control Panel.

The <BOI> may be used to start, load/unload, and/or stop the turbine and driven device. The <BOI>'s LCD screen is composed of two lines of 40 characters each. It can be used to view alarms and monitor turbine and driven device operation.

Turbine and driven device commands may be issued at any time from the <BOI> regardless of the status of the <I> and/or its communication link. This is a "Peer to Peer" control system: All operator interfaces can issue commands equally. The most recently issued command - from any interface (<I> or <BOI>) - will be the current status of the control system.

1-4. CONVENTIONS USED IN THIS MANUAL

The following sections define the conventions used in this manual to help the audience better understand the information provided.

1-4.1. Cursor Positioning Conventions

In order to operate and monitor a turbine and driven device using the Mark V's <I>, the operator will select displays, commands, and functions with the cursor positioning device. The cursor positioning device may be a computer mouse, a track-ball, or a touch-screen monitor. When using the mouse or trackball to "point" at the desired display, command, or function, the operator initiates the action by depressing the left-most button of the mouse or track-ball one time; this action is known as "clicking" the device. "Point and click" or "click" means to use the cursor positioning device to move the cursor to point at the display or target on the screen and depress the left button of the device one time. To "point and click" with a touch-screen monitor, the operator would physically touch a point on the screen. The on-screen cursor will move directly to the point of contact and the "clicking" action will take place when the finger is removed.

1-4.2. Keyboard Conventions

The <I> keyboard keys are printed in a different typeface, for example, the F1 key would be **F1**. When keys are to be pressed simultaneously, they will be shown with a " + " between them. For example, ALT+F11 means to press and hold down the ALT key and then (simultaneously) press the F11 key.

Additionally, there are eight display targets, maximum, at the bottom of the screen on any display. Any of the display targets at the bottom of the screen can be activated by pointing and clicking on that target in the display.

CHAPTER 2

THE PRIMARY OPERATOR INTERFACE

2-1. INTRODUCTION

The <I> is used to control a turbine and driven device, as well as obtain and log data about the status of equipment. The operator can choose from a number of pre-defined and user-configurable displays from the Main Menu (refer to Figure 2-1) and from the user-defined Display Menu (refer to Figure 2-2) by using the cursor positioning device to point and click to the desired display. The operator can quickly return to the Main Display or the Alarm Display from any display or menu by pointing and clicking on the Main Display or the Alarm Display targets at the bottom of the screen. The Main Menu can also be accessed from any display (except the Alarm Display) by pressing the ESC key on the keyboard.

Two types of alarms (Diagnostic Alarms and Process Alarms) and two types of events (Contact Inputs and Events) are logged to the printer(s) for historical purposes. Additionally, most gas turbine applications will log emissions-related data to the printer(s).

2-2. STARTING THE <I>

With the <I> system properly connected to the Mark V Control Panel via the stage link, the operator can issue commands to and receive alarms from the Mark V Control Panel. The order in which the individual <I> devices are energized is not critical.

When the <I> has completed its initialization routines and internal power-up diagnostics, it is ready to issue commands or monitor the turbine and driven device through the SPEEDTRONICTM Mark V Control Panel. At this point, the display defined as the "Main Display" (see Figure 2-3) will appear on the screen. Any subsequently annunciated alarms or data logging will be recorded/logged on the printer(s). The operator may then use the cursor positioning device and/or the function buttons to change displays, issue commands to and manage any alarms from the Mark V Control Panel.

Re-starting or "rebooting the <I> can be accomplished by pressing and holding down the CTRL+ALT+DEL keys in that order for approximately one second. This action causes the computer's internal microprocessor to re-initialize itself, perform its internal diagnostics, and re-establish communications with the Mark V Control Panel using the configurations stored on the computer's hard-disk.

2-3. MAIN MENU

The Main Menu is a list of displays (including the user-defined Display) that an operator and/or a maintenance technician can use to access information about the unit and/or driven device. To view the Main Menu from any display or sub-menu, press the ESC key at least once. To view one of the displays listed, point and click on the desired display. In succession, the following figures show Main Menus for gas turbine various applications. As the Mark V Turbine Control System allows a great deal of flexibility, these examples should be considered generic in nature and not patterns or prototypes that should be copied or emulated. The Main Menu can be configured by authorized personnel only. See Maintenance Manual GEH-5980.

DEMO UNIT UNIT T1	MAIN MENU Page 1	25-FEB-1993 16:30:28
POINT AND CLICK ON THE DESIRED DISPLAY.		
--- DISPLAY PROGRAMS --- User Defined Display Menu Logic Forcing Display Prevote Data Display Diagnostic Alarm Display Trip History Display Timers/Counters	--- UTILITY PROGRAMS --- Timeset Unit Card Identification Total Job Compiler Control Sequence Documentor (NOTE: Requires 1 to 2 hours to complete)	
--- OPERATING DATA --- Exhaust Thermocouples Wheel-space Thermocouples Vibration Levels	--- MARK V CONFIGURATION --- Control Sequence Editor Control Sequence Compiler I/O Configuration Editor Control Constants Adjust EEPROM Downloader Password Administration Metric Display Scaling English Display Scaling	
EXIT ALT+X	NEXT PAGE	ALARM DISPLAY MAIN DISPLAY

Figure 2-1. A Typical Main Menu

LTRA SYSTEMS UNIT S1	MAIN MENU Page 1	25-FEB-1993 19:28:17
POINT AND CLICK ON THE DESIRED DISPLAY.		
--- CONTROL DISPLAYS --- Control Mode Pre-Roll Warming Speed Setpoint Load / Load Limit Megawatt Control IPC and IPL Intercept Valves Exciter Interface Auto Synchronizing On-Line Valve Tests On-Line Tests Off-Line Tests Turning Gear Interface	--- DISPLAY PROGRAMS --- User Defined Display Logic Forcing Display Pre-vote Data Display Diagnostic Alarms	
--- MOV INTERFACE --- Stop Valve Drains Reheat Stop Valve Drains Steam Seal & Misc	--- DEMAND DATA DISPLAYS --- Trip Logic Speed Signals Proximity Monitoring 4-20mA Inputs Bearing Temp Monitoring RTD Monitoring TC Monitoring MOV's - General Info Trip History Display	
EXIT ALT+X	NEXT PAGE	ALARM DISPLAY MAIN DISPLAY

Figure 2-2. A Typical Main Menu - Continued

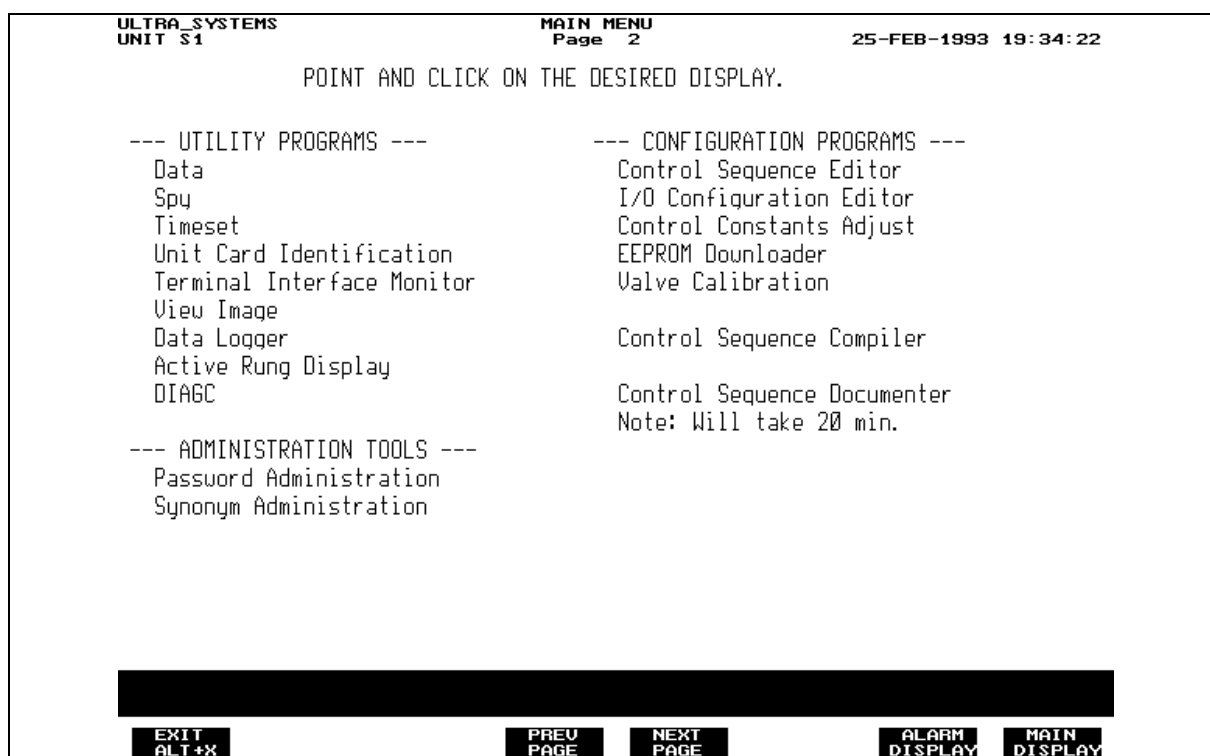


Figure 2-3. A Typical Main Menu - Continued

2-4. MAIN DISPLAY

The Main Display is intended to be the display the operator primarily uses to monitor the operation applications. It can be immediately accessed from any display by clicking on the "Main Display" target below the alarm window. The Main Display may either be a user-defined or animated display, according to the customer's requirements, see the Application Manual GEH-6195. The Main Display shows key turbine parameters and the main commands necessary to operate the turbine and driven device. The examples immediately below depict (in succession) Gas (two pages) and Steam (one page) Turbine Main Displays. As the Mark V Turbine Control System allows a great deal of flexibility, these examples should be considered generic in nature and not patterns or prototypes that should be copied or emulated.

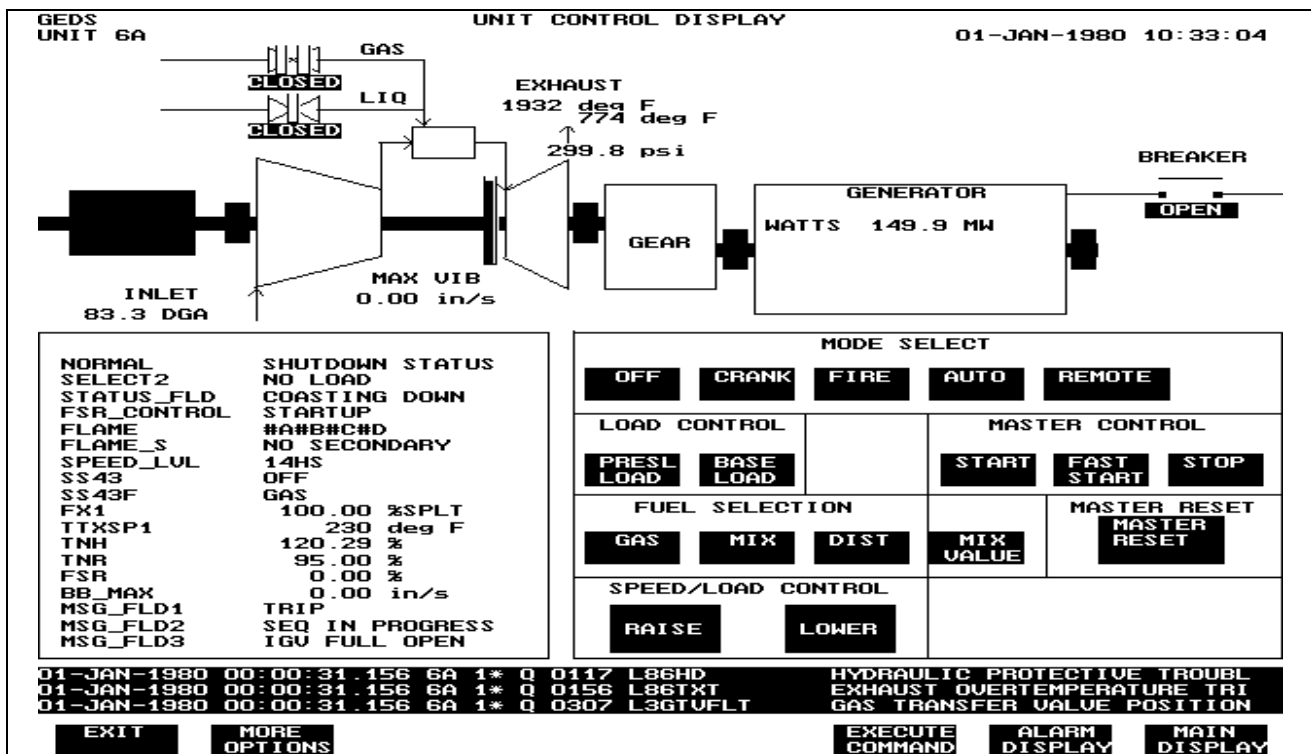


Figure 2-4. A Typical Main Display

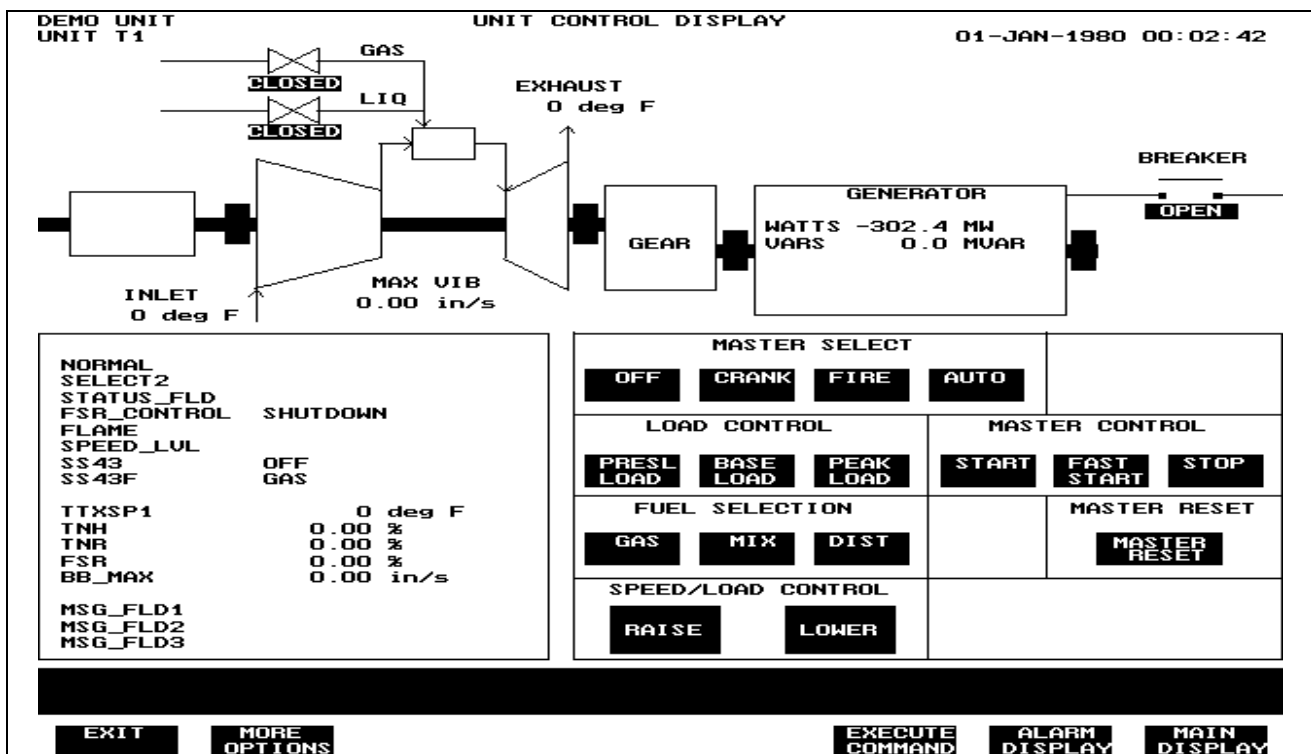


Figure 2-5. A Typical Main Display - Continued

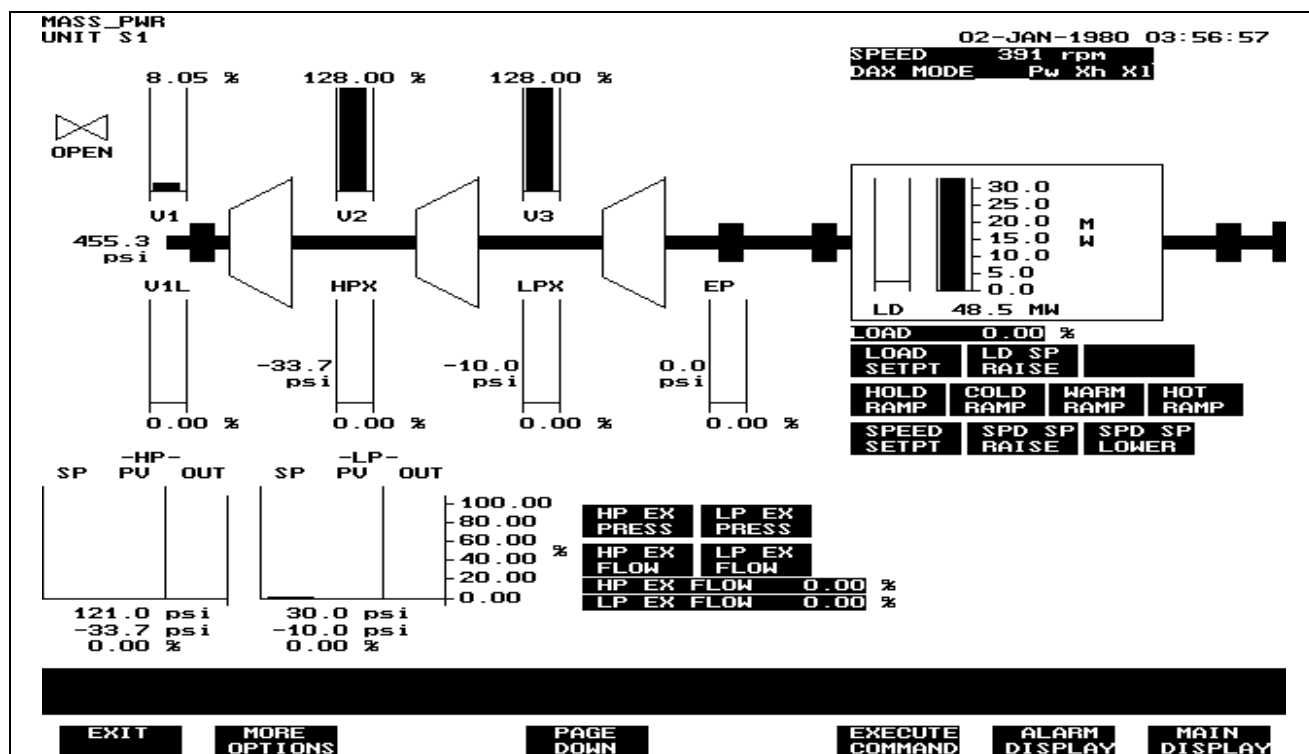


Figure 2-6. A Typical Main Display - Continued

2-5. MAIN MENU DISPLAYS AND FUNCTIONS

The following Main Menu displays and functions are used to manage access to or modify features of the <I>.

2-5.1. Password Administration

Operators, technicians, and service personnel can be permitted to access or use certain features of the SPEEDTRONIC™ Mark V's <I> through the use of passwords. In order to modify a control constant or force a logic point, for instance, the user must first gain access to the program/feature by enabling the current status of an appropriate Password Level. This is done by entering the proper password in the Password Administration Display of the Main Menu. Up to five levels of access, or privileges, to various functions can be protected by password(s). Password levels and the corresponding features they control are defined below:

OPERATOR	Allows the use of the Logic Forcing feature.
MAINTENANCE	Allows the use of all Customer-level features (see Table 2-1), plus operator privileges.
SUPERVISOR	Allows the setting of the Customer-level passwords by Customer's Supervisor(s).
SERVICE	Allows use of all Customer-level features (see Table 2-1); intended for use by GEDS, GE, and/or GE Business Associates Field Service personnel.

SUPPLIER Allows the use of all Customer-level features (see Table 2-1); intended for use by GEDS, GE, and/or GE Business Associates Factory personnel.

Sitename		PASSWORD ADMINISTRATION				29-MAY-1992 10:03:07	
PASSWORD LEVEL	CURRENT STATUS		BOOTUP STATUS				
OPERATOR	ENABLE	DISABLE	ENABLE	DISABLE			
MAINTENANCE	ENABLE	DISABLE	ENABLE	DISABLE			
SUPERVISOR	ENABLE	DISABLE	ENABLE	DISABLE			
SERVICE	ENABLE	DISABLE	ENABLE	DISABLE			
SUPPLIER	ENABLE	DISABLE	ENABLE	DISABLE			

EXIT
ALARM DISPLAY
MAIN DISPLAY

Figure 2-7. Password Administration with Operator Level Current & "BOOTUP" Status Enabled

All of the Password levels' Current and "BOOTUP" Statuses should be disabled if the users are not to have access to Logic Forcing, Control Constant adjustment, the Control Sequence Editor, and other such features. For example, to enable a new password level the user should access the Password Administration display from the Main Menu, click on the **ENABLE** target of the desired level, type in the correct password and press ENTER. If the proper password is entered, the **ENABLE** target's background will change to white and privileges will be enabled. As a suggested procedure, the user should remove the Password privileges after completing the assigned task(s).

2-5.1.1. PASSWORD LEVELS AND THEIR PRIVILEGES. Table 2-1 explains the view/modify privileges of the various password levels. Privileged view and/or modification of the various features is permitted when the current status of the appropriate password level is enabled. For more information on each feature, refer to the appropriate Mark V documentation.

Access/Use Privilege	OPERATOR	MAINTENANCE	SUPERVISOR	SERVICE	SUPPLIER
Control Constant Adjustment	v	v, m	v	v, m	v, m
Logic Forcing	v, m	v, m	v	v, m	v, m
EEPROM Upload/Download		v, m		v, m	v, m
Control Sequence Program Editor		v, m		v, m	v, m
Control Sequence Program Compiler		v, m		v, m	v, m
Control Sequence Program Documenter		v, m		v, m	v, m
I/O Configurator		v, m		v, m	v, m
Table Compiler		v, m		v, m	v, m
I/O Modification Utility		v, m		v, m	v, m
Spare Signal Pointname Editor		v, m		v, m	v, m
Control Lockout	v, m	v, m	v, m	v, m	v, m
Exit to DOS Command Line		v, m		v, m	v, m

Table 2-1. Privileges of the Five Password Levels
v = view, m = modify

2-5.1.2. ENABLING/DISABLING CURRENT STATUS. Figure 2-7 shows two Status columns (CURRENT and "BOOTUP") for each password level. Current Status refers to the present status of a password level and "BOOTUP" status refers to the status of the password level on startup or "re-boot" of the <I>. The targets with white backgrounds indicate the levels are currently enabled/disabled. Click on the desired **ENABLE** target to enable the current status of a password level. When a white rectangle appears under the password level's name, type in the password for that level and press **ENTER**. (Asterisks will be displayed as the password is typed in for security purposes). If the correct password was entered, the **ENABLE** target's background will become white and the white background of the password level's name will disappear. If the wrong password was entered, the white background of the password level's name will disappear and the **DISABLE** target's background will turn white.

To return to the Main Menu and save the present status of the password levels, click on the **EXIT** target at the bottom of the Password Administration Display. Click on the **DISABLE** target to disable that level. (It is not necessary to know a level's password in order to disable it.)

2-5.1.3. SETTING OR CHANGING PASSWORDS. The following table should be helpful in understanding which passwords can be set by each of the three password-setting levels.

Password Changing Privileges	SUPERVISOR	SERVICE	SUPPLIER
Change Operator Password	X	X	X
Change Maintenance Password	X	X	X
Change Supervisor Password	X	X	X
Change Service Password		X	X
Change Supplier Password			X

Table 2-2. Password-Changing Privileges of Three Password-setting Levels (Supervisor, Service, and Supplier)

Table 2-2 shows that passwords for the Operator, Maintenance, and Supervisor levels can be set by anyone with knowledge of the Supervisor, Service, and/or the Supplier passwords. Setting or changing a particular level's password requires the Current status of an appropriate password level be enabled. For example, changing the Supervisor level password requires that the Current status of either the Supervisor, Service, or Supplier levels be enabled. If one of these password levels is enabled, pressing **CTRL+S** and clicking on the **SET NEW PASSWORD** target of the Supervisor level will cause a white rectangle to appear under the password level name. Typing in the new password will cause the text to appear in the white rectangle. When the new password is confirmed, press **ENTER**. The white rectangle beneath the password level name will disappear to indicate the new password has been accepted. All future attempts to enable the Supervisor Password level require entering the new password. Clicking on the **EXIT** display target at the bottom of the display will save the present statuses and passwords and return the user to the Main Menu.

2-5.1.4. ENABLING/DISABLING THE BOOTUP STATUS. If the background of the **ENABLE** target of a password level's "BOOTUP" status is white, access to the programs/features of the <I> for that password level will be permitted (at any time) after a startup or "re-boot" of the <I>. For example, when the Current and "BOOTUP" statuses of the Operator password level are disabled and enabled respectively, the next startup or re-booting of the <I> enables both the "BOOTUP" and current status.

The "BOOTUP" status of any password level may be enabled/disabled as long as the concurrent or higher level current status function is enabled (the user must know the appropriate password for the desired level, or a level higher than is required). For example, enabling the Supervisor "BOOTUP" status requires that either the Supervisor, Service, or Supplier current status function be enabled. If the correct current status level has been enabled, the "BOOTUP" status may be turned on or off by clicking on the function's **ENABLE/DISABLE** targets respectively.

Clicking on the **EXIT** display target at the bottom of the display will save the present statuses of the various password levels to the <I>'s hard-disk and return the user to the Main Menu.

2-5.1.5. EXAMPLES AND NOTES. To maintain the operational integrity of the <I>, set and maintain unique Operator, Maintenance, and Supervisor password levels.

NOTE

The Supervisor, Service, or Supplier password levels should not be left enabled in either Current or "BOOTUP" status at any time as this would permit changing of the Operator, Maintenance, and/or Supervisor passwords by anyone.

If the Current status of a particular password level is enabled and its "BOOTUP" status is disabled, startup or "re-booting" the <I> will disable the Current status of that password level.

NOTE

Access to the DOS command line is allowed when the Current status of the Maintenance password level (or above) is enabled.

When the Maintenance password level is enabled a grey target will appear at the lower left-hand corner of the Main Menu screen. When this target is visible, pressing ALT + X will exit the user to the DOS command line. (Clicking on the dark grey rectangle will not permit access to the DOS command line.)

Access to the DOS command line of the <I> should be permitted only for maintenance, troubleshooting, or configuration purposes as required. Novice users executing certain DOS commands from the DOS command line can erase files in directories or the entire hard-disk. Also, software can only be loaded onto the <I> by typing in commands from the DOS command line. Disks containing computer viruses used to load software onto the computer and/or programs containing viruses loaded onto the <I> can impair the computer's ability to: 1. monitor turbine and driven device operation, 2. issue commands to a unit, and 3. annunciate unit alarms.

2-5.2. Time Set

The Mark V panel clock may be reset to reflect the time kept by the <I> processor. This update is accomplished by clicking on the TimeSet Menu target.

Time can be configured to send the <I>'s time to all Mark V Control Panels or just selected ones. It can also be set to automatically send a TimeSet command at preset intervals.

2-5.3. Synonyms

Control Data Base (CDB) signal pointnames used in the Mark V are intended to be descriptive acronyms. Examples of these pointnames are L52GX, a logic signal associated with the status of the generator breaker (52G); TNH, the percent of high-pressure turbine shaft speed; and CPD, the axial compressor discharge pressure. To the experienced individual these signal pointnames are meaningful and easily recognizable. The Synonym function of the <I> aids the operator and/or technician by allowing the individual to substitute a more recognizable mnemonic or acronym for the Mark V signal pointname. For example, the value associated with TNH (HP turbine shaft speed) could be displayed as "HP_SPEED". When the synonym function is enabled, the CDB signal pointname or the synonym can be used when adding points to a display (either user-defined Displays or animated displays). Synonyms can be defined and edited by authorized personnel only. (See Maintenance Manual GEH-5986.)

2-5.3.1. HOW TO ENABLE/DISABLE SYNONYMS. When the <I> is powered-up or "re-booted", the Data Dictionary Loader program searches the unit-specific directory for a SYNONYM.DAT file. If the file is found, its contents are loaded into the computer's Random Access Memory (RAM) and the synonyms are displayed in various screens by default. Any signal pointname which has a synonym defined file will be replaced by the its synonym on any display which it appears. The operator may enter either the signal pointname or the synonym when adding points to a display (either user-defined displays or animated displays). If a synonym exists in the <I> RAM, the synonym will replace the CDB signal pointname on the display when it is entered.

The display of synonyms can be temporarily disabled by accessing the Synonym Administration Display from the Main Menu and clicking on the DISABLE target. The display of synonyms will be disabled until the <I> is "re-booted" or the ENABLE target of the Synonym Administration Display is clicked on.

2-6. COMMON DISPLAY FIELDS

Common elements of each display include the display message field, the alarm window, and the display targets (refer to Figure 2-9). These non-configurable elements are described below.

2-6.1. Display Message Field

The area at the top of the screen is used to give the operator information about the display being viewed.

- **SITE NAME/DESIGNATION.** The site name/designation defined at the time of shipment is shown in the upper left-hand area of the screen.
- **DISPLAY GROUP/MENU NAME.** The name of the display group or menu currently being viewed on the monitor is shown in the upper center area of the screen.
- **DATE AND TIME.** The system date and time is shown on the monitor in the upper right area of the screen.
- **CURRENT DISPLAY DEFINITION.** The name of the current or most recently viewed display is shown on the monitor in the area just below the Site Name/Designation.

2-6.2. Alarm Window

The blue "bar" near the bottom of each display is the Alarm Window. Displayed in this area are the first three unacknowledged alarms, their dates, times, unit numbers, alarm statuses, acknowledgement statuses, drop numbers, and alarm messages. If more than three unacknowledged alarms have been annunciated, only the oldest three unacknowledged alarms will appear in the Alarm Window.

2-6.3. Display Target Field

Below the Alarm Window may be as many as eight "display" targets whose functions can be selected using the CPD device. Two display targets common to all displays are EXIT and MAIN DISPLAY. Pointing and clicking on the MAIN DISPLAY display target will return the Main Display to the monitor's screen. Additionally, an ALARM DISPLAY display target is available on every menu or display except the Alarm Display itself. Pointing and clicking on the ALARM DISPLAY display target will immediately dump to the Alarm Display. Clicking on the MORE OPTIONS display target (when present) will provide the operator with more display targets/choices.

2-6.4. Unit Command Targets

Displays available through the user-defined Display Menu have Unit Command Target Fields on the right-hand side of the screen (refer to Figure 2-9). Examples of unit commands could include:

- START
- STOP
- CRANK
- RAISE SPD SET

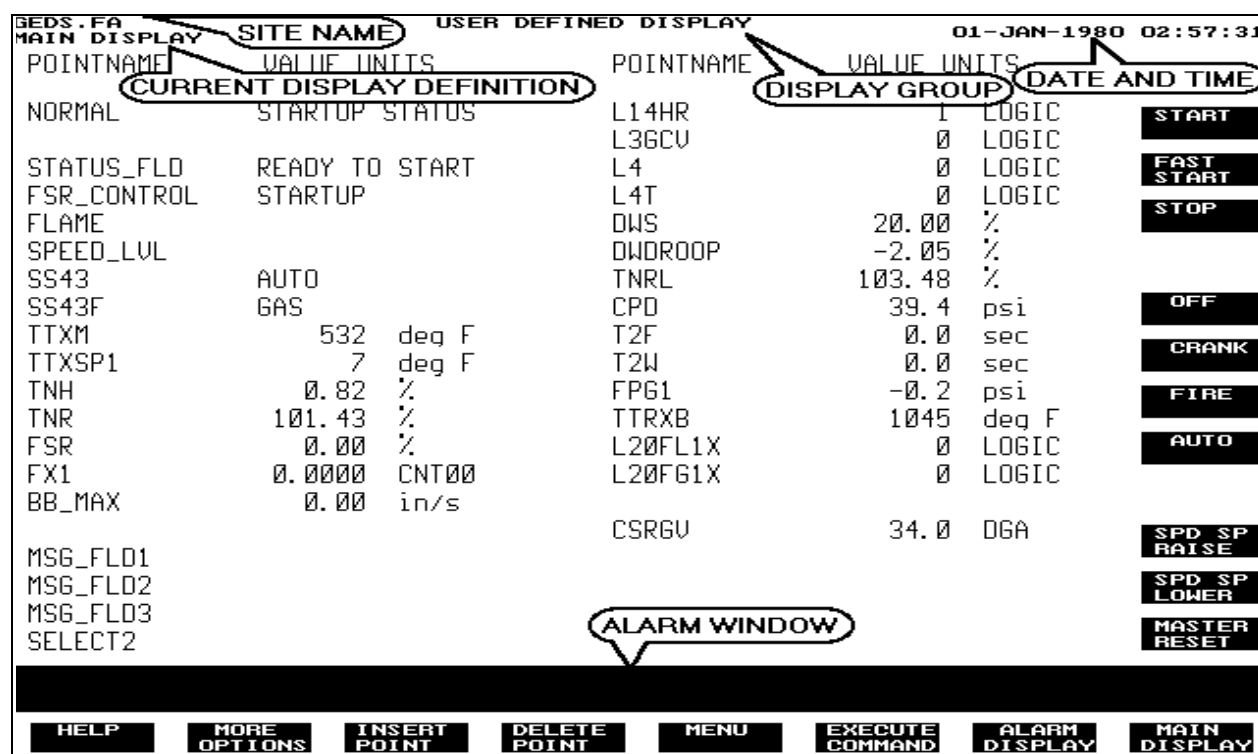


Figure 2-9. Example of a User-Defined Display Showing Alarm Window

There are three types of unit command targets:

1. **ARM/EXECUTE TARGETS.** Displayed with a green background with black text, these command targets require an arm/execute action to send the command to the Mark V Control Panel. For example, to initiate a turbine start from the Main Display, position the cursor on the START command target and click. The target background turns cyan (light blue) to indicate that the target is armed. Next, move the cursor to the EXECUTE COMMAND target at the bottom of the display (in the Display Target Field) and click. The two target backgrounds, START and EXECUTE COMMAND, then turn magenta (light purple) to indicate the command was sent to the Mark V Control Panel. When the START command is acknowledged by the Mark V Control Panel, the command target background reverts to green and the text in the target changes to yellow. These color changes indicate the command was accepted and is being implemented.
2. **IMMEDIATE ACTION TARGETS.** Displayed on red background with black text, immediate action targets send commands to the Mark V Control Panel immediately. That is, they do not require an arm/execute action. This type of target is used for commands where an arm/execute action is not required. For example, the RAISE SPD SET (increase the speed setpoint) is enabled by pointing and clicking on the RAISE SPD SET command target. Once selected, the text of the target changes to yellow to indicate that the command is being acknowledged by the Mark V Control Panel. This text reverts to black when the command sequence is completed.
3. **SETPOINT TARGETS.** Displayed with a grey background and black text, setpoint command targets require an arm/execute action to send a setpoint change command to the control panel. Arming a setpoint target entails clicking on it with the CPD device. When selected, the background of the target turns cyan. At this point, the user types in the new value for the setpoint, which appears on the second line of the target. After the desired value is inserted, clicking on the EXECUTE COMMAND target on the bottom of the display will cause the

backgrounds of the two targets to change to magenta. This color change indicates the command was sent to the control panel and was acknowledged. The setpoint or reference increases or decreases to the new value at a pre-programmed rate.

2-7. USER-DEFINED DISPLAYS

User-Defined Displays are displays that can be altered to conform to the user's needs. The sections that follow define, describe, and instruct the user in the use of User-Defined Displays.

2-7.1. User-Defined Display Menu

The User-Defined Display Menu is a list of alterable displays that **does not** include Animated Displays. These displays are typically known as "Demand" displays. Any Demand display may be selected from the User-Defined Display Menu by pointing and clicking on the desired display with the CPD. Figure 2-9 shows an example of a User-Defined Display Menu.

2-7.2. User-Defined Display Body

The main body of each User-Defined Display (other than the Main Menu or the User-Defined Display Menu) is actually a list of up to 40 pointnames and (if applicable) their associated values and units. This information is arranged in two columns of 20 pointnames each. Pointnames can be added or deleted from the display body by the user. Pointnames can be logic (for example L1START_CPB, L4QAZ, L63TK1L, and so on) or variable (TTXSP1, FSR, CPD, and so on) data points, message points (for example SS43, STATUS_FLD, FLAME, and so on), or annotations (for example TURBINE #1, SRV VALVE, REHEAT VALVE, and so on).

NOTE

Changes to the display body of any display are not saved in the <I>'s memory unless the user performs a DISPLAY UPDATE from the User-Defined Display Menu immediately after modifying the display. Changes to the display body of any display saved to the <I>'s memory are not saved permanently to the hard disk files until the operator performs a SAVE FILE operation; this must be done before leaving the User-Defined Display program. See section 2-7.3.5 for details for permanently changing the display body.

2-7.3. User-Defined Display Modifications

User-Defined Displays may be modified by adding or deleting pointnames. User-Defined Displays may also be added to or deleted from the User-Defined Display Menu. Procedures for the User-Defined Display modifications are described in the paragraphs below. Refer to the flowcharts in the accompanying figures for a quick step-by-step procedure for modifying User-Defined Displays.

2-7.3.1. ADDING A POINTNAME. To insert a pointname or notation in the body of a User-Defined Display, point and click on the display's INSERT POINT target. The background of the target will change to yellow to indicate the target is enabled. Using the CPD, point to the location in the body of the display where the new pointname or notation is to be inserted and click. The background of the INSERT POINT display target reverts to white and a white rectangle will appear on the display in the location chosen. Using the keyboard, enter the desired pointname or notation and press **ENTER**. The notation or the pointname and its value and units will appear on the display. Refer to Figure 2-10 for a flowchart of the steps involved in adding a pointname to a User-Defined Display.

Multi-unit <I> functionality permits points from more than one unit to be inserted into a single Demand Display. To enter a point from a unit that is currently not selected, repeat the steps above but be sure to add a unit specifier before the pointname. This added parameter should include the unit designation, which should be in turn followed by a colon and the pointname (for example T1:TTXMV4). When the point is displayed, the unit designation will also be shown.

Each time a new pointname is inserted, the pointnames below it scroll down one position. When the forty-first pointname is added to the display (counting any blank spaces inserted between pointnames) the pointname (or space) at the lower right of the body of the display **scrolls off the screen and is deleted from the display**.

To save pointname or notational additions to the display body, point and click on the MENU display target (this returns the User-Defined Display Menu to the screen). Check to see that the display named in the Current Display Definition field at the top of the screen is the name of the display just modified. If the display name is correct, point and click on the UPDATE DISPLAY display target (this action updates the Display/Menu files in the <I>'s memory).

NOTE

Modifications to the body of a user defined display will be lost if any display (including the Main Display) is viewed prior to performing an UPDATE DISPLAY action from the User-Defined Display Menu.

Modifications to a display or displays will be lost if the Main Display is viewed prior to performing a SAVE FILE action (refer to Section 2-9.4.).

2-7.3.2. DELETING A POINTNAME. To delete a pointname or notation from a display, point and click on the DELETE POINT display target. The background of the target will change to yellow to indicate the target is enabled. Using the CPD, point to the pointname or notation in the display body to be deleted and click. The selected notation or pointname will be deleted from the display. This method applies to multi-unit pointnames as well. Refer to Figure 2-11. for a flowchart of the steps involved in deleting a pointname to a User-Defined Display.

To save pointname or notational deletions from the display body, point and click on the MENU display target (this returns the User-Defined Display Menu to the screen). Check to see that the display named in the Current Display Definition field at the top of the screen is the name of the display just modified. If the display name is correct, point and click on the UPDATE DISPLAY display target (this action updates the Display/Menu files in the <I>'s memory).

2-7.3.3. ADDING A USER-DEFINED DISPLAY TO A MENU. To add a new display to a User-Defined Display Menu, switch to the desired unit by clicking on the unit specifier at the top right hand corner of the screen until the required unit is displayed. Click on any display in the User-Defined Menu. Repeat the steps outlined above in sections 2-7.3.1. and 2-7.3.2. to complete the necessary changes. Once the alterations to the display body have been made, click on the INSERT POINT display target and then click on the display title in the Current Display Definition Field at the top of the screen. The display title will change to reverse type. Enter in the new title using the keyboard (the BACKSPACE key erases the last character in the line; pressing CTRL+U causes the entire title to be erased from the field) and strike the keyboard ENTER key when finished (the title will be shown in normal fashion). Click on the MENU display target to return to the User-Defined Display Menu. From this display click on the UPDATE DISPLAY target. The new display will be added to the bottom of the current User-Defined Display Menu. To make the display addition permanent, click on the SAVE FILE display target. This will store the display addition on the <I>'s hard disk files. Refer to Figure 2-12 for a flowchart of the steps involved in adding a new display to a User-Defined Display Menu.

A User-Defined Display may be copied to multiple units within a multi-unit <I>.

2-7.3.4. DELETING A USER-DEFINED DISPLAY FROM THE MENU. To delete a display from the User-Defined Display Menu, click on the display to be deleted. A display cannot be deleted without first being viewed. Return to the User-Defined Display Menu by clicking on the MENU display target. The title of the display previously viewed will appear in the Current Display Definition Field. Click on the REMOVE DISPLAY display target. The name of the display just deleted will be removed from the User-Defined Display Menu even though it will still appear in the Current Display Definition Field. To

make the display deletion permanent, click on the SAVE FILE display target. This will store the deletion on the <I>'s hard disk files. Refer to Figure 2-13. for a flowchart of the steps involved in deleting a display from the User-Defined Display Menu.

2-7.3.5. MAKING MODIFICATIONS PERMANENT. To make changes to User-Defined Displays or the User-Defined Display Menu permanent **after** performing an Update Display action, click on the SAVE FILE display target **before** viewing the Main Display, the Alarm Display, or the Main Menu. This action saves the current User-Defined Displays and Menus from the <I>'s memory to the hard disk files.

2-7.3.6. COPYING USER-DEFINED DISPLAYS TO MULTIPLE UNITS. A screen that has been created or amended for a single unit (for example, T1) within a multi-unit <I>, can be copied to other units (for example T2, T3, and so on). This can be done by viewing the selected screen (this loads the screen in the screen buffer), exiting the screen to the User-Defined Display Menu, changing to the desired unit by clicking on the display's unitspecifier in the screen's upper right-hand corner, and then in succession executing the UPDATE DISPLAY and SAVE FILE commands. Copying the screen loaded in the screen buffer to subsequent units can now be accomplished by changing units and again executing the UPDATE DISPLAY and SAVE FILE commands.

NOTE

Performing a SAVE FILE action before executing an Update Display operation does not save any changes made to a display or the User-Defined Display Menu.

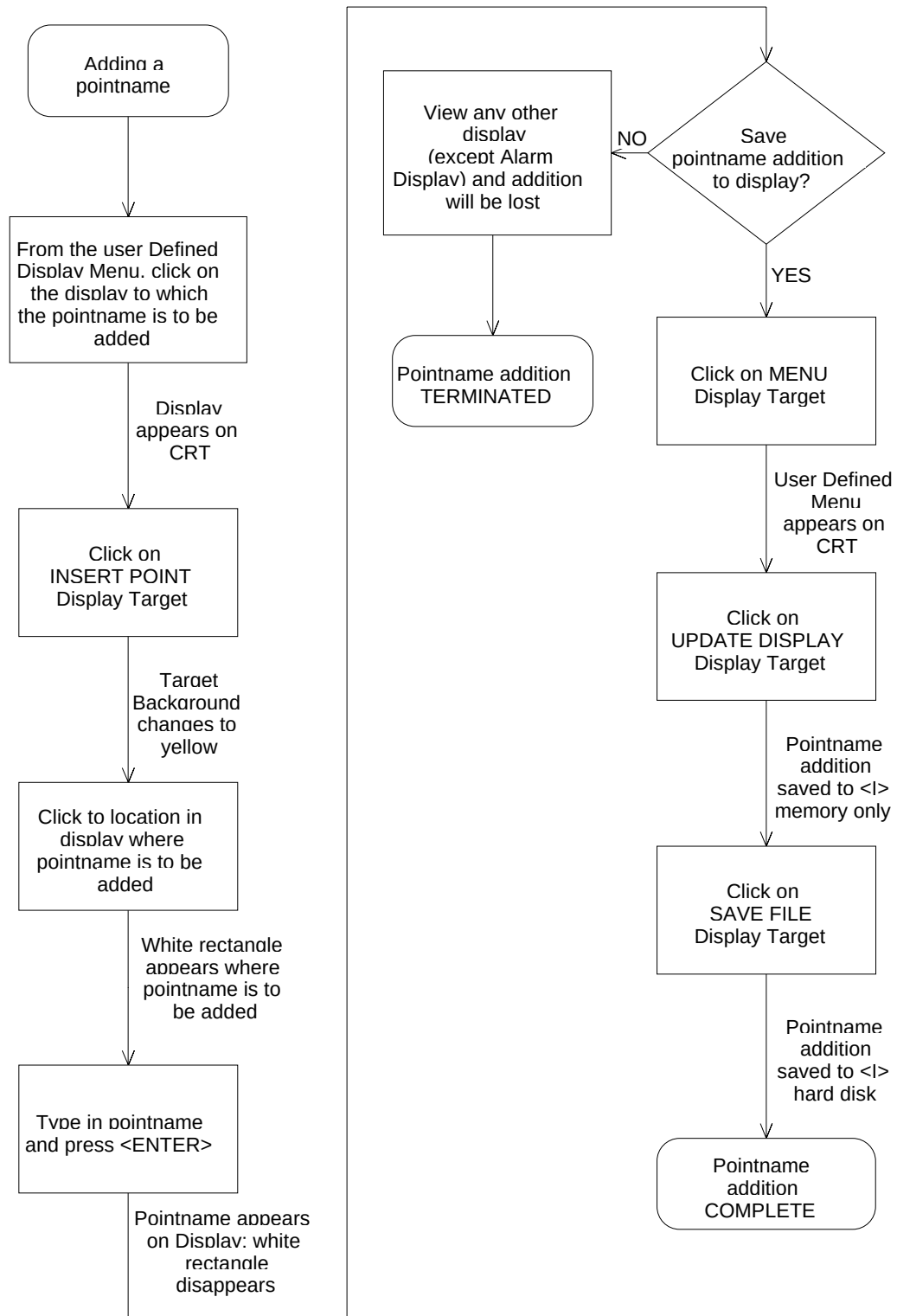


Figure 2-10. Steps Required for Adding a Pointname to a User-Defined Display

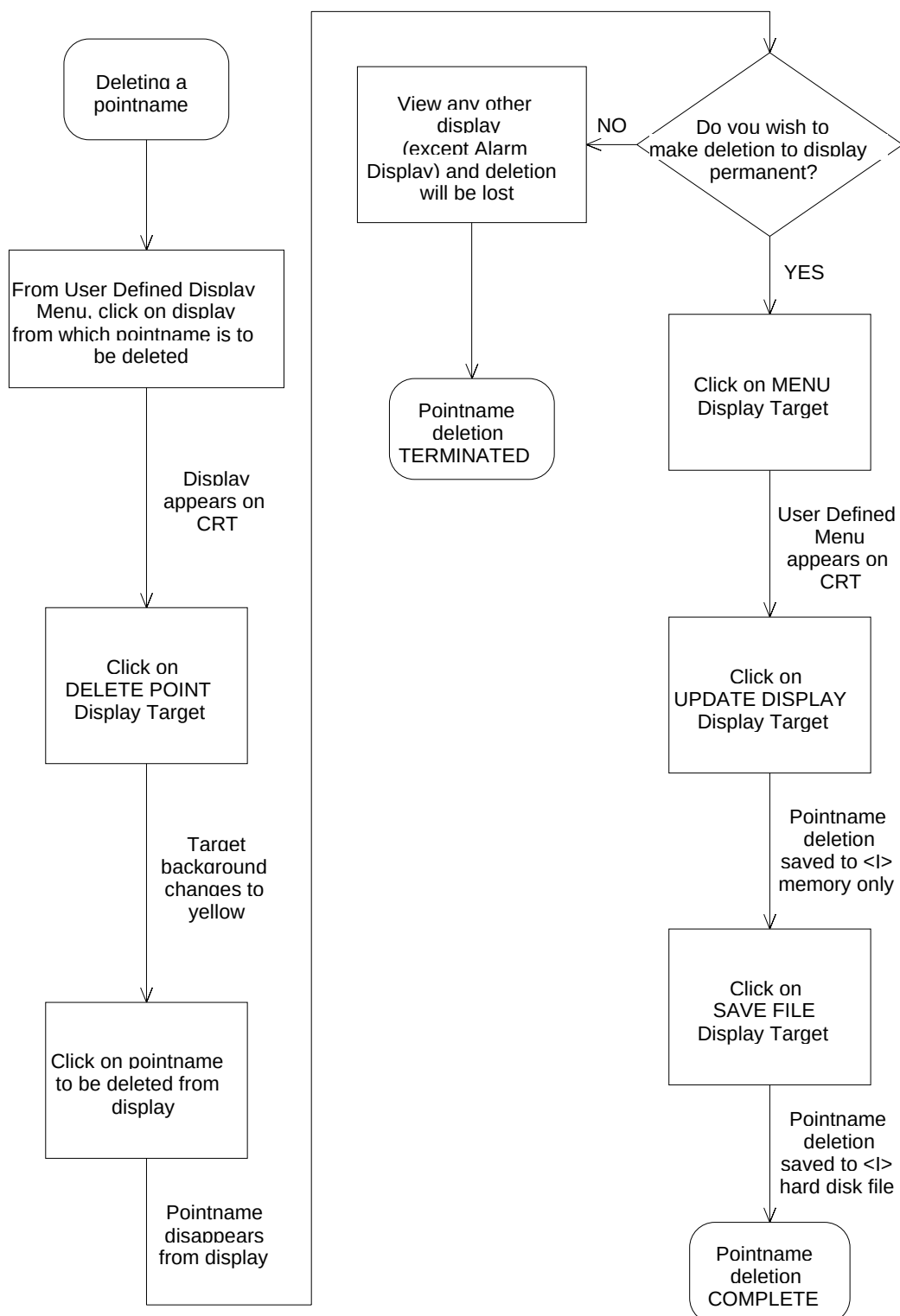


Figure 2-11. Steps for Deleting a Pointname from a User-Defined Display

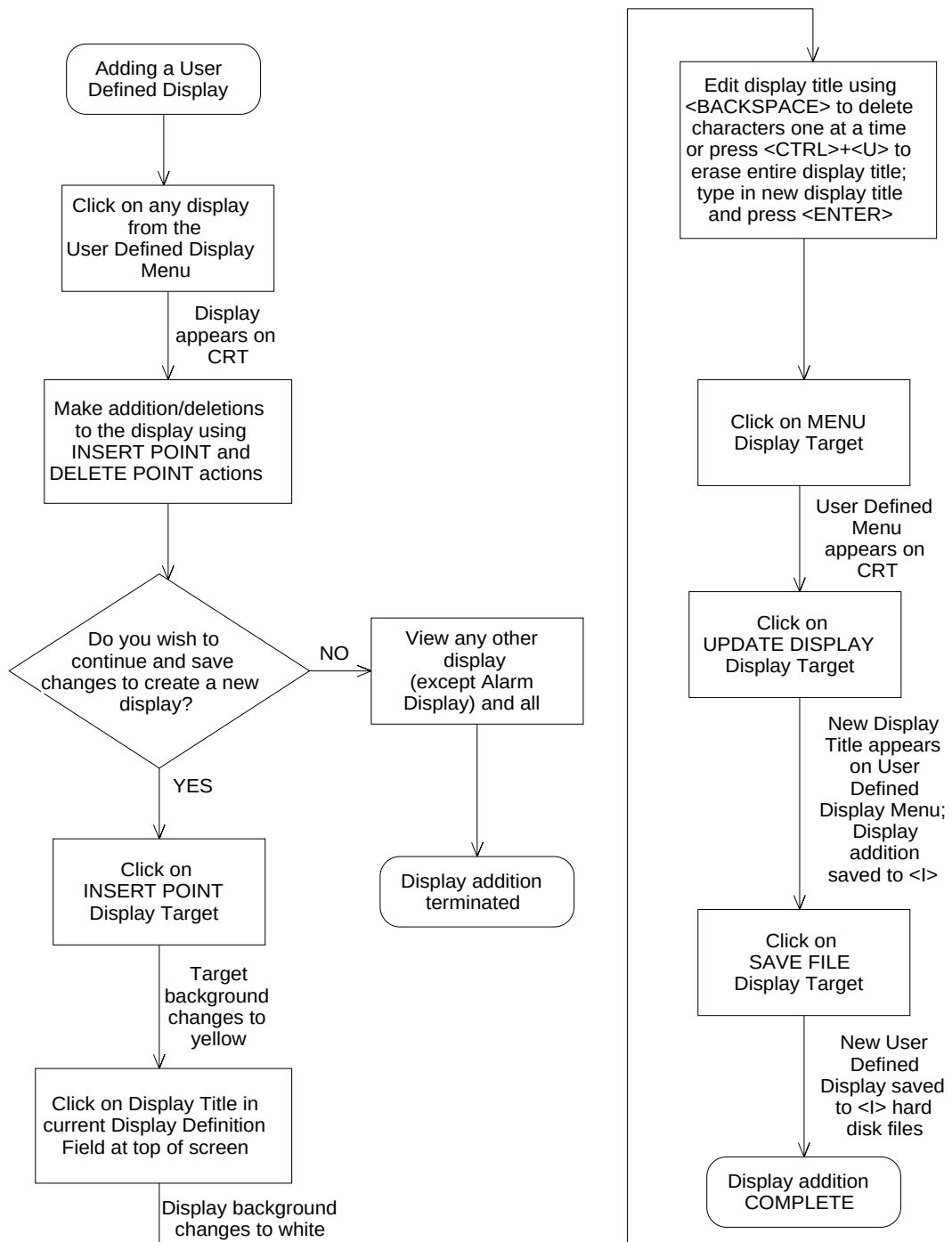


Figure 2-12. Adding a User-Defined Display to User-Defined Display Menu

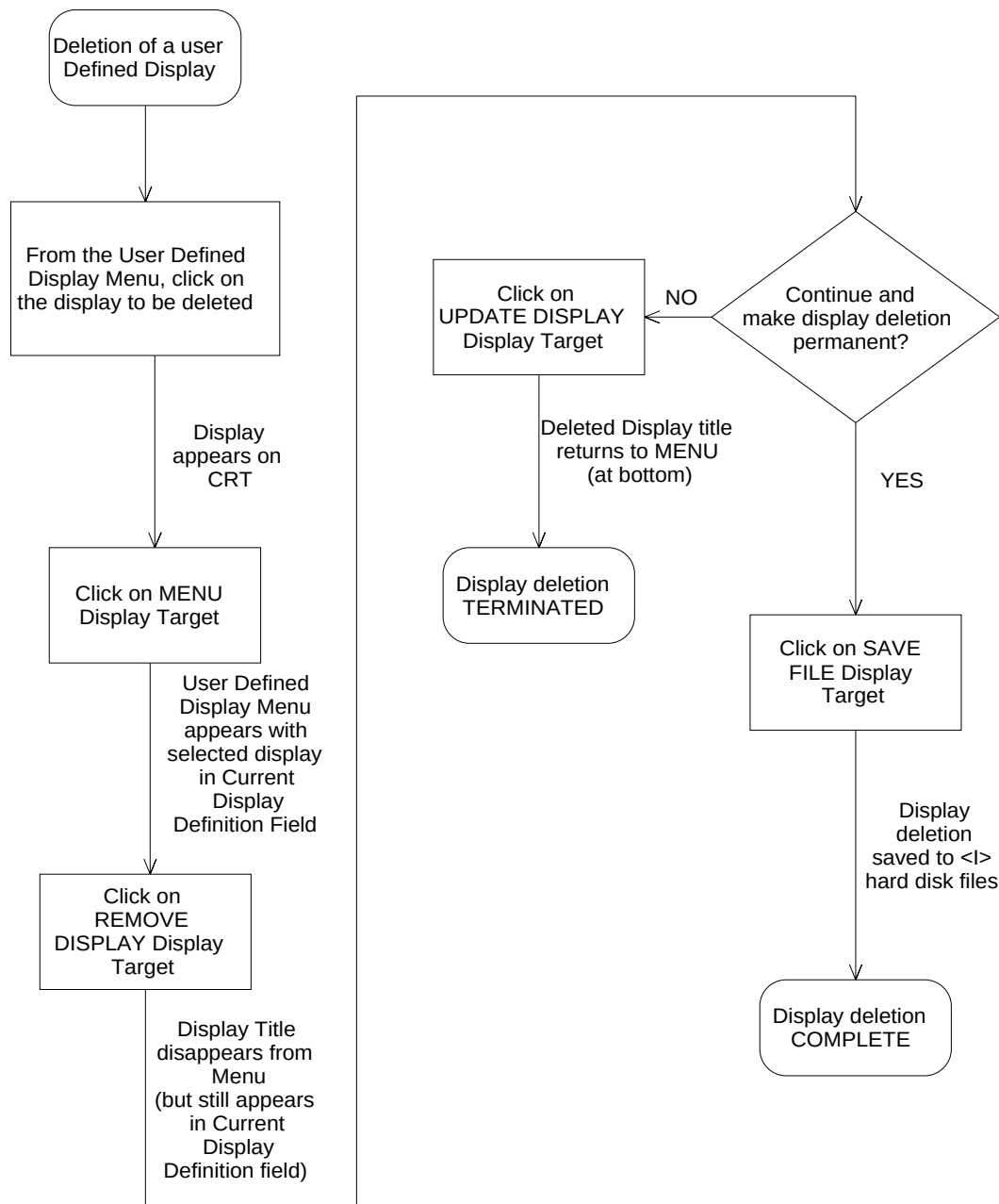


Figure 2-13 Deleting User-Defined Display from the User-Defined Display Menu

2-7.3.7. COMMAND TARGET ADDITIONS/DELETIONS. Command targets may be added or deleted from a User-defined screen by implementing the Edit Form function. To access the Edit Form screen, click on the MORE OPTIONS and EDIT FORM display targets in succession. The Edit Form screen for the current User-Defined Display (complete with the Alarm Window) lists the five groups of target definition fields for the 12 available target positions. The cyan fields are used to enter information for each command target. To enter information in a particular field, select it by clicking on it; the field background will change to white to indicate information may be typed in from the keyboard. Pressing ENTER or clicking on another field completes the action of typing information in a field. To correct, change, or delete information in a selected field, use the BACKSPACE key to erase one character at a time beginning with the last character on the line (pressing CTRL+U erases the field completely). The DATA DISPLAY and CHECK FORM targets are both unique to the Edit Form screen. Clicking on the DATA DISPLAY target returns the user to the current User-Defined Display. Clicking on the CHECK FORM target allows the user to check changes to the edited form for accuracy as the display highlights errors to modifications in yellow.

AUXILIARY CONTROL		USER DEFINED DISPLAY			
POINTNAME	VALUE TYPE AND VALUE "=+-"		FEEDBACK SIGNAL AND SENSE (0/1) UN: POINTNAME	TARGET TYPE "?!#"	TARGET NAME
UN: POINTNAME		1		2	
L43CD_ON_CPB Pushbutton	= 4	1		2	RATCHET ON
		1		2	
L43CD_OFFCPB Pushbutton	= 4	1		2	RATCHET OFF
		1		2	
		1		2	
L83DT_CMD Logic State	= 1 1 LOGIC	1	L4DE	2	DIESEL TEST ON
		1		2	
L83DT_CMD Logic State	= 0 0 LOGIC	0	L4DE	2	DIESEL TEST OFF
		1		2	
		1		2	
		1		2	

EXIT
DATA DISPLAY
CHECK FORM
SAVE IMAGE
ALARM DISPLAY
MAIN DISPLAY

Figure 2-14. Edit Form Screen

The five groups of fields for each command target are:

1. Command Pointname
2. Value
3. Feedback Signal (optional)
4. Target Type
5. Target Name

1. **Command Pointname Fields** - The two fields in this group indicate the unit name (in a multi-unit application) and the pointname of the logic signal which receives the command in the unit control panel. If the unit name field is left blank (it should be left blank when one or more <I>s are acting on a single unit control panel), the command will be sent to the current unit. The unit name field should only be filled in if there are commands which need to be sent to a different unit/location than the currently selected unit in a multi-unit installation.

Valid signal pointnames which can be acted on by command targets can be found in the UNITDATA.DAT file. After completing a command pointname entry, the user can verify the validity of the signal pointname which receives the command by clicking on the CHECK FORM display target. If the command pointname is valid, one of the four following messages will appear directly beneath the field: Pushbutton, Logic state, Analog setpoint, or Enumerated state.

If the entered signal pointname is invalid, executing the CHECK FORM function will cause it to be displayed with a yellow background or the error message "Not a command" to appear.

A pointname that is displayed with a yellow background indicates the <I> could not find a match in the Data Dictionary. A pointname that is found in the Data Dictionary but is not a valid signal pointname which can be acted on by a command target will cause the above error message to be displayed.

2. **Value Fields** - The Value and Value Type fields are used respectively to specify the actual value and value type that will be sent to the current unit control panel (this is for command targets which do not require the operator to enter in a setpoint or value when selected or executed).

The following represent the three valid value types:

- = For logic state, analog setpoint, and enumerated state command pointnames, this value type instructs the <I> to read the current value of the command pointname from the unit control panel into its memory, replace it with a value from the value field to the right, and send the new value to the unit control panel to be acted upon. If the command pointname is a pushbutton value, this value type tells the <I> to set and hold the command pointname equal to a logic "1" for the number of scans in the value field to the right. By default, when the command pointname is a pushbutton, the value type is set to " = " and the value field is set to " 4 " (meaning the pushbutton command pointname will be set for four scans of the unit control panel).
- + This value type can only be used with analog setpoint commands. Its function is to instruct the <I> to read the current value of the command pointname from the unit control panel into its memory, add the value from the value field to the right, and send the new value to the unit control panel to be acted upon.
- This value type is used in conjunction with analog setpoint commands; its function is to instruct the <I> to read the current value of the command pointname from the unit control panel into its memory, subtract the value from the value field to the right, and send the new value to the unit control panel to be acted upon.

Values entered and shown in the value field itself are hexadecimal values. When a value is entered into this field, the line directly below the field will contain the engineering units conversion of the hexadecimal value. This conversion will only be done if a valid command pointname has been entered into the command pointname field. **(It is not possible to enter a value in the value field in engineering units.)**

3. **Feedback Signal Fields** - When used, this option changes the color of the text of the command target to yellow based on the logic state of the command pointname. For example, the text of ARM/EXECUTE targets used to select or change the operating state of a turbine changes to yellow as an extra indication to the viewer of the current operating state (this is the most common usage of this option). The three fields in this option are feedback sense of the signal pointname (that is, either "0" or "1"), unit number/designation (the two character designator for the desired unit), and the signal pointname (whose feedback sense will be used to set the color of the text of the command target). If logic "1" is selected as the feedback sense, the text of the target will be displayed in yellow when the feedback signal pointname is a logic is "1".
4. **Target Type Field** - This field is used to specify the type of target, and consequently, its background color. ARM/EXECUTE targets have a green background, SETPOINT targets have a dark grey background, and IMMEDIATE ACTION targets have a red background. The following values are used in this single-character field to specify the type of target:
 - ? This symbol is used to specify an ARM/EXECUTE target.
 - # This symbol is used to specify a SETPOINT target.
 - ! This symbol is used to specify an IMMEDIATE ACTION target.
5. **Target Name** - This is the text which will appear in the target on the display. A maximum of two lines of eight characters per line may be typed in. (To allow space for the outline around the target, the first character in each line should be a blank space). Remember, setpoint command targets which prompt the operator for a value use the lower line of the target for the entry; therefore, the main function of the target, or the most descriptive term, should be placed on the upper line of the target.

2-8. ALARM DISPLAY

The Alarm Display is a list of turbine and driven device alarms (refer to Figure 2-15). Alarms are listed on the display with the latest, that is, the very last alarm condition to have occurred, at the top of the list. This is the "Track Latest" mode. When an alarm condition is annunciated, it also appears in the blue Alarm Window of any display. The display message field of the Alarm Display includes an additional line of information about the number of acknowledged and unacknowledged alarms. Alarm management is required to correct, resolve, and remove annunciated alarms from the display (alarm management tasks are explained further in this section). Annunciated and changed state alarms are automatically logged by the <I> printer.

GEDS.FA		Alarm Display			29-JUL-1991 18:25:53	
Page:	1	Total:	9	Unacked:	2	
Date/Time	U	SA	P	Drop	Description	
01-JAN-1980 01:58:44.281	GT	1*	Q	0128	MANUAL TRIP	
01-JAN-1980 01:58:40.906	GT	0*	Q	0167	WHEELSPACE TEMP DIFFERENTIAL HIGH	
01-JAN-1980 00:46:33.156	GT	1	Q	0007	LUBE OIL PRESSURE SWITCH TROUBLE	
01-JAN-1980 00:46:22.406	GT	1	Q	0025	DIESEL FAILURE TO STOP	
01-JAN-1980 00:46:20.156	GT	1	Q	0046	LOSS OF EXTERNAL SETPOINT LOAD SIGNAL	
01-JAN-1980 00:13:56.000	GT	1	C	0000	DIAGNOSTIC ALARM <C>	
01-JAN-1980 00:09:26.218	GT	1	Q	0075	LOSS OF COMPRESSOR DISCHARGE PRESS BIAS	
01-JAN-1980 00:00:32.031	GT	1	Q	0158	#3 DRAIN VALVE POSITION TROUBLE	
01-JAN-1980 00:00:32.031	GT	1	Q	0147	STEAM INJECTION NOT SELECTED	

01-JAN-1980 01:58:40.906	GT	0*	Q	0167	WHEELSPACE TEMP DIFFERENTIAL HIGH
01-JAN-1980 01:58:44.281	GT	1*	Q	0128	MANUAL TRIP

HELP	MORE OPTIONS	ACK ALL	RESET ALL	SILENCE	TRACK LATEST	MAIN DISPLAY

Figure 2-15. A Typical Alarm Display

2-8.1. Alarm Information

Each annunciated alarm on the display includes the following information:

- **DATE/TIME.** This value defines the date and time (from the Mark V Control Panel's system clock) that the alarm condition first occurred and was annunciated (prior to being reset).
- **UNIT NUMBER/DESIGNATION.** Found under the "U" column of the Alarm Display, this value defines the unit number or designation of the turbine control panel which annunciated the alarm condition.
- **ALARM STATUS FLAG.** Found under the "S" column of the Alarm Display, this value defines the current status of the alarm condition. A logic "1" in this column indicates an alarm condition currently exists and requires corrective action to be reset (or cleared from the screen). A logic "0" in this column indicates the alarm condition no longer exists and the message can be cleared from the screen by performing an alarm reset.
- **ALARM ACKNOWLEDGEMENT.** Found under the "A" status column of the Alarm Display, an asterisk (*) in this column indicates the alarm condition **has not** been acknowledged. The absence of an asterisk in this column indicates the alarm condition **has** been acknowledged. Acknowledgement of an alarm is necessary before an alarm can be reset, even if the status flag for an alarm is a logic "0".
- **PROCESSOR.** The characters in this column ("P") indicate which processor(s) annunciated the listed alarms.
- **ALARM DROP NUMBER.** The value in the "Drop" column for an alarm is the drop number for the alarm being annunciated. (Drop numbers are useful when troubleshooting alarms with the unit elementaries.)
- **ALARM MESSAGE.** This is a short written description of the alarm condition being annunciated.

2-8.2. Silencing Annunciated Alarms

The first step in resolving an alarm condition is to silence the alarm horn. To this end, there are two methods. The first (and simplest) is simply to click anywhere in the Alarm Window. The second method involves changing to the Alarm Display by clicking on the ALARM DISPLAY display target, and clicking on the SILENCE target.

2-8.3. Acknowledging Alarms

Alarm conditions annunciated on the <I> require an acknowledgement indicating that the operator is aware of the alarm. The operator can acknowledge any or all unacknowledged alarms by clicking on the ACK ALL target of the Alarm Display. When alarms are acknowledged, the asterisks (*) denoting their unacknowledged condition are deleted from the Alarm Display's Acknowledgement Status column; also, the associated alarm messages are removed from the Alarm Window. Alarms may be acknowledged individually from the Alarm Display by clicking on the desired alarm message ("selecting" the alarm). The alarm message is highlighted in a grey rectangle and the text of the alarm message changes to green. The display targets at the bottom of the screen change to allow individual acknowledgement (and resetting) of the selected alarm; clicking on the ACK ALARM display target will acknowledge only the selected alarm. Another method of acknowledging an alarm is to click on one character/space on either side of the Acknowledgement Status asterisk in the Alarm Window. This will send a command to the Control Panel to acknowledge the alarm, delete the Acknowledgement Status asterisk from the alarm message on the screen, and delete the associated message from the Alarm Window.

2-8.4. Resetting Alarms

When an alarm condition has been corrected or satisfied, the Status Flag of the alarm message changes from a logic "1" to a logic "0". To remove acknowledged, invalid alarm messages from the Alarm Display once the conditions have been corrected or satisfied, the operator performs an alarm reset action by clicking on the RESET ALL display target.

NOTE

Before alarms can be reset, they must be acknowledged (no asterisk in the Acknowledgement Status column) and the alarm conditions must no longer exist (a logic "0" in the Status Flag column).

Resetting an alarm causes future occurrences of the alarm condition to be annunciated with an audible signal. Failure to reset an alarm condition which has been corrected or satisfied will prevent future occurrences of the alarm from being annunciated by an audible signal. They will however be logged to the printer and in the Historical Log Alarm Queue. Individual acknowledged alarms may be reset from the Alarm Display by clicking on the desired alarm message ("selecting" the alarm), then clicking on the RESET ALARM display target. The highlighted alarm will be erased from the Alarm Display.

2-8.5. Locking Out Alarms

An alarm whose condition is changing repeatedly (dithering) and whose Status Flag is toggling between logic "1" and logic "0" can be a nuisance. Alarms such as these are logged to the printer and to the Historical Log Alarm History queue where they take up valuable alarm history queue space. An operator may prevent such an alarm from being continually logged by selecting the alarm, clicking on the MORE OPTIONS display target, and clicking on the LOCK ALARM display target. The Status Flag of the selected alarm message will change to an "L" to indicate that the alarm is locked-out (refer to Figure 2-16). The locked-out alarm is logged to the printer with an appropriate message, date, and time. Subsequent changes in the status of the alarm will not be logged to the printer or the Historical Log Alarm History queue.

Alarm Display									
GEDS.FA		Page: 1		Cursor: 2		Total: 9		Unacked: 1	
29-JUL-1991 18:28:33									
Date/Time		U		SA		P		Drop Description	
01-JAN-1980 01:58:44.281		GT		1*		Q		0128 MANUAL TRIP	
01-JAN-1980 01:58:40.906		GT		L		Q		0167 WHEELSPACE TEMP DIFFERENTIAL HIGH	
01-JAN-1980 00:46:33.156		GT		1		Q		0007 LUBE OIL PRESSURE SWITCH TROUBLE	
01-JAN-1980 00:46:22.406		GT		1		Q		0025 DIESEL FAILURE TO STOP	
01-JAN-1980 00:46:20.156		GT		1		Q		0046 LOSS OF EXTERNAL SETPOINT LOAD SIGNAL	
01-JAN-1980 00:13:56.000		GT		1		C		0000 DIAGNOSTIC ALARM <C>	
01-JAN-1980 00:09:26.218		GT		1		Q		0075 LOSS OF COMPRESSOR DISCHARGE PRESS BIAS	
01-JAN-1980 00:00:32.031		GT		1		Q		0158 #3 DRAIN VALVE POSITION TROUBLE	
01-JAN-1980 00:00:32.031		GT		1		Q		0147 STEAM INJECTION NOT SELECTED	
01-JAN-1980 01:58:44.281 GT 1* Q 0128 MANUAL TRIP									
HELP		MORE OPTIONS		FIRST ALARM		LOCK ALARM		UNLOCK ALARM	
SILENCE		TRACK LATEST		MAIN DISPLAY					

Figure 2-16. Alarm Display with an Alarm Selected and Locked Out

CAUTION

Full understanding of the consequences of an alarm condition to the unit operating system should be known prior to locking the alarm out.

Failure to unlock and reset an alarm after the dithering condition has been corrected or satisfied prevents future occurrences of the alarm from being annunciated and logged. Immediately after resolving a dithering alarm condition, unlock and reset the alarm to allow annunciation and logging of the alarm.

2-8.6. Unlocking Alarms

Once a dithering alarm condition has been corrected, it is necessary to unlock the alarm in order to reset the alarm (clear it from the alarm display). Alarms are unlocked from the Alarm Display by selecting the alarm which is to be unlocked by clicking on it, clicking on the MORE OPTIONS display target, and clicking on the UNLOCK ALARM display target. The Status Flag of the selected alarm will revert to the actual state of the alarm condition (if the alarm condition has been corrected or satisfied, the Status Flag will be a logic "0"). An unlocked, acknowledged alarm whose Status Flag is a logic "0" can then be reset from the Alarm Display.

2-8.7. Printing The Alarm Display

A color print of the Alarm Display may be made at any time by clicking on the display's MORE OPTIONS display target **twice**, and then clicking on the COLOR PRINT display target.

2-8.8. Diagnostic Alarms

Internal diagnostic self-checks and tests are performed in the Mark V Control Panel by the processors and other components (that is, individual printed wiring assemblies). Whenever a component or process fails one of these internal tests, the result is reported to the operator as a Diagnostic Alarm on the Alarm Display and consequently the Alarm Display window. Diagnostic Alarms are annunciated by an audible alarm horn. This horn can in turn be silenced in a manner identical to that for process alarms (See section 2-8.2.). Annunciated Diagnostic Alarms that appear in the Alarm Display are logged to the printer in the format shown below:

```
Date/Time           U   SA P Drop Description
13-MAY-1994 16:15:13.015 S1  1* Q 0000 TRUE DALARM DIAGNOSTIC ALARM <C><Q>
```

Figure 2-17. Diagnostic Alarm Format

Note that the alarm message details the processor in which the alarm occurred (Q) while the alarm description is defined simply as "DIAGNOSTIC ALARM." The viewing of a silenced Diagnostic Alarm and its complete description can be done via the Diagnostic Alarm Display (See Figure 2-18). To access the display, exit to the Main Menu and click on the Diagnostic Alarm Display selection. For a printout of the Diagnostic Alarm Display click on MORE OPTIONS and COLOR PRINT display targets in succession. These targets are located at the bottom of the screen.

NOTE

Diagnostic Alarms should be reported to the proper personnel for investigation and resolution. They serve as an indication of the internal operation of the Mark V Control Panel and as such, should be dealt with promptly to ensure continued availability and reliability of the control system and turbine.

From the Diagnostic Alarm Display, diagnostic alarms may be manipulated (selected, locked out, unlocked) just like process alarms on the normal Alarm Display. Diagnostic Alarms must be acknowledged, resolved and reset from the Diagnostic Alarm Display, just like process alarms are from the normal Alarm Display. Once a Diagnostic Alarm condition has been resolved, the Diagnostic Alarm Status Flag on the Diagnostic Alarm Display will change to a logic "0". This will allow the alarm to be reset (by clicking on the RESET ALL display target) and cleared from the Diagnostic Alarm Display. When all Diagnostic Alarms have been cleared from the Diagnostic Alarm Display, the Alarm Status Flag on the normal Alarm Display will change to a logic "0". This will permit the diagnostic alarm to be reset/cleared from the normal Alarm Display.

NOTE

The Diagnostic Alarm annunciation on the normal Alarm Display can only be reset, or cleared, from the display when all Diagnostic Alarms have been acknowledged, resolved, and reset from the Diagnostic Alarm Display.

WHEELABRATOR		Diagnostic Alarm Display			23-SEP-1993 10:53:00	
Page: 1		Total: 9 Unacked: 9				
Date/Time		U	SA	P	Drop	Description
13-JUL-2524	23:32:17.000	S1	1*	C	0330	LCC Frame rate or EEprom mismatches VDP
15-FEB-1980	21:39:13.000	S1	1*	C	0338	LCC failed DCC I/O configuration
15-FEB-1980	21:39:13.000	S1	1*	C	0334	LCC major revision mismatches VDP
15-FEB-1980	21:39:13.000	S1	1*	C	0333	LCC DCC major revision mismatches VDP
15-FEB-1980	21:39:13.000	S1	1*	C	0332	LCC name mismatches VDP
15-FEB-1980	21:39:13.000	S1	1*	C	0331	LCC DCC name mismatches VDP
15-FEB-1980	21:39:13.000	S1	1*	C	0329	LCC Vote Table checksum mismatches VDP
15-FEB-1980	21:38:53.000	S1	1*	C	0034	DCC I/O card went to state A3
15-FEB-1980	21:38:53.000	S1	1*	C	0019	DCC IO card could not configure card

EXIT	MORE OPTIONS	ACK ALL	RESET ALL	SILENCE	TRACK LATEST	MAIN DISPLAY

Figure 2-18. Example of the Diagnostic Alarm Display

2-9. TRIP LOG DISPLAY

The function of the Trip Log Display is to assist in the evaluation of circumstances that lead to turbine trip events. The display accomplishes this by providing a chronological record of relevant data gathered by the Mark V Control Panel. When accessed, the Trip Log Display allows the user to view, save, and print turbine trip data. Screens and the signal point information they depict are organized within the display according to post-trip, pre-trip, and alarm categories. Control Signal Database information logged in the alarm section of the display is not user-definable. However, Control Signal Database Points (CDBs) can be defined for both pre-trip and post-trip screens. These definitions (64 max.) are made within a single file (HIST_B.SRC) and are identical for the two screen types. All data in the display is chronologically indexed according to Mark V Control Panel time and a separate panel counter (HIS_AGE CNTS).

2-9.1. Display Header Information

The Trip Log Display can be accessed from the Main Menu system.

In the top left-hand corner of the display, four separate fields define the site name (GEDS), unit number (6A), page number of the display (PAGE #), and sampling rate at which the exhibited data was collected (1 second). To the right of this information are two fields that define the display's title (TRIP LOG DISPLAY) and status (CURRENT LOG). This latter designation specifies whether the display is presenting the latest data received from the panel (CURRENT LOG) or data that has been previously viewed and saved to a file on the <I>'s hard drive (SAVED LOG). The date and time specifiers in the display's top right corner represent Mark V Control Panel time for the panel being interrogated (6A).

GEDS UNIT 6A PAGE 2 LIST 1 sec		TRIP LOG DISPLAY CURRENT LOG					12-FEB-1993 15:00:22	
TIME		HIS_ AGE CNTS	DWATT MW	TNH %	FSR %	L52GX LOGIC	L14HR LOGIC	
12-FEB-1993 10:29:52		234	2.7	100.08	32.89	1	0	
12-FEB-1993 10:29:51		233	2.5	100.08	32.14	1	0	
12-FEB-1993 10:29:50		232	2.4	100.08	31.24	1	0	
12-FEB-1993 10:29:49		231	2.3	100.07	30.69	1	0	
12-FEB-1993 10:29:48		230	2.1	100.07	29.86	1	0	
12-FEB-1993 10:29:47		229	2.0	100.09	29.29	1	0	
12-FEB-1993 10:29:46		228	1.8	100.09	28.25	1	0	
12-FEB-1993 10:29:45		227	1.7	100.07	27.84	1	0	
12-FEB-1993 10:29:44		226	1.6	100.07	27.07	1	0	
12-FEB-1993 10:29:43		225	1.5	100.06	26.38	1	0	

EXIT MORE OPTIONS PREV PAGE NEXT PAGE < 6 POINTS > 6 POINTS ALARM DISPLAY MAIN DISPLAY

Figure 2-19. Trip Log Display

2-9.2. First Displayed Screen (PAGE 2)

The screen shown in Figure 2-19 is the first to appear when the Trip Log Display is called. However, it is not the first page of the display. The first screen displayed is actually the second page (PAGE 2) of information. The first displayed page (PAGE 1) is a register (updated once-per-second) of the first three seconds of data gathered after a trip has occurred (LIST POST). The rationale for this arrangement is twofold: 1. it prevents the user from being presented a blank screen if the display is accessed and no trip has occurred 2. should a turbine trip occur, data recorded up until the time of the trip will be displayed immediately when the Trip Log menu is selected.

2-9.3. Time vs. HIS_AGE CNTS

For pre-trip and post-trip screens, time (TIME) tag definitions are listed for the displayed Control Data Point information. These designations provide a chronological index that ties the exhibited signal information to Mark V Control Panel time. This register can provide valuable information in terms of determining the sequence of events that lead to a turbine trip. If the panel time is reset during an event however, this index will be lost. To prevent such an occurrence, the Trip Log Display is equipped with a second counter that, though internal to the Mark V Control Panel, runs independently of the panel clock. Updated once-per-second, this counter (HIS_AGE), advances until a maximum value is reached (65535). At that point, the counter returns to zero and restarts.

NOTE

In the post-trip example (Figure 2-22.), there is a discrepancy between the panel time designations and the HIS_AGE counter. The panel time continues for all three seconds while HIS_AGE stops incrementing. This is due to the fact that the counter (HIS_AGE) is enabled/disabled by the L4 permissive, which is in turn disabled (set to 0) by a turbine trip event.

2-9.4. Control Signal Database Pointnames

Each Mark V Control Signal Database point defined for the Trip Log Display is incorporated into pre-trip and post-trip screens as a column header (for example DWATT, TNH, FSR, L52GX, L14HR). Underneath these point definitions are fields that display their respective scale types (MW, %, LOGIC, and so on). Although only five data points are viewable in the illustration above, pre-trip and post-trip screen types can display the data of up to 64 points. Points that are not immediately viewable can be examined by wrapping the screen using the <6 POINTS and >6 POINTS targets at the bottom of the display below the alarm window. Note that each wrapped screen will show six data points, five new points plus the HIS_AGE counter.

2-9.5. Display Targets

In addition to the <6 POINTS and >6 POINTS targets described above, there are display targets defined for the Trip Log Display that allow the user to save, print, and switch screens (in both CURRENT and SAVED logs) as well as exit the program altogether. All of these targets can be viewed by clicking on the MORE OPTIONS selection.

Exiting the display to the Main Menu can be accomplished using the CPD to click on the EXIT target. Similarly, the Alarm or Main Displays can be directly accessed by executing the ALARM DISPLAY or MAIN DISPLAY commands. Clicking on the MORE OPTIONS target results in the following targets being displayed:

Supplementary targets in this new set include CURRENT LOG, SAVED LOG, UPDATE CUR LOG, and UPDATE SAV LOG.



Figure 2-20. Display Targets (2nd Set)

2-9.5.1. CURRENT LOG/SAVED LOG. The (Current) Trip Log Display is essentially a fixed "snapshot" of binary data retrieved from a Mark V Control Panel buffer. This Current Log exists in the Mark V Control Panel. As such, the user may wish to update the display log information by copying new information from the buffer. This can be done using the UPDATE CUR LOG display target.

NOTE

Updating the Trip Log will cause data previously stored to be overwritten and lost unless the old log is saved first.

Recorded Trip log information may be copied from the Mark V Control Panel to a unit-specific file (F:\RUNTIME\HISTORYF.B#) in the <I> by executing the UPDATE SAV LOG command.

NOTE

Updating the unit-specific file stored in the RUNTIME directory will cause previously saved data to be overwritten and lost. This can be avoided by copying the data file to another location before an update is executed. Current and Saved Logs can be examined by executing the CURRENT LOG and SAVED LOG commands respectively.

2-9.5.2. PRINT REPORT. If executed, the PRINT REPORT command will cause the sum of the information in the log currently being viewed (Current Log, Saved Log) to be sent to the printer. The CURRENT LOG or SAVED LOG reports can be printed individually using this function.

2-9.5.3. PRINT IMAGE/SAVE IMAGE. If, from the initial target set, the MORE OPTIONS target is clicked on twice, the following display target options will appear:



Figure 2-21. Display Targets (3rd Set)

Again, as in all Trip Log Display target sets, the EXIT, ALARM DISPLAY, and MAIN DISPLAY targets are shown. This uniformity permits direct access to either Alarm or Main Displays or the Main Menu from anywhere in the Trip Log Display. Supplemental commands in this series are found in the PRINT REPORT, SAVE IMAGE and PRINT IMAGE targets. The PRINT REPORT target was discussed in the previous section. The SAVE IMAGE command saves the currently viewed image to a file. When the SAVE IMAGE command is executed, the SAVE IMAGE target will momentarily indicate the number of the image file into which the screen is being saved. Image files are created and stored in the F:\USER directory. The PRINT IMAGE target sends to the printer the image currently being viewed.

2-9.7. Pre-Trip Screens

In terms of formatting, the pre-trip display screen is identical to the post-trip screen. Screen header information and signal point data is shown in an identical fashion. However, whereas there is only one post-trip screen, there are five (5) pre-trip screens. These screens record information at varying time intervals. The first pre-trip screen is updated once-per-second while subsequent screens are updated at ten second, one minute, ten minute, and one hour intervals. For pre-trip screens with update intervals of more than one second, the HIS_AGE counter can not only act as a backup timing device but also help to enhance resolution of the intervals between screen updates.

GEDS UNIT 6A PAGE 1 LIST POST		TRIP LOG DISPLAY CURRENT LOG					12-FEB-1993 14:59:39	
TIME		HIS_ AGE CNTS	DWATT MW	TNH %	FSR %	L526X LOGIC	L14HR LOGIC	
12-FEB-1993 10:29:55		234	-0.9	100.00	0.00	1	0	
12-FEB-1993 10:29:54		234	-0.9	100.07	0.00	1	0	
12-FEB-1993 10:29:53		234	2.9	100.08	0.00	1	0	

EXIT	MORE OPTIONS	PREV PAGE	NEXT PAGE	< 6 POINTS	> 6 POINTS	ALARM DISPLAY	MAIN DISPLAY

Figure 2-22. Post-Trip Display

2-9.8. Alarms

The alarm screens in the Trip Log Display form an itemized list of the last sixty alarm events that occurred before the turbine trip event. Individual alarms are chronologically labelled according to panel time.

NOTE

Although they can be displayed, the <6 POINTS and >6 POINTS targets have no effect on alarm screens. All other display targets remain functional for the alarm section.

2-9.9. Defining Control Signal Database Points

A single set of Control Signal Database Points may be defined for both pre-trip and post-trip sections of the Trip Log Display. For details, see the Maintenance Manual GEH-5980.

2-10. EPA DISPLAY

Located in the Main Menu, the Environmental Protection Agency (EPA) display allows the user to view, save, and print environmental data for gas turbine applications. This data is displayed in terms of both hourly and minute-to-minute rolling averages. Hourly rolling averages are computed according to data received once a minute while minute-to-minute rolling averages are computed on the basis of 60 second intervals.

GEDS UNIT 6A PAGE 2 LIST 1 sec		TRIP LOG DISPLAY					12-FEB-1993 15:00:22	
		CURRENT LOG						
TIME		HIS_ AGE CNTS	DWATT MW	TNH %	FSR %	L52GX LOGIC	L14HR LOGIC	
12-FEB-1993 10:29:52		234	2.7	100.08	32.89	1	0	
12-FEB-1993 10:29:51		233	2.5	100.08	32.14	1	0	
12-FEB-1993 10:29:50		232	2.4	100.08	31.24	1	0	
12-FEB-1993 10:29:49		231	2.3	100.07	30.69	1	0	
12-FEB-1993 10:29:48		230	2.1	100.07	29.86	1	0	
12-FEB-1993 10:29:47		229	2.0	100.09	29.29	1	0	
12-FEB-1993 10:29:46		228	1.8	100.09	28.25	1	0	
12-FEB-1993 10:29:45		227	1.7	100.07	27.84	1	0	
12-FEB-1993 10:29:44		226	1.6	100.07	27.07	1	0	
12-FEB-1993 10:29:43		225	1.5	100.06	26.38	1	0	

EXIT	MORE OPTIONS	PREV PAGE	NEXT PAGE	< 6 POINTS	> 6 POINTS	ALARM DISPLAY	MAIN DISPLAY

Figure 2-23. Post-Trip Display - Continued

2-10.1. Example

The screen shown in Figure 2-25 is an example of the EPA display. In the top left-hand corner there are three fields that define site and unit information. Also shown is the specific page number of the display. Moving to the top right, the display shows the name of the display (EPA DATA DISPLAY) and the current Mark V Control Panel date and time.

Below the display information, to the left side of the display, there are headers that label the HOUR AVERAGE and MINUTE AVERAGES. The Time (definition field) for the hourly average is static in the sense that it is not replicated every time an update occurs. When an update takes place, the time exhibited in the field changes to denote the time the new hourly average was calculated. Conversely, the MINUTE AVERAGES fields are reproduced in vertical succession each minute. This means that eventually the screen will scroll down until all 60 minute averages have been displayed. At that point, the hourly average will be updated and the minute averages will start over. Each Mark V data point defined for the EPA display is incorporated into the screen as a column header (DWATT, CTIM, TTXM, WXJ, WXC, CMHUM).

Underneath these point definitions are fields that display their respective scale types. Although there are only six data points defined in the example, the EPA screen can display the rolling averages of up to sixteen Control Data Points. Data points and their rolling averages that are not immediately viewable can be examined by wrapping the screen using the < POINTS and >

TraxSim INIT 6A PAGE 7 LIST ALARMS		TRIP LOG DISPLAY CURRENT LOG		12-FEB-1993 10:47:02	
TIME		S	P	DROP/NAME	DESCRIPTION
12-FEB-1993 10:37:19.281	1	Q	0480		FIRE IN TURBINE OR ACCESSORY AREA
12-FEB-1993 10:37:19.281	1	Q	0085		CUSTOMER TRIP
12-FEB-1993 10:37:19.218	1	Q	0573		ELECTRICAL TROUBLE - NORMAL SHUTDOWN
12-FEB-1993 10:37:19.218	1	Q	0536		DISTILLATE FUEL SKID TROUBLE
12-FEB-1993 10:37:19.218	1	Q	0235		RELATIVE HUMIDITY SENSOR FAULT
12-FEB-1993 10:37:19.218	1	Q	0196		GENERATOR DIFFERENTIAL TRIP
12-FEB-1993 10:37:19.218	1	Q	0188		BUS UNDERVOLTAGE - NO AUTO SYNCH
12-FEB-1993 10:37:18.781	1	Q	0478		FIRE PROTECTION TRIP RELAY UNDERVOLTA
12-FEB-1993 10:37:18.781	1	Q	0477		PRE FIRE ALARM
12-FEB-1993 10:37:18.781	1	Q	0476		FIRE PROTECTION SYSTEM TROUBLE
12-FEB-1993 10:37:18.781	1	Q	0176		DISTILLATE FUEL TEMPERATURE HIGH
12-FEB-1993 10:37:03.593	1	Q	0549		EXT. LEAN-LEAN MODE HIGH EMISSIONS
12-FEB-1993 10:35:52.031	1	Q	0000		DIAGNOSTIC ALARM <C><Q>
12-FEB-1993 10:35:51.968	1	Q	0000		DIAGNOSTIC ALARM <C><Q>
12-FEB-1993 10:35:38.375	0	Q	0157		EXHAUST THERMOCOUPLES OPEN TRIP
12-FEB-1993 10:35:38.375	0	Q	0287		PROTECTIVE MODULE ACCELERATION TRIP-
12-FEB-1993 10:35:38.375	0	Q	0072		PROTECTIVE MODULE OVERSPEED TRIP - HP
12-FEB-1993 10:37:03.593 6A 0* Q 0549 EXT. LEAN-LEAN MODE HIGH EMISSIONS 12-FEB-1993 10:37:18.781 6A 0* Q 0176 DISTILLATE FUEL TEMPERATURE HIGH 12-FEB-1993 10:37:18.781 6A 0* Q 0476 FIRE PROTECTION SYSTEM TROUBLE					
EXIT		MORE OPTIONS		PREV PAGE	
				NEXT PAGE	
				< 6 POINTS	
				> 6 POINTS	
				ALARM DISPLAY	
				MAIN DISPLAY	

Fig. 2-24. Alarm Screen

POINTS targets at the bottom of the display. In addition to these targets, the PREV PAGE and NEXT PAGE targets permit viewing of more than one screen. This function can be useful for inspecting Minute averages that have scrolled off the initial display. Other targets shown below the alarm window include the EXIT, MORE OPTIONS, ALARM DISPLAY, and MAIN DISPLAY targets. The EPA screen can be exited to the Menu system by clicking on the EXIT target. Clicking on the ALARM DISPLAY or MAIN DISPLAY targets effects an exit to these respective displays. The MORE OPTIONS target can be used to bring up the following additional targets: SAVE IMAGE and PRINT IMAGE. These items can be used to save the screen currently displayed to the F:\USER directory or print the screen currently displayed. If the PRINT IMAGE command is executed, the screen image will be sent to the print queue.

2-11. PRINTING FUNCTIONS

Various functions of the Mark V Control Panel are logged to the printer(s) automatically while others make use of the printer on command.

```

Mark V Trainer          EPA DATA DISPLAY          24-JUL-1996 10:38:41
UNIT T3
PAGE 1
  HOUR AVERAGE

  TIME                DWATT    CTIM    TTXM    WXJ    WXC    FQG
                   MW      deg F    deg F    RATIO  RATIO  #/sec
01-JAN-1980 00:00:00    0.0      0      0    0.000  0.000  0.00

  MINUTE AVERAGES

01-JAN-1980 00:00:54.093 T3 1* Q 0286 GENERATOR RTD OUT OF LIMITS
01-JAN-1980 00:00:55.218 T3 1* Q 0142 INLET GUIDE VANE CONTROL TROUBLE ALARM

  EXIT  MORE  SAVE  PRINT  ALARM  MAIN
        OPTIONS  IMAGE  DISPLAY  DISPLAY

```

Figure 2-25. EPA Screen

2-11.1. Alarm Logging

Mark V Control Panel diagnostic and process alarms are logged on the printer(s) when they are annunciated and when they are resolved. When an alarm is annunciated, the printed alarm status will read "True". When the alarm condition is corrected, resolved, or satisfied, the event is logged to the alarm status and will read "False". The format of logged alarms is shown in Figure 2-26.

DATE & TIME	UNIT NUMBER	ALARM DROP NUMBER	ALARM TYPE	ALARM TEXT/MESSAGE
04-DEC-1991 08:15:01.062	T1 Q 0408	TRUE	PALARM	DUPLEX FILTER DIFF PRESS HIGH
04-DEC-1991 08:15:01.875	T1 Q 0268	TRUE	PALARM	STOP VALVE LIMIT SWITCH TRFUBLE
04-DEC-1991 08:15:01.974	T1 Q 0267	TRUE	PALARM	GENERATOR BREAKER TRIPPED
04-DEC-1991 08:15:02.125	T1 Q 0408	FALSE	PALARM	DUPLEX FILTER DIFF PRESS HIGH
04-DEC-1991 08:15:02.346	T1 Q 0268	FALSE	PALARM	STOP VALVE LIMIT SWITCH TROUBLE
PROCESSOR	STATUS			
04-DEC-1991 08:17:36.125	T1 Q U408	LOCK	PALARM	DUPLEX FILTER DIFF PRESS HIGH
04-DEC-1991 08:17:49.376	T1 Q 0000	TRUE	DALARM	DIAGNOSTIC ALARM <Q>

Figure. 2-26. A Sample of an Alarm Printout

When an alarm is logged to the printer with a FALSE status, the date and time the alarm condition was resolved is noted.

2-11.2. Event Logger

The event logger consists of two fields that use the printer(s) as described below.

2-11.2.1. POINTNAME. This field identifies the pointname which has been selected/designated to be logged to a printer when a change of state occurs.

2-11.2.2. STATUS. There are two status conditions for events which are logged.

- **TRUE** If the event logged with a TRUE status is a logic pointname, the pointname's logic value just changed to a logic "1".
- **FALSE** If the event logged with a FALSE status is a logic pointname, the pointname's logic value just changed to a logic "0".

2-11.3. Event Type

Two types of events can be logged to the printer(s) in the Mark V system. The first includes digital contact inputs which have been selected/designated to print out on a change of state. The second entails selected logic state changes (update at frame rate). The date and time, unit number, and processor fields of logged events are identical to those of the alarm logger. The fields unique to the event logger are described below.

- **CONT_IN** If an event logged to the printer is a CONT_IN (contact input) type, the logic value of the pointname which is printed as part of the event is "attached" directly to (or "driven by") an external contact input device such as a limit switch, temperature switch, pressure switch, and so on. For example, if the following event were logged to the printer, it would be an indication that the limit switch 26QT2A had just changed state.

```
10-DEC-1991 17:03:22.679 T1 Q L26QT2AH      TRUE  CONT_IN L.O. TEMP TRIP SWITCH
```

- **EVENT** If an event logged to the printer is an EVENT type, the logic value of the pointname has just changed state. For example, if the following event was logged to the printer, it would be an indication that the primary overspeed test mode had been deselected.

```
10-DEC-1991 11:15:10.150 T1 C L83POST_ONL  FALSE EVENT  ON-LINE OVERSPEED TEST
```

2-11.4. View Image/Save Image

The functions of the Image Viewer are to view, print, and delete image files saved with the SAVE IMAGE target. This target can be found on most of the <I> displays. An image is, in effect, a 'snapshot' of a Mark V screen. Images may be useful for logging current operating data, or for referencing screens when creating new ones.

The Image Viewer may be accessed from the Main Menu System. Clicking on the View Image option will display the screen shown in Figure 2-27.

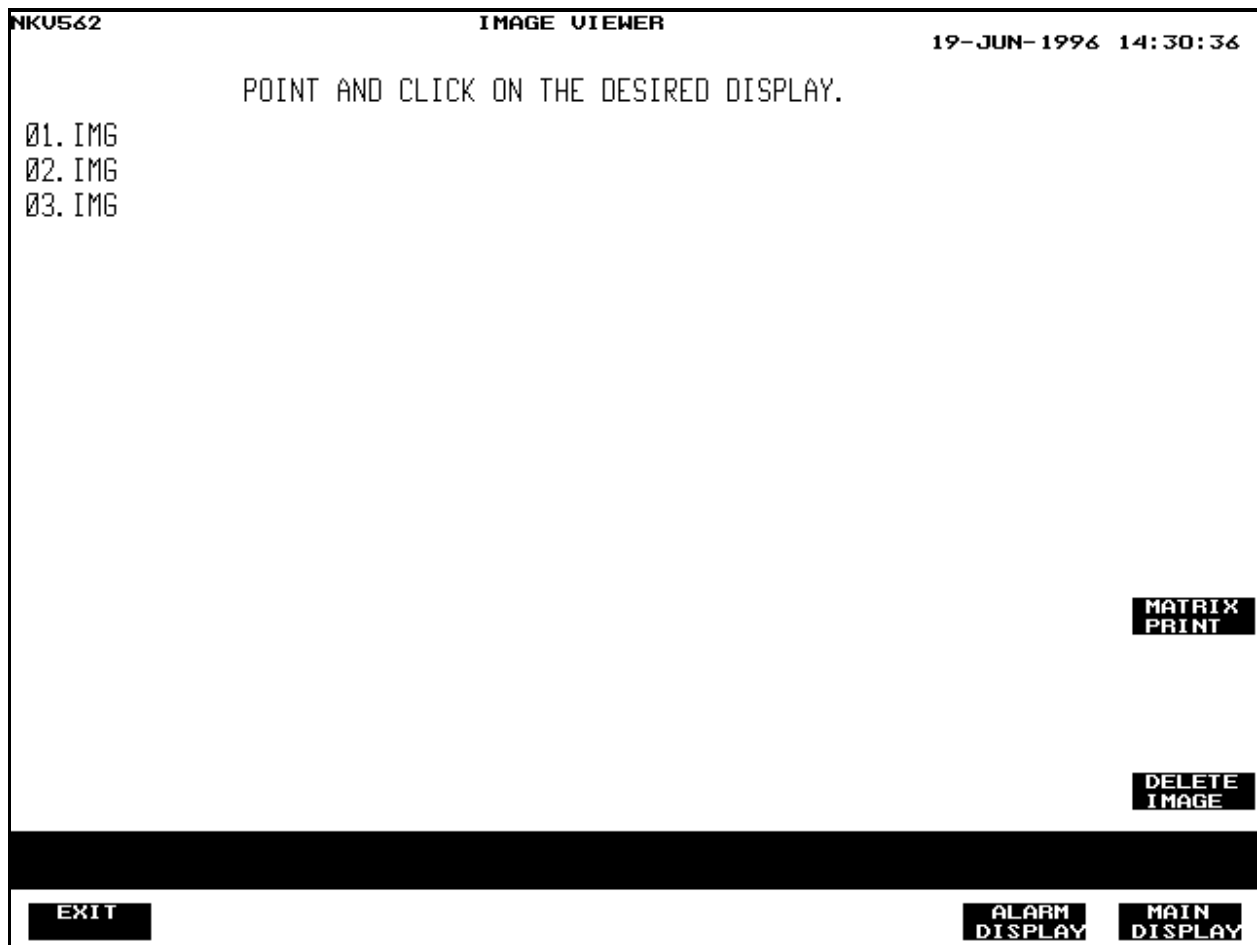


Figure 2-27. Sample of Image Viewer Screen Display

The display includes the following information and options:

- **DISPLAY HEADER INFORMATION.** The field at the top center of the display defines the display title IMAGE VIEWER. The top left-hand field displays the site name NRV562, and top right-hand field displays the <I> time. Under the title is the instruction to "CLICK ON THE DESIRED DISPLAY."
- **DISPLAY TARGETS.** The Image Viewer has three targets located at the bottom of the display. Return to the Main Menu by using the CPD to click on the EXIT target. Similarly, access the Alarm or Main displays by executing the ALARM DISPLAY or MAIN DISPLAY commands.
- **SAVED IMAGES.** The body of the Save Image Display is a menu of images saved from other displays. The menu lists the saved images numerically. When the SAVE IMAGE target is selected from the other displays, the system saves the image and names the file with a sequential number (01, 02, 03, and so on) and an ".IMG" extension. Successive numeric values are assigned to files according to availability. For example, if the file 02.IMG is deleted and the files 01.IMG and 03.IMG exist, the next execution of SAVE IMAGE from a display will save the image as 02.IMG. The SAVE IMAGE target will supply the user with the image name when the file is saved.

- **VIEWING AN IMAGE.** To view an image, select it with the CPD device. Note that the EXIT, ALARM DISPLAY, and MAIN DISPLAY targets flash between white and cyan. This is to show that this is a frozen image, not a real time display, and that these three targets are active while viewing an image. Any keyboard action or a CPD click will return to the menu of saved images. Selecting an image highlights the image name in yellow.
- **PRINTING AN IMAGE.** On the right-hand side of the display, display targets listing the printers defined for the system are presented. Clicking on a printer target will send the highlighted image to the selected printer. Be sure not to delete an image until it has completed printing as it will not print. Also, it is recommended that not more than ten images be sent to the printer spooler at one time. If more than ten files are sent, only the first ten will be printed. When the printer completes the printing of a file, the spooler will accept another file in succession.
- **DELETING AN IMAGE.** The DELETE IMAGE target at the bottom will delete the image from the disk. Use this feature to make room on the hard drive for more images or for deleting unwanted image files.

CHAPTER 3

USING THE BACKUP OPERATOR INTERFACE

3-1. INTRODUCTION

The backup operator interface <BOI>, or backup display, is a second means of monitoring turbine and driven device operation and/or issuing commands to the Mark V Control Panel (refer to Figure 3-1). Typically mounted on the Mark V Control Panel enclosure, it is comprised of an integrated keypad and LCD display. The backup display is capable of annunciating alarms, acknowledging alarms, resetting alarms, initiating turbine startups and normal shutdowns, loading and unloading the turbine and driven device, displaying operating data in both pre-defined and user-defined displays, and performing manual operations on the turbine and driven device. Help screens are available on the backup operator interface to assist the operator in the use of the backup operator interface displays.

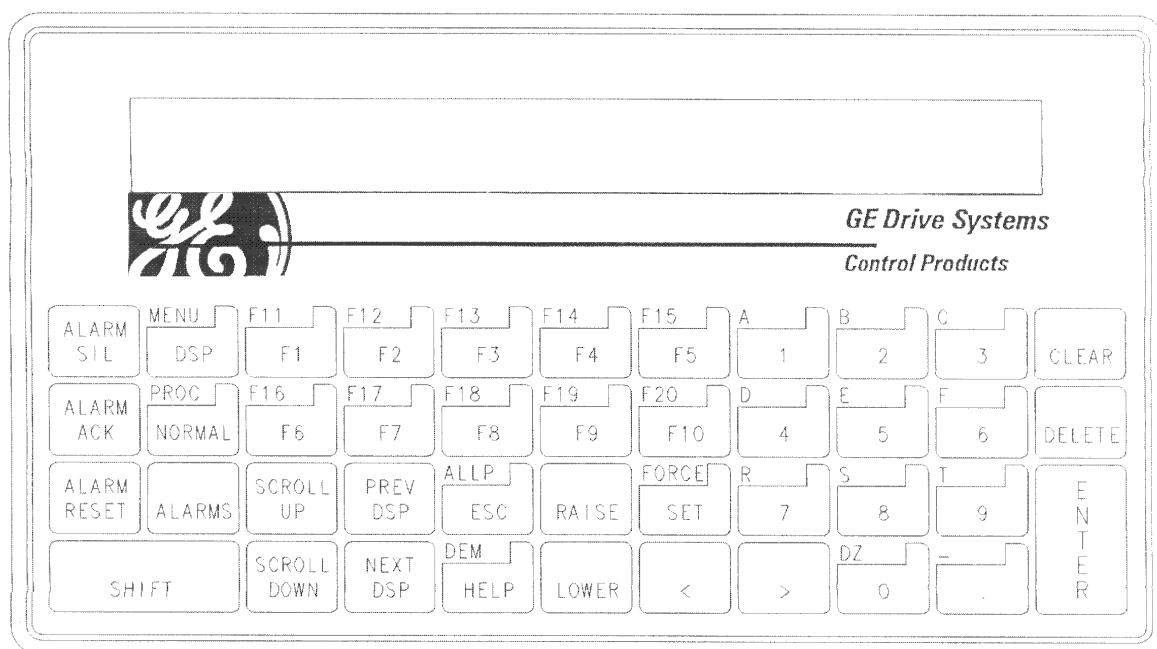


Figure 3-1. Backup Operator Interface <BOI>

Intended for use as an alternate means of turbine/process control and monitoring in the event of loss of communications between the <I> and the Mark V Control Panel, or a failure of the <I>, the <BOI> can be used to monitor turbine and driven device operation and issue commands at any time. The <BOI> Control and Display functions are fully configurable. For details see the Maintenance Manual GEH-5980.

CAUTION

Turbine and driven device commands may be issued at any time from the <BOI> regardless of the status of the <I> and/or its communication link with the Mark V Control Panel. Therefore, care should be taken not to initiate unit commands from the <BOI> when control is being executed from the <I> as the Mark V Control Panel will execute these commands.

In a Mark V TMR Control Panel, the <BOI> is connected to <R>, <S>, and <T> ; commands are therefore issued from the <BOI> to all three processors. Conversely, data shown on the <BOI> display is received from a single "designated processor." The processor typically selected for this function is <R>, however, the <BOI> allows the user to choose which processor (<R>, <S>, <T>) will be used to update the display (See section 3-9, Processor Select Display). In a Simplex Mark V Control Panel, the <BOI> is connected to the <R> processor; as such, data transmission only occurs between the <BOI> and this device.

Several of the <BOI> displays are multi-page (that is, there is more than one screen of information or commands available). To advance to the next page or return to the previous page of a display, use the SCROLL UP and SCROLL DOWN keys on the <BOI> keypad.

3-2. MENU DISPLAY

The Menu Display is a multi-page listing of Enumerated Switch and Main/Normal displays (max. 32). It can be accessed by pressing and holding the SHIFT key while the MENU key is depressed. Four Enumerated Switch or Main/Normal displays, including their corresponding function keys (F1 - F20), can be viewed at one time. Any Menu Display screen can be examined by using the SCROLL UP and SCROLL DOWN keys; also, an individual Menu display may be directly accessed by pressing the appropriate function key. The first twenty Menu displays can be accessed using the function keys (F1-F20); in addition, these and any other Menu Display (1-32) can be accessed by pressing the DSP and the numbered value keys (0 - 9).

While viewing the Menu Display, pressing the HELP key presents the operator with the following multi-page message:

MENU SHOWS THE KEY WHICH SELECTS A
DISPLAY. DISPLAYS CAN ALSO BE SELECTED
BY PRESSING DSP, ENTERING A DISPLAY
NUMBER, AND PRESSING ENTER. SCROLL KEYS
MOVES THE DISPLAY THROUGH THE MENU LIST

Figure 3-2. Multi-Page Instruction Message

The Menu Display can also be accessed from any display by pressing DSP, pressing the "0" key, and pressing ENTER.

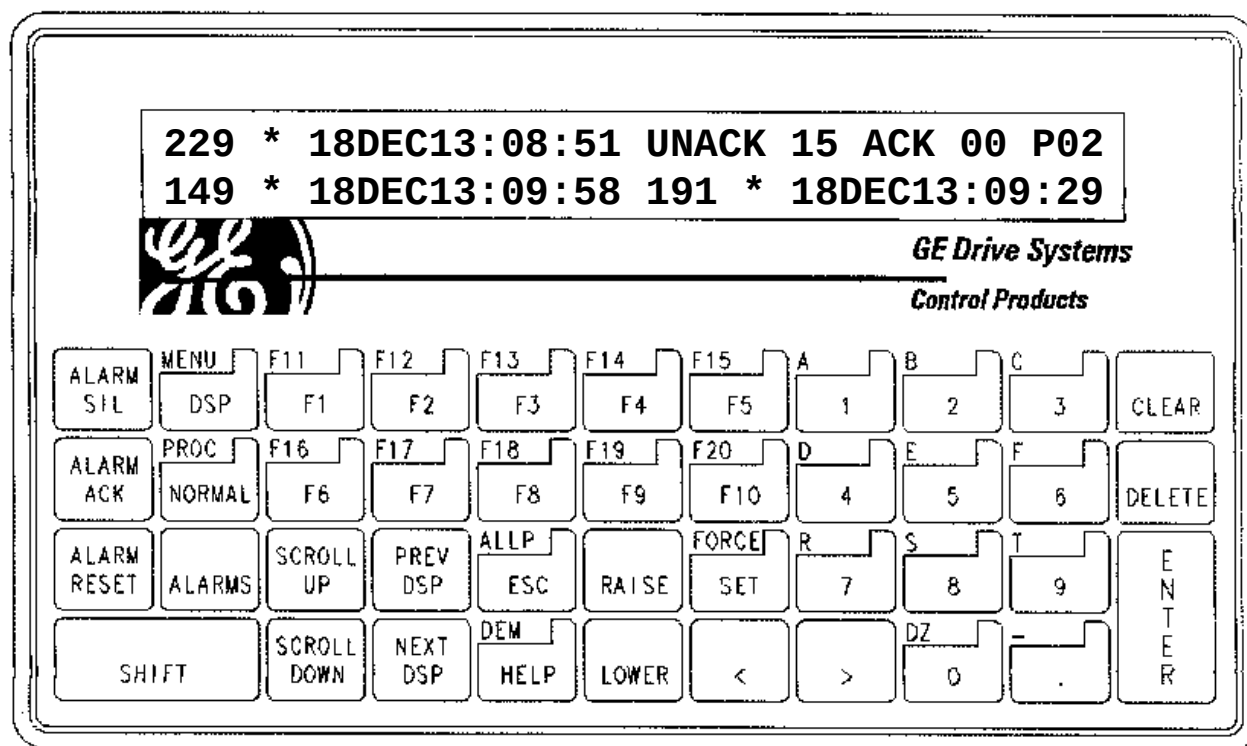


Figure 3-3. <BOI> Display Showing Portion of Alarm Display

3-3. ALARM DISPLAY

The Alarm Display can be accessed at any time by pressing the ALARMS key. The display lists alarms in the <RST> alarm queue in order of occurrence. The last annunciated alarm is shown in the upper left-hand field of page 1 (see figure 3-3). The Alarm Display pages are divided into four fields; the upper right-hand field shows the number of unacknowledged and acknowledged alarms and the page number of the Alarm Display. The Display's three remaining fields display annunciated alarms. If more than three alarms are annunciated, subsequent pages of the Alarm Display can be accessed by pressing the SCROLL DOWN key. Each annunciated alarm is displayed with an alarm drop number, the status flag/acknowledge condition, and the date and time the alarm occurred. (Note that these signifiers are identical in function to those displayed in the Alarm Display of the <I>. See section 2-8.1., Alarm Information.) An asterisk "*" in the status flag column indicates the alarm has **not** been acknowledged.

While viewing the Alarm Display, pressing the HELP key presents the operator with the following multi-page message:

THE DISPLAY COMES UP SHOWING THE NEWEST
UNACKNOWLEDGED ALARMS. AN * IN THE STATE
FIELD INDICATES AN UNACKNOWLEDGED ALARM.
PRESSING THE ALARM ACK ACKNOWLEDGES THE
ALARMS SHOWN. PRESSING THE ALARM RESET
REMOVES ALL THE ALARMS WHICH ARE
ACKNOWLEDGED AND HAVE A ZERO STATE.
SCROLL KEYS MOVES DISPLAY THROUGH THE
ALARM LIST.

Figure 3-4. Alarm Display Multi-Page Message

Alarm management using the <BOI> requires silencing of the audible alarm horn, acknowledgement of the annunciated alarm, and resetting the alarm (removing it from the display) once the alarm condition has been corrected or satisfied. These actions are described in the following sections.

3-3.1. Alarm Management

The following sections provide information concerning the management of alarms.

3-3.1.1. Silence. To silence the audible alarm horn in the Mark V Control Panel, press the ALARM SIL key on the <BOI> keypad..

3-3.1.2. Acknowledge. To acknowledge an alarm using the <BOI> Alarm Display, press the ALARM ACK key on the device keypad. This action acknowledges the alarm(s) exhibited in the Display's current page and increments the acknowledged alarms counter in the upper right-hand field of the backup display. The asterisk in the status flag column of the alarm(s) will change to either "1" or "0", depending on the current condition of the alarm. To acknowledge other annunciated alarms (if present), use the SCROLL DOWN key to move to the next page of the Alarm Display and press ALARM ACK until all alarms have been annunciated. The unacknowledged alarm counter in the upper right-hand field will show "00". Alarms must be acknowledged in order to be reset (removed from the display) once the alarm condition has been corrected.

3-3.1.3. Reset. An acknowledged (annunciated) alarm condition that has been corrected or satisfied may be reset (removed from the display) by pressing the ALARM RESET key. (Only an acknowledged alarm with a status field value of logic "0" can be reset.) Resetting an alarm causes future occurrences of the alarm condition to be annunciated with an audible signal in order to alert the operator. Failure to reset an alarm condition which has been corrected or satisfied will prevent future occurrences of the alarm from being annunciated by an audible signal; they will, however, be logged to the printer and in the Historical Log Alarm Queue.

3-4. ENUMERATED SWITCH DISPLAYS

Enumerated Switch Displays are operator selectable modes of operation (for example, OFF, AUTO, MANUAL, BASE LOAD, and so on) that can be executed from the <BOI>. To select a different function on an Enumerated Switch Display, use the cursor left, < , and cursor right, > , keys to move the locator (or cursor) symbol to the desired function and press the ENTER. The newly selected function will now be preceded by an asterisk (see Figure 3-5). If an Enumerated Switch Display has more functions than can be shown on a single page, the SCROLL DOWN and SCROLL UP keys can be used to view the additional functions.



Figure 3-5. <BOI> Display Showing Preselect Load Selection Display

While viewing the Enumerated Switch Displays, pressing the HELP key presents the operator with the following multi-page message:

THE FUNCTION PREFIXED BY AN * IS THE
SELECTED FUNCTION. THE < AND > KEYS ARE
USED TO MOVE TO A NEW FUNCTION. THE NEW
FUNCTION WILL BE PREFIXED BY AN >. THE
ENTER KEY WILL SELECT THE NEW FUNCTION
PREFIXING IT WITH AN *) AND DESELECT
THE OLD FUNCTION. IF THERE ARE MORE THAN
1 WINDOW OF FUNCTIONS, THE SCROLL KEYS
WILL MOVE THE DISPLAY TO THE NEXT WINDOW
OF FUNCTIONS.

Figure 3-6. Enumerated Switch Display Multi-Page Message

3-5. MAIN/NORMAL DISPLAYS

Main or Normal Displays are used to implement such functions as Lead/Lag Pump or Fan Selection, Speed or Load Setpoint Command and Selection, and so on (see Figure 3-7). Typically broken into four fields, the points which can be selected are prefixed by the symbol " ^ ". The cursor symbol ">" on a Main/Normal Display can be moved by using the left arrow "<" and right arrow ">" keys. Selected points are prefixed with an asterisk, "*". With the locator in front of a desired point, pressing ENTER will select the point; this is indicated by the appearance of an asterisk in front of the point. Points can be deselected by pressing the ESC key. Only one point can be selected at a time. If the selected point is a command "pushbutton", pressing the RAISE or LOWER key will send the command to the Mark V Control Panel. If the selected point is a logic representation of a two-position switch (either "0" or "1"), pressing RAISE will change the state from a logic "0" to a logic "1" while pressing LOWER will change the state from a logic "1" to a logic "0".

If the selected point is an analog type, two methods are available for changing its value. The first involves implementing the RAISE and LOWER keys which can be used to increase or decrease the point's value. The second entails direct entry of a value via the Set mode screen. Access to this screen can be had by pressing the SET key. Within the screen, the selected value and a field into which the new value may be entered directly will be shown. After entering the new value into the field, the new value will be transmitted directly to the processor(s) by pressing ENTER. Pressing the ESC key will transfer the operator back to the Main Display from which the Set Mode was entered.

LOAD_S		>PS_CMD	15.0 MW
		DW	15.2 MW

Figure 3-7. <BOI> Display Showing Load Selection Display

While viewing Main/Normal Displays, pressing the HELP key presents the operator with the following multi-page message:

```
THE POINTS PREFIXED BY AN ^ ARE THE
POINTS WHICH CAN BE RAISED, LOWERED AND
SET. THE POINT PREFIXED BY > IS THE
CURRENT POINT. THE < AND > KEYS ARE USED
TO MOVE TO A NEW POINT. THE ENTER KEY
WILL SELECT THE NEW POINT (PREFIXING IT
WITH AN *) AND DESELECT AN OLD POINT. THE
SELECTED POINT CAN THEN BE RAISED AND
LOWERED. PRESSING ESC WILL DESELECT THE
POINT. PRESSING SET DISPLAYS THE SELECTED
POINT IN THE SET MODE. TO SET THE POINT
TO A NEW VALUE IN THE SET MODE, KEY IN
THE VALUE AND PRESS ENTER. ESC WILL EXIT
THE SET MODE.
```

3-6. NORMAL DISPLAY

The Normal Display (see Figure 3-8), also known as the Monitor Display, is a single user-configurable display that can be immediately accessed by pressing the NORMAL key. Showing up to four data points or one Enumerated Switch, it is essentially a display (0-32) configured from the DEMAND SECTION of the BOI_Q.SRC source file. Multiple screen Enumerated Switch displays can be viewed by pressing the SCROLL UP and SCROLL DOWN keys.

MODE_S	AUTO	DW	89.1	MW
CONTRL	LOOP	FSR	64.51	%

Figure 3-8. <BOI> Display Showing Normal Display (Monitor Display)

While viewing the Normal Display, pressing the HELP key presents the operator with the following message:

```
SCROLL KEYS MOVE THE DISPLAY THROUGH
THE FUNCTIONS
```

3-7. ALL POINTS DISPLAY

The All Points Display depicts all of the points that can be accessed by the <BOI>. It is a copy of the POINTNAME column of the BOI_Q.SRC source file's DISPLAY SECTION. Downloading the BOI_Q.SRC file will cause an updating of the display. The function of this display is not only to depict accessible <BOI> points, but to permit Operator Demand Displays to be created from the <BOI>. The latter operation can be accomplished using the All Points Display's Build Demand Mode. For more information, see Maintenance Manual, GEH-5980.

To place a point into the Operator Demand Display, scroll through the points until the desired point is shown. Use the < and > keys to locate the point (the located point will be prefixed by a ">"). Pressing the ENTER key will select the located point and prefix it with an asterisk (*). The Build Demand Mode is then accessed by pressing the SET key. In this mode, the selected point is shown in the left-half of the top line of the display. The right-half of the top line shows the current point in the Demand Display at the location shown on the bottom line (see Figure 3-9).


```

AP      -327.4 . . . 0 cnt 15
ENTER: 01

```

Figure 3-9. <BOI> Build Demand Mode

To put the point into the Demand Display, select the desired location with the raise and lower keys and press ENTER. The point will then be put into the Demand Display in the selected location. Pressing the ESC key will exit the build mode.

NOTE

Only Main/Normal Display types can be inserted in an Operator Demand Display using the <BOI>.

3-8. OPERATOR DEMAND DISPLAY

The Operator Demand Display is a user-configurable list of Main/Normal and/or Enumerated Switch Display types that can be immediately accessed by pressing the SHIFT + HELP keys. Two (2) Demand Displays can be created with each holding up to four Main/Normal data points (POINT_TAGS) or one Enumerated Switch Display which must include SIGNAL_TAG, MASK_TAG, ENUM_TAG, and COMMAND_TAG parameters. Four data points or Enumerated Switch mode options can be viewed at one time.

```

IP  53.3  psi  HPXP  -586  psi
AP  -327  psi  EV   -2.5  in Hg

```

Figure 3-10. Operator Demand Display with Four Data Points.

Operator Demand Displays that incorporate Main/Normal Display types may be constructed from the <BOI> or the <I> processor (see the ALL POINTS DISPLAY section of this chapter and the BOI_Q.SRC section in the Maintenance Manual GEH-5980). Enumerated Switch Display types may be inserted into the Operator Demand Display only through the use of the BOI_Q.SRC file located in the UNIT(n) directory of the <I> processor (also see BOI_Q.SRC File in the Maintenance Manual GEH-5980).

The Operator Demand Display can be accessed by pressing the SHIFT + HELP keys. Any screen in the display can be viewed by using the SCROLL keys. Individual points in the display can be raised, lowered, forced, and set. The < and > keys are used to locate a specific point. A located point is prefixed by a >. Pressing the ENTER key will select the located point, prefixing it with an "*". Selected points can then be increased and decreased by the RAISE and LOWER keys. Pressing the ESC key deselects the point. The force key selects a located logic point, prefixing it with an "!". The RAISE key forces the point to a one while the LOWER key forces the point to a zero. Pressing CLEAR will unforce the selected point. A selected analog point which is prefixed by an "*" can be displayed in the SET Mode by pressing the SET key. The SET Mode shows

the current value of the point and allows it to be set to a value. To set a value, key in the desired number and press ENTER. The ESC key can be used to exit the SET Mode.

3-9. PROCESSOR SELECT DISPLAY (PROC)

The <BOI> can be configured to receive data from any one of the three cores <R>, <S>, or <T> in TMR configurations. Simplex <BOI> panels are limited to receiving data from the default processor <R>. Processor selection can be performed via the (shifted) R, S, or T keys or the Processor Select Display. To access the Processor Select Display, press the SHIFT + NORMAL keys. When the display is pictured, select the desired processor by pressing the < and > keys; pressing ENTER will execute the selection.



Figure 3-11. <BOI> Processor Display (TMR Configuration)

3-10. DESIGNATED PROCESSOR

For TMR applications, the <BOI> is equipped with a designated processor function that allows communication to be reestablished when the selected processor fails. If a communication failure occurs, press the SHIFT + PROC keys. This will establish a communication link between the <BOI> and the designated processor and restore the <BOI> display.

NOTE

The control hierarchy of TMR panels automatically compensates for the loss of the designated processor, <R>, by reassigning this role to <S>, and finally <T> if successive processors are lost. This allows communication between the panel and the <BOI> to be regained if only one processor remains operable.

CHAPTER 4

CONTROL LOCATIONS

4-1. Control Lockout

Working in conjunction with Password Level Administration, Control Lockout is a means by which an Operator or Supervisor can disable an <I> from issuing commands to the Mark V Control Panel. This option is an exclusive function of the <I> processor and does not require changes to the configuration of a panel.

NOTE

Initiating Control Lockout does not affect MODBUS or ETHERNET links. However, it can limit the <I> to becoming a view-only device for Mark V data.

Rebooting the <I> will not affect the state of Control Lockout Commands. However, the status is not saved until the Control Lockout Administration is exited normally by clicking on the EXIT target at the bottom of the display..

The enable/disable Commands function can itself be disabled or enabled according to two levels of authorization (OPERATOR, SUPERVISOR). Authorization is carried out through the <I>'s Password Administration scheme.

4-1.1. Implementing Control Lockout Using Password Administration

Control Lockout is a function that is subject to Password Administration enabling. Without the proper level of authorization, the Control Lockout feature cannot be utilized. There are two levels of Password Administration required to implement Control Lockout, SUPERVISOR and OPERATOR.

4-1.2. Control Lockout for Multi-Panel <I>s

In circumstances where a single <I> processor is controlling multiple panels, Control Lockout may be implemented in such a way that the <I> is prohibited only from sending (COMMANDS or ALARMS Commands) signals to specific panels.

Multi-panel <I>s will necessarily have their configuration files setup to facilitate multi-panel control. Specifically, this entails configuring the CONFIG.DAT file. Divided into two sections (UNIT_DATA & NETWORK_DATA), this data file is responsible for defining which of the panels the <I> should communicate with, and consequently, the Stage Link address of each. It is here (specifically the UNIT_DATA section) that the Control Lockout program looks to see if the <I> is multi-panel functional. The following is a conventional example of a UNIT_DATA segment that defines multi-panel (3 panels) capability:

;	UNIT#	UNIT NAME	PATH TO CONFIG DATA
;	----	-----	-----
;	UNIT_DATA		
	1	T1	F:\UNIT1
	2	T2	F:\UNIT2
	3	T3	F:\UNIT3
	4	T4	F:\UNIT4
	5	T5	F:\UNIT5

If the file specifies multi-panel operation, the Control Lockout program will automatically compensate to allow separate panel lockout capability. From the example above, the Control Lockout Display shown in Figure 4-2 would be constructed.

GE Drive Systems		CONTROL LOCKOUT ADMINISTRATION				21-JAN-1993 11:32:56	
UNIT		COMMANDS		ALARMS			
T1	SUPERVISOR	ENABLE	DISABLE	ENABLE	DISABLE		
	OPERATOR	ENABLE	DISABLE	ENABLE	DISABLE		
T2	SUPERVISOR	ENABLE	DISABLE	ENABLE	DISABLE		
	OPERATOR	ENABLE	DISABLE	ENABLE	DISABLE		
T3	SUPERVISOR	ENABLE	DISABLE	ENABLE	DISABLE		
	OPERATOR	ENABLE	DISABLE	ENABLE	DISABLE		

Clicking on this target will cause targets to appear which will allow you to set any unit back to a control location of ZERO (0).

SHOW RESET

EXIT **ALARM DISPLAY** **MAIN DISPLAY**

Figure 4-1. Control Lockout Screen with Multi-Unit Configuration

Operation of multi-panel Control Lockout is essentially identical to that for single panel <I>s except for the fact that more than one panel can be locked out at a time. With this configuration, the Password Administration program will enable/disable all OPERATOR and/or SUPERVISOR levels at the same time.

4-2. CONTROL HIERARCHY

Control Hierarchy is an optional scheme to define different control locations and pass control between these locations. Control locations are defined, and then different elements in the system are configured to only send commands if the current control location allows them to send commands.

To implement the Control Hierarchy option, please contact the local GE Power Generation Field Service Office.



Problem Report

General Electric Company

To:
GE Industrial Control Systems
Product Service, Room 191
1501 Roanoke Blvd.
Salem, VA 24153-6492 USA

Fax: 001-540-387-8606

Name	Telephone Number
Company Name	Fax Number
Address	Job Site
	GE Requisition Number
SPEEDTRONIC™ Mark V Turbine Control: User's Manual	

Problem Description (Describe problem thoroughly. Include sequence leading up to problem.)

Detach, fold, and mail – or fax this side only.

..... Fold here and close with staple or tape

Place
stamp
here

GE Industrial Control Systems
Product Service, Room 191
1501 Roanoke Blvd.
Salem, VA 24153-6492 USA

..... Fold here first



Reader Comments

General Electric Company

To:
GE Industrial Control Systems
Technical Publications, Room 191
1501 Roanoke Blvd.
Salem, VA 24153-6492 USA

Fax: 001-540-387-8606

We welcome comments and suggestions to make this publication more useful.

Name		Telephone Number
Company Name		Fax Number
Address		Job Site
		GE Requisition Number
Publication No.	Issue/Revision Date	Today's Date

GENERAL COMMENTS

	Excellent	Good	Fair	Poor
Contents	☐	☐	☐	☐
Organization	☐	☐	☐	☐
Technical accuracy	☐	☐	☐	☐
Clarity	☐	☐	☐	☐
Completeness	☐	☐	☐	☐
Drawings, figures, and tables	☐	☐	☐	☐
Referencing and tables of contents	☐	☐	☐	☐
Readability	☐	☐	☐	☐

SPECIFIC COMMENTS (Corrections, information that could be expanded, and so on)

Page Number	Comment

Other suggestions for improving this publication:

As compared to publications from other manufacturers of similar products, how would you rate this document?

- ☐ Superior ☐ Comparable ☐ Inferior ☐ Do not know

Indicate the type of user/reader function that best describes you:

☐ System Integrator	☐ Distributor	☐ OEM	☐ Installation
☐ Programmer	☐ Maintenance	☐ Operator	☐ Other (please specify)

Detach, fold, and mail – or fax this side only.

..... Fold here and close with staple or tape

Place
stamp
here

GE Industrial Control Systems
Technical Publications, Room 191
1501 Roanoke Blvd.
Salem, VA 24153-6492 USA

..... Fold here first



*GE Industrial
Control Systems*

*General Electric Company
1501 Roanoke Blvd
Salem, VA 24153-6492 USA*



GEK 107359
April 2000
Replaces ATCMKV_VI

GE Power Systems Gas Turbine

Annunciator Troubleshooting Chart

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes the matter should be referred to the GE Company.

© 2000 GENERAL ELECTRIC COMPANY

<I>/HMI Alarm Message, Logic & No.		Cause	Action
L63ADL_ALM	Atomizing Air Diff. Pressure Low	Atomizing air compressor not providing adequate pressure.	Check atomizing air system.
L26AAH_ALM	Atomizing Air Temp. High	Failure of atomizing precooler louvers to open and close.	Check water supply to the atomizing air precooler, isolating valve position flow restrictions.
L86S	Auto Synchronizing Lockout	Auto synchronizing self-checking system has detected a synchronizing equipment abnormality.	Investigate synchronization system to determine exact cause of problem.
L52HQ_ALM	Auxiliary Hydraulic Oil Pump Motor Running	Accessory gear-driven hydraulic pump has not supplied sufficient pressure because of leaks or failure of pump.	Check hydraulic system.
L52QA_ALM	Auxiliary Lube Oil Pump Motor Running	The main accessory gear driven lube oil pump is supplying insufficient lube oil pressure due to pump failure or leaks	Examine main lube pump. Check pump output and main lube filters for leaks or plugging.
L49X_ALM	Auxiliary Motor Overload	One of the auxiliary motors is overloaded.	Check auxiliary motors to determine which motor is overloaded and the cause of the overloading.
L52QS_ALM	Auxiliary Seal Oil Pump Running	Insufficient pressure from main seal oil supply pump.	Check seal oil supply system components.
	Battery 125 VDC Ground	Insulation failure has resulted in a ground on the 125 VDC system.	Isolate and remove ground from the system.
L27BLN_ALM	Battery Charger AC Undervoltage	Battery charger AC undervoltage.	Check battery charger AC breaker. Check voltage magnitude.
	Battery DC Undervoltage	Battery system voltage is low. Battery charger is not functioning properly, excessive drain on the batteries, or bad cells in battery.	Check battery charger for proper operation, correct excessive drain on battery, check for bad cells. The gas turbine should not be operated unless DC power is available to the emergency DC lube oil pump.

<I>/HMI Alarm Message, Logic & No.		Cause	Action
L30LOA	Bearing Drain Temperature High	High bearing drain temperature.	Check lube oil feed and drain piping.
	Bearing Metal Temperature High	Bearing or lube oil problem.	Check bearings and lube oil system.
L27VVN_ALM	Black Start Inverter Trouble	The black start inverter output voltage has gone low, ignition power has been transferred to the MCC 12 VAC.	Troubleshoot black start inverter.
L27BN_ALM	Bus Undervoltage – No Auto Synch	Bus synchronizing potential not available.	Check bus PT fuses and wiring. Do not use auto synchronizing or manual synchronizing until problem is resolved.
L28FD_SD	Chamber Flamed Out During Shutdown	Flame loss during fired shutdown period.	Investigate cause and remedy before restarting turbine. Monitor vibration on the way up.
L30SPA	Combustion Trouble	Faulty thermocouples, gas path hardware or uneven distribution of fuel to the fuel nozzles.	Analyze data for trends. At earliest shutdown check thermocouples. Perform borescope or combustion inspection. Check flow divider fuel pressures. Check for plugged nozzles.
LCOM_B_ALM	Common IO Communication Loss (MKV Control Only)	<C> processor is no longer communicating.	Check <C> power supply card and cabling.
L86TCI	Compressor Inlet Thermocouples Disagree	Bad thermocouple signal. Thermocouples in the inlet have failed, shorted or open.	Check thermocouples and wiring and replace faulty thermocouple(s).
L86CB1	Compressor Bleed Valve Position Trouble	Compressor bleed valves have not operated properly. They are in the wrong position or required an excessive amount of time to move from one position to the other.	Investigate problem. The problem should be corrected before restarting. The Master Reset switch must be pressed before restarting.

<I>/HMI Alarm Message, Logic & No.		Cause	Action
L30 COMM_IO_R	VCM I/O State Exchange for <R> failed (MKVI Only)	<R> Processor is no longer communicating.	Check <R> power supply, cards, and cabling.
L30 COMM_IO_S	VCM I/O State Exchange for <S> failed (MKVI Only)	<S> Processor is no longer communicating.	Check <S> power supply, cards, and cabling.
L30 COMM_IO_T	VCM I/O State Exchange for <T> failed (MKVI Only)	<T> Processor is no longer communicating.	Check <T> power supply, cards, and cabling.
L26CTH_ALM	Control Panel Temp High	Air conditions not maintaining proper temperature.	Check air conditioners.
L12HF	Control Speed Signal Loss - HP	Machine tripped due to loss of speed signal.	Check wiring to speed pickups.
L12HFD_C	Control Speed Signal Trouble - HP	HP speed pickup voting mismatch in <Q>.	Check and recalibrate HP speed pickups.
L12HFD_P	Protective Speed Signal Trouble - HP	HP speed pickup voting mismatch in <P>.	Check and recalibrate HP speed pickups.
L12LF	Control Speed Signal Trouble - LP	LP speed pickup voting mismatch.	Check and recalibrate LP speed pickups.
L30CD	Cooldown Trouble	Unit failed to go on cooldown, or the cooldown cycle was aborted prior to cooldown timer timeout.	Check ratchet system. Monitor vibration when cooldown cycle is reinitiated.
L52FC_ALM	Cooling Fan Motor Breaker Open	Cooling fan motor did not start.	Check cooling fan motor module in PECC.
L71WL_ALM	Cooling Water Level Low	Cooling water tank level low.	Check cooling water system for leaks.
L63QQ3H_ALM	Coupling Oil Filter Diff Pressure High	Clogged filter.	Replace filter.
L3CP_ALM	Customer Start Inhibit	Customer contact input not enabled.	Check customer's permissive.
L4CT_ALM	Customer Trip	Customer trips input to the L4CT logic have caused an automatic trip of the unit.	Determine which of the customer trip devices caused the trip and correct.

<I>/HMI Alarm Message, Logic & No.		Cause	Action
L27QEL_ALM	DC Motor Undervoltage (Lube Oil)	DC power not supplied to emergency DC lube pump.	Check power to DC lube pump (MCC breaker on). The gas turbine should not be operated unless DC power is available to the emergency DC lube pump.
L30DIAG_C	Diagnostic Alarm <C> (Mark V Control Only)	The microprocessor self-checking program has uncovered a control panel problem.	Call up diagnostic display.
L30DIAG_Q	Diagnostic Alarm <Q> (Mark V Control Only)	The microprocessor self-checking program has uncovered a control panel problem.	Call up diagnostic display.
L26DWH_ALM	Diesel Engine Cooling Water Temp High	Diesel cooling water temperature is high.	Check diesel cooling water system.
L2DWZ2	Diesel Failure to Break Turbine Away	Diesel was unable to accelerate to maximum rpm.	Check diesel. Check diesel maximum torque solenoid.
L48DSX	Diesel Failure to Start	Diesel has failure to start.	Check diesel fuel tank.
L4DEY_ALM	Diesel Failure to Stop	Diesel should stop automatically after a 5 minute cooldown period.	Check diesel stop solenoid 20DV.
L63QDN_ALM	Diesel Lube Oil Pressure Low	Diesel lube oil pressure is low.	Check diesel lube oil system.
L83DT1	Diesel Test Mode Selected	Indication that diesel test pushbutton permissive has been activated.	Test mode should be deselected once the test is complete.
L63LF2H_ALM	Distillate Fuel Filter Differential Pressure High	Clogged filter.	Replace filter.
L26FD1H_ALM	Distillate Fuel Temperature High	Possible cooling system problem.	Check temperature sensor and cooling system.
L12H	Electrical Overspeed Trip - HP	The speed control system has not limited HP turbine speed within the trip limits.	Isolate problem and correct.
L12L	Electrical Overspeed Trip - LP	The speed control system has not limited LP turbine speed within the trip limits.	Isolate problem and correct.

<I>/HMI Alarm Message, Logic & No.		Cause	Action
L72QEZ_ALM	Emergency Lube Oil Pump Motor Running	Loss of AC power to main lube oil pumps.	Determine cause of AC power loss.
L72ES_ALM	Emergency Seal Oil Pump Running	Generator seal oil pressure is low.	Check main and auxiliary seal oil supply system components.
L59E_ALM	Exciter Overvoltage	Excessive field volts have been detected.	Check exciter.
L94EK	Exciter Rect Cooling Trouble - Trip 52G	Breaker has tripped and machine is at FSNL because of problem with exciter rectifier cooling.	Investigate exciter rectifier cooling system.
L26SFH_ALM	Exciter Rectifier Bridge Temp High	Possible cooling system problem.	Check exciter rectifier cooling system.
L86TXT	Exhaust Overtemperature Trip	Turbine has tripped due to high median exhaust temperature.	Investigate.
L86TXT	Exhaust Overtemperature Trip	The temperature control system has not limited exhaust temperature within the trip limits.	Isolate problem and correct.
L63TK_ALM	Exhaust Frame Cooling Air Pressure Low	Exhaust frame blower motor not operating. Air passages blocked.	Check motor operation. Inspect cooling air flow passages.
L90TKL	Exhaust Frame Cooling System Trouble - Unload	Exhaust frame cooling fans 88TK-1,2 problem or system problem.	Investigate exhaust frame cooling system.
L63EAH_ALM	Exhaust Pressure High Alarm	Exhaust pressure has risen above recommended levels.	Inspect exhaust filter and ducting for blockage.
L63ETH	Exhaust Pressure High Trip	Exhaust pressure has risen above the trip level.	Inspect exhaust filter and ducting for blockage.
L63ETHX_ALM	Exhaust Pressure Switch Trouble	Bad signal from exhaust pressure switch.	Check switches and switch wiring.
L30TXA	Exhaust Temperature High	The exhaust gas temperature is excessive.	Check all thermocouples. Replace any bad thermocouples. If problem is not thermocouples, isolate portion of Control System causing the problem.
L30TXA	Exhaust Temperature High	High median exhaust temperature calculated in.	Lower load to reduce exhaust temperature. Investigate.

<I>/HMI Alarm Message, Logic & No.		Cause	Action
L30SPTA	Exhaust Thermocouple Trouble	Faulty thermocouple.	Check thermocouples.
L86TFB	Exhaust Thermocouples Open Trip	Excessive number of thermocouples not connected.	Check and reconnect thermocouples.
L63FLZ_FLT	Failure to Establish Liquid Fuel Press.	Liquid fuel forwarding system problem.	Check that power is being supplied to liquid fuel forwarding pump/motor. Troubleshoot per system components per instructions.
L30FD_ALM	Failure to Ignite	Failure to fire within the one minute period.	Check that ac power is supplied to the ignition system.
L62TT2_ALM	Failure to Start	The master protective logic signal "L4" has not been set within 30 seconds of the start signal, has tripped the unit twice or, if the unit is operating in remote, flame was not established after two tries.	Check all signals making up the L4 logic signal to determine which caused the problem, or determine cause of lack of flame establishment.
L3Z	Failure to Synchronize	Unit did not synchronize and close generator breaker within the normal expected time (15 seconds).	Check all signals going making up the L4 logic signal to determine which caused the problem or determine the cause of lack of flame establishment.
L45FTX2_ALM L45FTX1_ALM	Fire in Zone #1 or Zone #2 Trip	Fire in the turbine or accessory compartment.	Restarting after an operation of the CO ₂ system requires that the CO ₂ system be reset, including all doors and dampers, and the CO ₂ release mechanism.
L45FAX_ALM	Fire Protection System Inoperative	CO ₂ pressure or control problem.	Check fire protection system.
L28FD_ALM	Flame Detector Trouble	One of the detectors operating when no flame is present.	Check for proper operation of the flame detection system. Check that the flame detector quartz window are clean.

<I>/HMI Alarm Message, Logic & No.		Cause	Action
L60FSRG	FSR Gag Not at Max Limit	Manual FSR control has not been reset to a position where it will not interfere with automatic FSR control.	Raise the manual FSR control to maximum.
L3GCVFLT	Gas Control Valve Servo Trouble	The gas control valve feedback signal is abnormal.	Check LVDT.
L63HGL_SENSR	Gas Fuel Hydraulic Pressure Switch Trouble	Bad signal from hydraulic pressure switch.	Check switch and switch wiring.
L63HGL_ALM	Gas Fuel Hydraulic Trip Pressure Low	Low oil pressure in gas fuel hydraulic oil trip circuit.	Check the control oil filter and control oil piping. This alarm will actuate if the turbine is tripped with the manual emergency trip valve on the turbine or a large leak were to occur in the hydraulic trip circuit piping.
L3GFIVP	Gas Fuel Intervalve Pressure Trouble	Pressure sensed between the gas control valve and the speed ratio valve is abnormal.	Check GRV control system, intervalve vent, and pressure transducer.
L63PGFT	Gas Fuel Nozzle Purge System Pressure High	Problem with valves.	Determine cause of incorrect valve positioning.
L94PGT	Gas Fuel Nozzle Purge System Trouble Trip	Either VA13-1 or -2 or 20VG-2 are stuck open and machine has tripped. Gas may be backing through the system.	Check valves for cause. Correct positioning prior to refire.
L33PGFT	Gas Fuel Nozzle Purge Valve Fail to Close	VA13-1 or -2 are obstructed.	Check valves to remove obstruction to resume purge.
L33PGO_ALM	Gas Fuel Nozzle Purge Valve Fail to Open	No atomizing air flow; VPR44-1 stuck.	Check valve.
L63FGL_ALM	Gas Fuel Pressure Low	Gas fuel pressure to turbine has been sensed as low.	Check cause of low supply pressure.
L3GRVFLT	Gas Ratio Valve Position Servo Trouble	The gas ratio valve feedback signal is abnormal.	Check LVDT.
L63CA3L_ALM	Gen Air Filter Cleaner Pressure Low	Generator air inlet filter cleaning system problems.	Check air inlet filter cleaning components.

<I>/HMI Alarm Message, Logic & No.		Cause	Action
L43HPA_ALM	Gen Purge System on Manual Control	Operator has selected manual control.	Change to automatic control.
L52GA_ALM	Gen. Inlet Air Dirt Separator Not Running	Generator inlet air dirt separator malfunction.	Check separator motor for proper operation. Check supply system wiring.
L63GFH_ALM	Generator Air Filter High Pressure Drop	High pressure differential across generator air inlet filters.	Inspect and clean/change filter elements, as required.
L63BQL_ALM	Generator Bearing Vacuum Low	Generator bearings are sealed by vacuum. This alarm indicates a potential problem with the sealing system.	Investigate generator bearing sealing system.
L52G_ALM	Generator Breaker Tripped	Generator breaker has been tripped by an automatic protective device or manually.	Determine device that tripped the breaker.
L63GKL_ALM	Generator Casing Hydrogen Press. Low	Low hydrogen pressure in generator.	Check hydrogen supply system.
L71WGH_ALM	Generator Casing Liquid Level High	Liquids have accumulated in bottom of generator.	Remove liquids, check for leaks and take action to prevent recurrence of problem.
L33GCC_ALM	Generator CO ₂ Door Trouble	Generator CO ₂ door is closed.	Door must be opened and the latch reset.
L86TGT_ALM	Generator Differential Trip	A generator panel protective device has tripped the 86G lockout relay.	Determine which protective device tripped the 86G and correct the abnormality that precipitated the trip.
L64F_ALM	Generator Field Ground	A ground on the generator field has been detected.	Operation of the generator with the field grounded is not recommended as a second ground could result in excessive damage to the generator field.

<I>/HMI Alarm Message, Logic & No.		Cause	Action
L94H_ALM	Generator Hydrogen Purge Shutdown	Shutdown initiated due to one or more hydrogen system problems, e.g., hydrogen purity has fallen to shutdown level.	Check hydrogen cabinet for undervoltage. Check hydrogen control switch in maintenance/auto. Check and restore hydrogen purity. Check seal unit. If purity continues to deteriorate, a possible hazard condition may develop.
L49GH_ALM	Generator Stator Temp High	Generator stator temperature is excessive caused by lack of cooling or overload.	The generator should not be operated when the stator temperature is excessive. Check cooling system, reduce overload on generator.
L94GEN	Generator Ventilation Trouble Shutdown	Temperature in generator compartment exceeds limits. Vent fans inoperable or insufficient to handle ventilation requirements.	Check generator ventilation system for proper fan/motor operation. Check ventilation dampers for proper operation/position.
L63FU2LA	Heavy Fuel Pressure Low, Auto Xfer to Dist	Problem with heavy fuel system.	Investigate heavy fuel system.
L26FU2LA	Heavy Fuel Temp Low, Auto Xfer to Dist	Problem with heavy fuel system.	Investigate heavy fuel system.
L3FUZ	Heavy Fuel Transfer Permissive Trouble	Turbine unable to transfer to heavy fuel.	Check heavy fuel system. Be sure fuel is warm and free-flowing.
L30SPT	High Exhaust Temp. Spread Trip	Faulty thermocouples, gas path parts or uneven distribution of fuel to the fuel nozzles.	Analyze data for trends. Perform borescope or combustion inspection. Check flow divider, fuel pressures. Check for plugged nozzles.
L39VA	High Vibration Alarm	High vibration at one or more bearings.	Monitor vibration readings.
L39VTX_ALM	High Vibration Trip or Shutdown	High vibration due to bowed rotor, mechanical imbalance, bearing failure, etc.	Check that the hydraulic ratchet is operating properly. Check for mechanical failures, observe vibration level on the next startup.

<I>/HMI Alarm Message, Logic & No.		Cause	Action
L30TNH_DIFF	HP Speed Signal Differential Alarm	One of the HP speed sensors is showing a different speed than the other two.	Check HP speed pickups.
L63HF1H_ALM	Hydraulic Filter Differential Pressure High	Clogged filter.	Loss of fluid pressure and deterioration of fluid purity may result. Change filter.
L86HD	Hydraulic Protective Trouble	One second after the hydraulic oil trip is initiated either the liquid fuel stop valve is not closed or the hydraulic trip pressure (63HG, 63HL) has not decreased sufficiently.	Check operation of 20FL and 20HD servos.
L63HQ1L_ALM	Hydraulic Supply Pressure Low	Hydraulic supply pressure is low.	Check hydraulic supply pressure filter and differential pressure gauge, regulating valve or pump.
L27GHN_ALM	Hydrogen Control Panel Undervoltage	Ac power supply voltage low.	Check power supply for proper operations. Check wiring.
L63GL_GH_AL	Hydrogen Pressure High or Low (Gen)	High machine gas pressure or low manifold gas pressure.	Check generator hydrogen system.
L63HHL_ALM	Hydrogen Pressure Low (Skid)	Hydrogen supply skid pressure low.	Check skid components for proper operation.
L30HP	Hydrogen Purity Trouble	Bad generator hydrogen purity or purity pressure.	Check generator hydrogen system.
LWLX4MIN	Injection to Fuel Ratio Low-Four Minute Average	Steam (water) injection flow four minute average low.	Check steam (water) injection system.
LWLXHR	Injection to Fuel Ratio Low-Hourly Average	Steam (water) injection flow one hour average low.	Check steam (water) injection system.
L86GVA	Inlet Guide Vane Control Trouble Alarm	IGV control system problem.	Check IGV control system.
L4IGVT	Inlet Guide Vane Control Trouble Trip	IGV control system problem.	Check IGV control system.
L3IGVFLT	Inlet Guide Vane Position Servo Trouble	Incorrect servo operation.	Check servos.

<I>/HMI Alarm Message, Logic & No.		Cause	Action
L30TNI_DIFF	IP Speed Signal Differential Alarm	One of the IP speed sensors is showing a different speed than the others.	Check IP speed pickups.
L71WG_ALM	Liquid Detected in Generator	Excessive liquid in bottom of generator.	Remove liquid and take corrective action to prevent recurrence of problem.
L3LFLT	Liquid Fuel Control Fault	Liquid fuel checking system has detected an abnormal servo or LVDT position or signal.	Determine abnormal condition by reading signals (L3LFLT1 to L3LFLT5).
L63LF1H_ALM	Liquid Fuel Filter Differential Pressure High	Clogged filter.	Loss of fluid pressure and deterioration of fluid purity may result. Change filter.
L30FQL_DIFF	Liquid Fuel Flow Differential Alarm	Speed pickups on flow divider disagree.	Check and recalibrate speed pickups.
L63HL_SENSR	Liquid Fuel Hydraulic Pressure Switch Trouble	Bad signal from hydraulic pressure switch.	Check switch and switch wiring.
L63HLL_ALM	Liquid Fuel Hydraulic Trip Pressure Low	Low oil pressure in liquid fuel hydraulic oil trip circuit.	Check the control oil filter and control oil piping. This alarm will actuate if the turbine is tripped with the manual emergency trip valve on the turbine or a large leak were to occur in the hydraulic trip circuit piping.
L63FLZ_ALM	Liquid Fuel Pressure Low	Liquid fuel forwarding system problem.	Check fuel forwarding system components for proper operation. Check liquid fuel forwarding piping for leaks.
L3LFP_FLT	Liquid Fuel Pump Control Trouble	Problem with one or more control devices.	Troubleshoot liquid fuel pump control components to determine problem and correct.
L33FL_ALM	Liquid Fuel Stop Valve Failure to Open	Valve or control failure.	Check operation of VSI and controls.
L26FL2LA	Liquid Fuel Temp Low, Auto Xfer to Dist	Heavy fuel temperature is low. Unit has been automatically transferred to distillate fuel operation.	Check heavy fuel supply heating equipment.

<I>/HMI Alarm Message, Logic & No.		Cause	Action
L3TFLT	Loss of Compressor Discharge Pressure Bias	Bad signal from compressor discharge pressure transmitter.	Check transmitter and associated connections for proper bias signal.
L3DWRF	Loss of External Setpoint Load Signal		
L28FDT	Loss of Flame Trip	Failure of one of the detectors to detect flame.	Check for following: fuel being supplied to the combustors, flame in all chambers, damaged crossfire tubes, or combustors. Check for proper control valve position and fuel pressure.
L63QTX	Low Lube Oil Pressure Trip	Lube oil pressure has fallen below the trip level.	Determine cause and correct before restarting unit.
L30TNL_DIFF	LP Speed Signal Differential Alarm	One of the LP speed sensors is showing a different speed than the other two.	Check HP speed pickups.
L26QA_ALM	Lube Oil Header Temp High	Lube header temperature above recommended limits.	Check for proper operation of the lube oil heat exchangers, cooling water fans (proper rotation) and temperature regulating valve.
L26QT_ALM	Lube Oil Header Temp High Trip	Lube header temperature above recommended limits.	Check for proper operation of the lube oil heat exchangers, cooling water fans (proper rotation) and temperature regulating valve.
L71QH_ALM	Lube Oil Level High	Lube oil tank level high.	Investigate cause of high level alarm and restore normal level.
L71QL_ALM	Lube Oil Level Low	Lube oil tank level low.	Check for leaks, restore normal level.
L63QA1L_ALM	Lube Oil Pressure Low	Lube system leaks or pump trouble.	Repair leaks or pump.
L63QT_SENSR	Lube Oil Pressure Switch Trouble	Bad signal from lube oil pressure switch.	Check switches and switch wiring.
L26QN_ALM	Lube Oil Tank Temperature Low	Lube tank temperature below recommended limits (see piping schematic).	Check for proper operation of the lube oil tank heaters. Starting is inhibited if the tank temperature is low.

<I>/HMI Alarm Message, Logic & No.		Cause	Action
L26QT_SENSR	Lube Oil Temperature Switch Trouble	Bad signal from lube oil temperature switch.	Check switches and switch wiring.
L63QQ1H_ALM	Main LO Filter Diff Pressure High	Clogged filter.	Loss of fluid pressure and deterioration of fluid purity may result. Change filter.
L43MAINT	Maintenance - Forcing Mode Enable	Auto calibrate, memory changing or logic forcing mode of operation has been selected.	When done with the operation, deselect the operation.
L86MAN_SYNC	Manual Synchronizing Lockout	Manual synch lockout has been selected on Operator Interface. Breaker will not close.	Determine why manual synch has been locked out. Reset using Master Reset pushbutton on Operator Interface.
L5E_ALM	Manual Trip	The emergency stop pushbutton has been pressed.	Correct abnormality that caused the operator to push the emergency stop pushbutton.
L86MP	Master Protective Startup Lockout	Within the turbine control panel the three microprocessor controllers R, S and T are in disagreement for the proper condition of the Master Protective logic "4X".	Determine which controller is in disagreement with the other two.
L27MC1N_ALM	MCC Undervoltage	Motor control center undervoltage.	Check that power is supplied to the motor control center.
L30LTA	No. 3 Bearing Temperature High	High number 3 bearing temperature.	Check lube oil feed and drain piping.
L33BS_ALM	No. 3 Drain Valve Position Trouble	Valve incorrectly positioned.	Check drain valve operations.
L3NZFLT	Nozzle Control Servo Trouble	Problem with second stage nozzle servo.	Check servo wiring and hydraulic oil system.
L43DIAG_ALM	Off-Line Diagnostics Running	Off-line diagnostic operation has been selected.	Do not start unit until diagnostics are complete.
L3WCTIM_ALM	On Line Water Wash Inhibited	Ambient temperature is below 50 deg F.	Wait to water wash until ambient temperature is higher.

<I>/HMI Alarm Message, Logic & No.		Cause	Action
L12HBLT_ALM	Overspeed Bolt Trip - HP	The speed control system has not limited turbine speed within the trip limits.	Isolate problem and correct.
L83HOST	Overspeed Test Mode Selected - HP	HP overspeed trip being tested.	See "Overspeed Trip Checks" section of text.
L83LOST	Overspeed Test Mode Selected - LP	LP overspeed trip being checked.	See "Overspeed Trip Checks" section of text.
L30EK	Prim Exciter Rect Cooling Fan Trouble	Problem with primary exciter rectifier cooling fan.	Determine and correct problem with primary exciter rectifier cooling fan.
L4ETR_FLT	Protective Module ETR Relay Trouble	Trip due to master protective relay (4's) circuit has a problem.	Isolate <P> Protective Module and correct the problem.
L12H_P_ALM	Protective Module Overspeed Trip - HP	<P> module HP overspeed trip.	Investigate cause of overspeed.
L12L_P_ALM	Protective Module Overspeed Trip - LP	<P> module LP overspeed trip.	Investigate cause of overspeed.
L12LF_OS	Protective Speed Signal Trouble - LP	LP speed pickup voting mismatch in <P>.	Check and recalibrate LP speed pickups.
L30HRX2	Ratchet Did Not Start	Ratchet did not initiate a ratchet stroke in the prescribed time.	Check ratchet permissives.
L49HR1A_ALM	Ratchet Motor Overload	Ratchet motor overload.	Check ratchet motor overload (MCC). Check for proper operation of ratchet mechanism.
L30HRX1	Ratchet Trouble	Ratchet did not complete a prescribed motion in normal time.	Check for proper operation of ratchet mechanism.
L30RHFLT_X	Relative Humidity Sensor Fault	Humidity sensor failure.	Check sensor and wiring.
R5E_ALM	Remote Emergency Trip	Unit was tripped with the remote emergency trip pushbutton.	Investigate and correct cause of trip. Manually reset pushbutton.
L63SAL_ALM	Seal Oil Diff. Pressure Low	Low seal oil pressure across bearings.	Check seal oil system.
L63ST	Seal Oil Diff. Pressure Low Shutdown	Seal oil pressure across bearings has reached shutdown setpoint.	Correct seal oil system problem before restarting.

<I>/HMI Alarm Message, Logic & No.		Cause	Action
L71SDH_ALM	Seal Oil Drain Liquid Level High	Seal oil drain system problem.	Check generator seal oil drain system.
L63STX_ALM	Seal Oil Press. Shutdown Switch Trouble	Bad signal from seal oil pressure switch.	Check switches and switch wiring.
L30WC_LAG	Standby Cooling Water Pump Running	Either low cooling water pressure, or a problem with the main cooling water pump.	Investigate problem with cooling water system or main cooling water pump.
L30FD_LAG	Standby Dist Fuel Fwd Pump Running	Low distillate fuel pressure or problem with main dist fuel fwd pump.	Investigate fuel forwarding system and main pump.
L4DT	Starting Device Lockout		
L3SMT	Starting Device Trip	The turbine has been tripped because the starting device has failed to start the turbine.	Note where in the start sequence the turbine tripped to aid in determining cause of trip. Check the suspect system.
L4CRT	Starting Motor Breaker Did Not Pick Up	Starting motor did not start.	Checking starting motor module in PEECC.
L49CR_ALM	Starting Motor Overload	Starting motor is showing an overload.	Investigate starting motor circuits.
L86CRTX	Starting Motor Protective Lockout	Cranking motor circuit electrical fault.	Clear fault and reset 88CR.
L2SFT	Startup Fuel Flow Excessive Trip	Excessive fuel for startup has been detected. For gas fuel the gas control valve is open too far.	Check the servo and feedback signals for proper operation.
L30EKR	Stby Exciter Rect Cooling Fan Running	Problem with primary exciter rectifier cooling fan.	Determine and correct problem with primary exciter rectifier cooling fan.
L60APHA_ALM	Steam Augmentation - High Pressure	High steam pressure.	Reduce steam pressure.
L60APHT	Steam Augmentation - High Pressure Trip	Steam augmentation system tripped due to high pressure.	Correct problem before restarting steam augmentation.
L60ATHT	Steam Augmentation - High Temp. Trip	Steam augmentation system tripped due to high temperature.	Correct problem before restarting steam augmentation.
L60ATHA_ALM	Steam Augmentation - High Temperature	High steam temperature.	Reduce steam temperature.

<I>/HMI Alarm Message, Logic & No.		Cause	Action
L60APLA_ALM	Steam Augmentation - Low Pressure	Low steam pressure.	Increase steam pressure.
L60ALPT_ALM	Steam Augmentation - Low Pressure Trip	Steam augmentation system tripped due to low pressure.	Correct problem before restarting steam augmentation.
L60ATLT_ALM	Steam Augmentation - Low Temp. Trip	Steam augmentation system tripped due to low temperature.	Correct problem before restarting steam augmentation.
L60ATLA_ALM	Steam Augmentation - Low Temperature	Low steam temperature.	Increase steam temperature.
L60WL1_ALM	Steam Flow High	Excessive steam flow.	Check steam system.
L60WQPL_ALM	Steam Flow High Lockout	Excessive steam flow.	Correct problem before restarting.
L30SJ	Steam Injection Not Selected	NOx control steam injection system inoperative.	Select Steam Injection on Operator Interface.
L60SPHA_ALM	Steam Pressure High	High steam pressure.	Reduce steam pressure.
L60SPHT_ALM	Steam Pressure High Lockout	High steam pressure.	Correct steam pressure before restarting.
L60SPLA_ALM	Steam Pressure Low	Low steam pressure.	Increase steam pressure.
L60SPLT_ALM	Steam Pressure Low Lockout	Low steam pressure.	Correct steam pressure before restarting.
L60STHA_ALM	Steam Temperature High	High steam temperature.	Reduce steam temperature.
L60STHT_ALM	Steam Temperature High Lockout	High steam temperature.	Correct steam temperature before restarting.
L60STLA_ALM	Steam Temperature Low	Low steam temperature.	Increase steam temperature.
L60STLT_ALM	Steam Temperature Low Lockout	Low steam temperature.	Correct steam temperature before restarting.
LWLXHR	Steam to Fuel Ratio Low – Hourly Average	Steam (water) injection flow one hour average low.	Check steam (water) injection system.
L63QQ2H_ALM	Trip Oil Filter Diff Pressure High	Clogged filter.	Replace filter.
L63TF1H_ALM	Turbine Air Inlet Differential Pressure Alarm	Clogged filter.	Replace filter.

<I>/HMI Alarm Message, Logic & No.		Cause	Action
L63TFH_ALM	Turbine Air Inlet Differential Pressure Shut-Down	Clogged or iced filter.	Determine cause of blockage.
L63TFH_SENSR	Turbine Air Inlet Differential Pressure Switch Trouble	Bad signal from differential pressure switch.	Check switch calibration and switch wiring.
L30TFX	Turbine Air Inlet Trouble	Inlet filter excessive pressure drop or inlet filter motor overloaded or inlet compartment bypass door is not in proper position.	Check the following: Inlet filter for blockage. Inlet filter motor for proper operation. Inlet house bypass door.
L26BT1H_ALM	Turbine Compartment Temp High	Compartment temperature excessive.	Check cooling air fan for proper operation.
L83KU_ALM	Turbine Compressor Abrasive Cleaning Selected	Compressor being cleaned.	Turn function off when cleaning is complete.
L48	Turbine Incomplete Sequence	Failure of unit to reach complete sequence.	Check equipment which is causing the problem in the normal sequence.
L3A	Turbine Underspeed	Turbine has bogged down.	Reduce the load that will be applied to the generator before reclosing the generator breaker.
L39VD3_ALM	Vibration – Start Inhibit	Vibration protection system problem.	Check vibration protection system.
L39VDIFF	Vibration Differential Trouble	Vibration protection system problem.	Check vibration protection system.
L39VD1	Vibration Sensor Disabled	Signal from vibration sensor is faulty.	Check vibration sensors and wiring.
L39VF	Vibration Transducer Fault	Vibration detector impedance is not within normal bounds.	Check impedance of each vibration detector.
L3WFD_ALM	Water Flow Feedback Trouble	A disagreement between the water flow sensors has been detected.	Determine failed sensor and replace.
L86WN3	Water Flow High Lockout	Water injection system locked out due to excessive water flow. This is dangerous because it could extinguish flame.	Investigate water injection system.

<I>/HMI Alarm Message, Logic & No.		Cause	Action
L3WFLT_ALM	Water Flow Sensor Trouble	Water flow sensors disagree.	Recalibrate or replace faulty flow sensor.
L86WN1	Water Inj Suction Pressure High Lockout	High supply pressure.	Check water supply system.
L86WN2	Water Injection Discharge Pressure Low Lockout	Low supply pressure.	Check water supply system.
L30WN	Water Injection Not Selected	NOx control water injection system inoperative.	Select Water Injection on Operator Interface.
L26JS2H_ALM	Water Skid Enclosure Temperature High	Failure of exhaust fan.	Check exhaust fan/motor components for proper operation.
L26ALL_ALM	Water Skid Enclosure Temperature Low	Failure of heaters.	Check heater and blower for proper operation.
L86WN4	Water System Trouble Lockout	Water injection system not ready for use.	Check water injection system components.
L3WSFLT_ALM	Water Valve LVDT Trouble	Water valve LVDTs disagree.	Recalibrate or replace faulty LVDT.
L30TWW	Water Wash Inhibit Wheelspace Temp High	Turbine not sufficiently cooled before attempting water wash.	Allow turbine to cool to specification prior to selection.
L30WSA1	Wheelspace Temp Differential High	Excessive differential between wheelspace thermocouples.	Check thermocouples for shorts, grounds or opens. Replace failures. If condition persists investigate for seal failure.
L30WSA2	Wheelspace Temperature High	High wheelspace temperature. Check thermocouples, investigate for seal failure.	



GE Power Systems

General Electric Company
One River Road, Schenectady, NY 12345
518 • 385 • 2211 TX: 145354

Tab 21

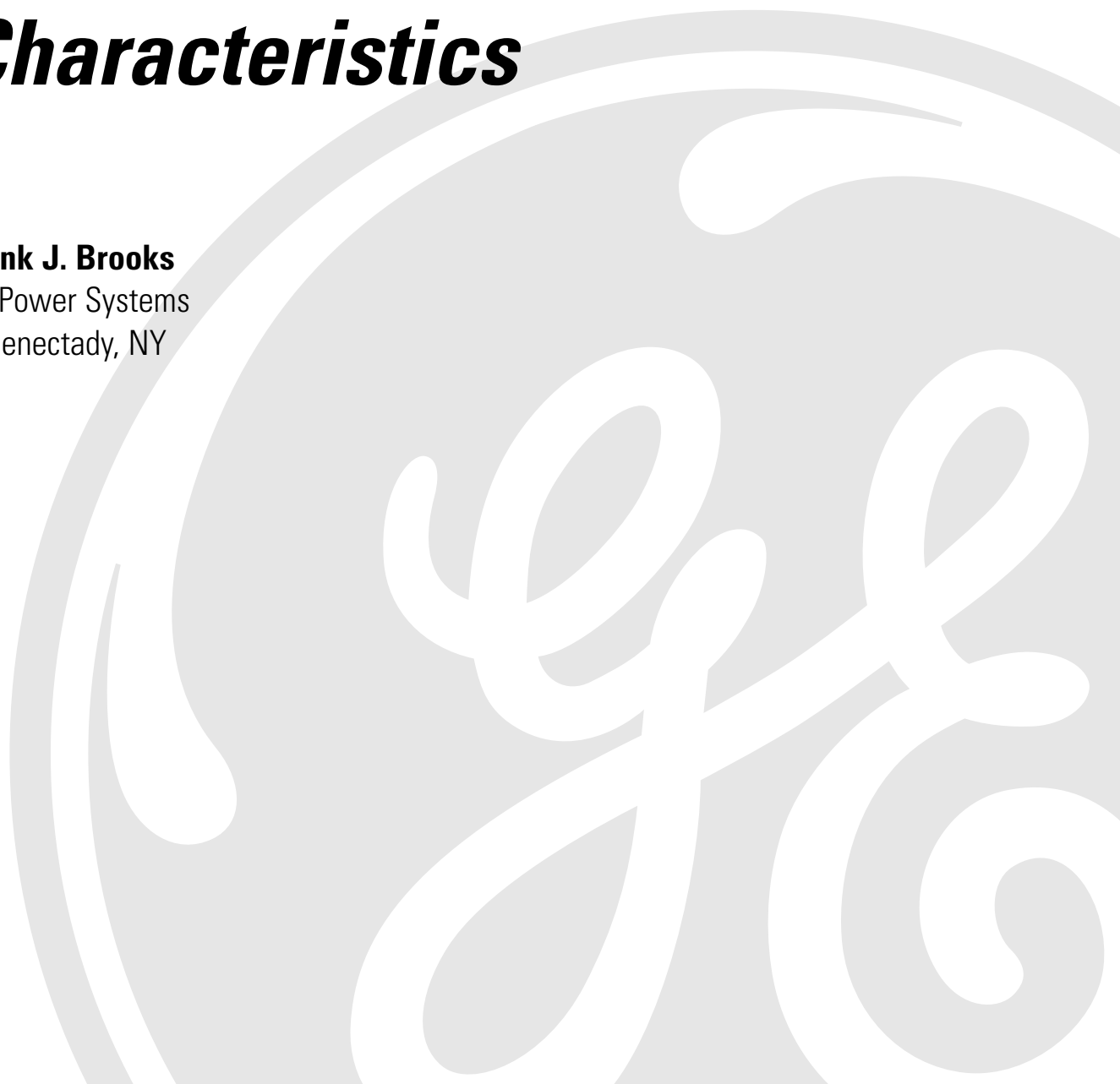


GER-3567H

GE Power Systems

GE Gas Turbine Performance Characteristics

Frank J. Brooks
GE Power Systems
Schenectady, NY



GE Gas Turbine Performance Characteristics

Contents

Introduction	1
Thermodynamic Principles	2
The Brayton Cycle	3
Thermodynamic Analysis	6
Combined Cycle	7
Factors Affecting Gas Turbine Performance	8
Air Temperature and Site Elevation	8
Humidity	8
Inlet and Exhaust Losses	9
Fuels	10
Fuel Heating	11
Diluent Injection	12
Air Extraction	12
Performance Enhancements	12
Inlet Cooling	13
Steam and Water Injection for Power Augmentation	14
Peak Rating	14
Performance Degradation	14
Verifying Gas Turbine Performance	15
Summary	15
List of Figures	16
List of Tables	16

GE Gas Turbine Performance Characteristics

GE Gas Turbine Performance Characteristics

Introduction

GE offers both heavy-duty and aircraft-derivative gas turbines for power generation and industrial applications. The heavy-duty product line consists of five different model series: MS3002, MS5000, MS6001, MS7001 and MS9001.

The MS5000 is designed in both single- and two-shaft configurations for both generator and mechanical-drive applications. The MS5000 and MS6001 are gear-driven units that can be applied in 50 Hz and 60 Hz markets.

tions the product line covers a range from approximately 35,800 hp to 345,600 hp (26,000 kW to 255,600 kW).

Table 1 provides a complete listing of the available outputs and heat rates of the GE heavy-duty gas turbines. *Table 2* lists the ratings of mechanical-drive units, which range from 14,520 hp to 108,990 hp (10,828 kW to 80,685 kW).

The complete model number designation for each heavy-duty product line machine is provided in both *Tables 1 and 2*. An explanation of

GE Generator Drive Product Line									
Model	Fuel	ISO Base Rating (kW)	Heat Rate (Btu/kWh)	Heat Rate (kJ/kWh)	Exhaust Flow (lb/hr) x10 ⁻³	Exhaust Flow (kg/hr) x10 ⁻³	Exhaust Temp (degrees F)	Exhaust Temp (degrees C)	Pressure Ratio
PG5371 (PA)	Gas	26,070.	12,060.	12,721	985.	446	905.	485	10.6
	Dist.	25,570.	12,180.	12,847	998.	448	906.	486	10.6
PG6581 (B)	Gas	42,100.	10,640.	11,223	1158.	525	1010.	543	12.2
	Dist.	41,160.	10,730.	11,318	1161.	526	1011.	544	12.1
PG6101 (FA)	Gas	69,430.	10,040.	10,526	1638.	742	1101.	594	14.6
	Dist.	74,090.	10,680.	10,527	1704.	772	1079.	582	15.0
PG7121 (EA)	Gas	84,360.	10,480.	11,054	2361.	1070	998.	536	12.7
	Dist.	87,220.	10,950.	11,550	2413.	1093	993.	537	12.9
PG7241 (FA)	Gas	171,700.	9,360.	9,873	3543.	1605	1119.	604	15.7
	Dist.	183,800.	9,965.	10,511	3691.	1672	1095.	591	16.2
PG7251 (FB)	Gas	184,400.	9,245.	9,752	3561.	1613	1154.	623	18.4
	Dist.	177,700.	9,975.	10,522	3703.	1677	1057.	569	18.7
PG9171 (E)	Gas	122,500.	10,140.	10,696	3275.	1484	1009.	543	12.6
	Dist.	127,300.	10,620.	11,202	3355.	1520	1003.	539	12.9
PG9231 (EC)	Gas	169,200.	9,770.	10,305	4131.	1871	1034.	557	14.4
	Dist.	179,800.	10,360.	10,928	4291.	1944	1017.	547	14.8
PG9351 (FA)	Gas	255,600.	9,250.	9,757	5118.	2318	1127.	608	15.3
	Dist.	268,000.	9,920.	10,464	5337.	2418	1106.	597	15.8

GT22043E

Table 1. GE gas turbine performance characteristics - Generator drive gas turbine ratings

All units larger than the Frame 6 are direct-drive units. The MS7000 series units that are used for 60 Hz applications have rotational speeds of 3600 rpm. The MS9000 series units used for 50 Hz applications have a rotational speed of 3000 rpm. In generator-drive applica-

the model number is given in *Figure 1*.

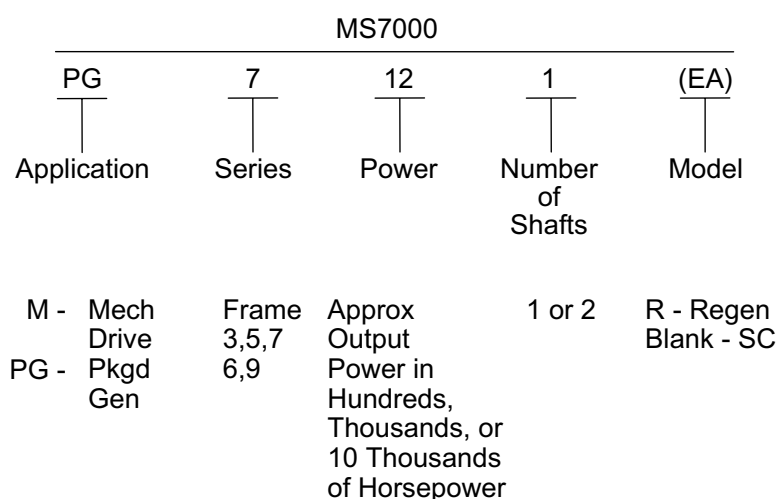
This paper reviews some of the basic thermodynamic principles of gas turbine operation and explains some of the factors that affect its performance.

GE Gas Turbine Performance Characteristics

Mechanical Drive Gas Turbine Ratings									
Model	Year	ISO Rating Continuous (kW)	ISO Rating Continuous (hp)	Heat Rate (Btu/shp-hr)	Heat Rate (kJ/kWh)	Mass Flow (lb/sec)	Mass Flow (kg/sec)	Exhaust Temp (degrees F)	Exhaust Temp (degrees C)
M3142 (J)	1952	11,290	15,140	9,500	13,440	117	53	1,008	542
M3142R (J)	1952	10,830	14,520	7,390	10,450	117	53	698	370
M5261 (RA)	1958	19,690	26,400	9,380	13,270	205	92	988	531
M5322R (B)	1972	23,870	32,000	7,070	10,000	253	114	666	352
M5352 (B)	1972	26,110	35,000	8,830	12,490	273	123	915	491
M5352R (C)	1987	26,550	35,600	6,990	9,890	267	121	693	367
M5382 (C)	1987	28,340	38,000	8,700	12,310	278	126	960	515
M6581 (B)	1978	38,290	51,340	7,820	11,060	295	134	1,013	545

Table 2. GE gas turbine performance characteristics - Mechanical drive gas turbine ratings

GT25385A



GT23054A

Figure 1. Heavy-duty gas turbine model designation

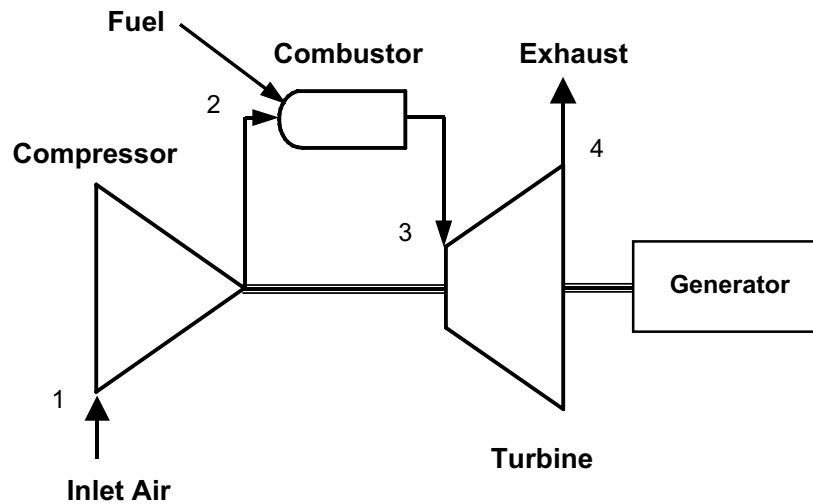
Thermodynamic Principles

A schematic diagram for a simple-cycle, single-shaft gas turbine is shown in *Figure 2*. Air enters the axial flow compressor at point 1 at ambient conditions. Since these conditions vary from day to day and from location to location, it is convenient to consider some standard conditions for comparative purposes. The standard conditions used by the gas turbine industry are 59 F/15 C, 14.7 psia/1.013 bar and 60% relative humidity, which are established by the International Standards Organization (ISO) and frequently referred to as ISO conditions.

Air entering the compressor at point 1 is compressed to some higher pressure. No heat is added; however, compression raises the air temperature so that the air at the discharge of the compressor is at a higher temperature and pressure.

Upon leaving the compressor, air enters the combustion system at point 2, where fuel is injected and combustion occurs. The combustion process occurs at essentially constant pressure. Although high local temperatures are reached within the primary combustion zone (approaching stoichiometric conditions), the

GE Gas Turbine Performance Characteristics



GT08922A

Figure 2. Simple-cycle, single-shaft gas turbine

combustion system is designed to provide mixing, burning, dilution and cooling. Thus, by the time the combustion mixture leaves the combustion system and enters the turbine at point 3, it is at a mixed average temperature.

In the turbine section of the gas turbine, the energy of the hot gases is converted into work. This conversion actually takes place in two steps. In the nozzle section of the turbine, the hot gases are expanded and a portion of the thermal energy is converted into kinetic energy. In the subsequent bucket section of the turbine, a portion of the kinetic energy is transferred to the rotating buckets and converted to work.

Some of the work developed by the turbine is used to drive the compressor, and the remainder is available for useful work at the output flange of the gas turbine. Typically, more than 50% of the work developed by the turbine sections is used to power the axial flow compressor.

As shown in *Figure 2*, single-shaft gas turbines are configured in one continuous shaft and, therefore, all stages operate at the same speed. These units are typically used for generator-drive applications where significant speed variation is not required.

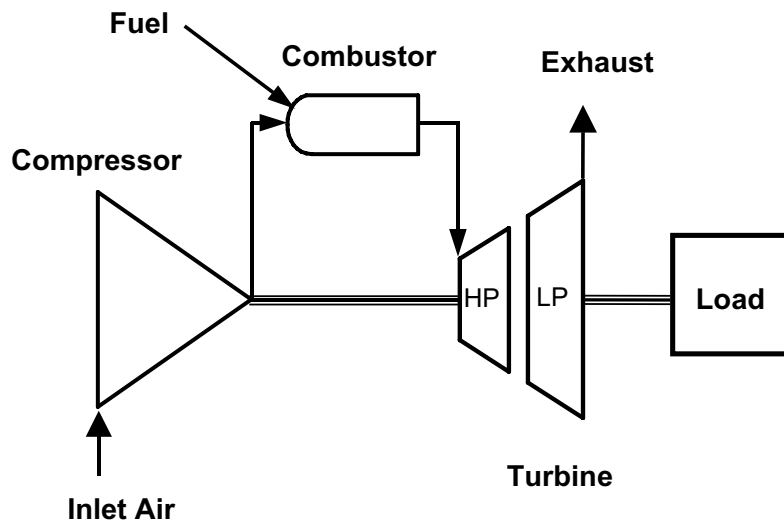
A schematic diagram for a simple-cycle, two-shaft gas turbine is shown in *Figure 3*. The low-pressure or power turbine rotor is mechanically separate from the high-pressure turbine and compressor rotor. The low pressure rotor is said to be aerodynamically coupled. This unique feature allows the power turbine to be operated at a range of speeds and makes two-shaft gas turbines ideally suited for variable-speed applications.

All of the work developed by the power turbine is available to drive the load equipment since the work developed by the high-pressure turbine supplies all the necessary energy to drive the compressor. On two-shaft machines the starting requirements for the gas turbine load train are reduced because the load equipment is mechanically separate from the high-pressure turbine.

The Brayton Cycle

The thermodynamic cycle upon which all gas turbines operate is called the Brayton cycle. *Figure 4* shows the classical pressure-volume (PV) and temperature-entropy (TS) diagrams for this cycle. The numbers on this diagram cor-

GE Gas Turbine Performance Characteristics



GT08923C

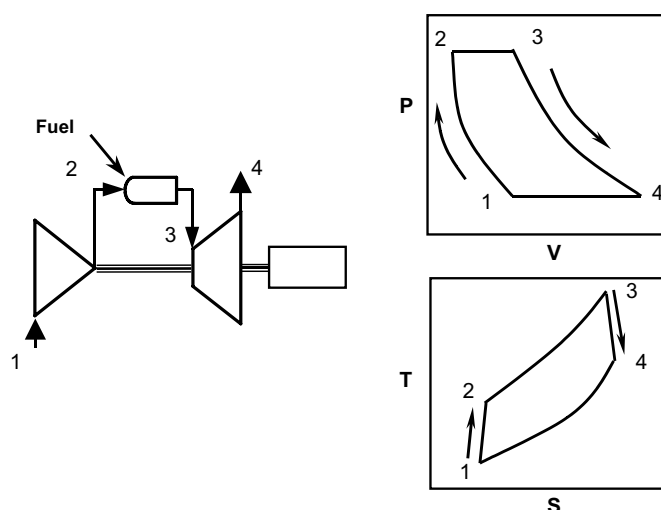
Figure 3. Simple-cycle, two-shaft gas turbine

respond to the numbers also used in *Figure 2*. Path 1 to 2 represents the compression occurring in the compressor, path 2 to 3 represents the constant-pressure addition of heat in the combustion systems, and path 3 to 4 represents the expansion occurring in the turbine.

The path from 4 back to 1 on the Brayton cycle diagrams indicates a constant-pressure cooling process. In the gas turbine, this cooling is done by the atmosphere, which provides fresh, cool

air at point 1 on a continuous basis in exchange for the hot gases exhausted to the atmosphere at point 4. The actual cycle is an “open” rather than “closed” cycle, as indicated.

Every Brayton cycle can be characterized by two significant parameters: pressure ratio and firing temperature. The pressure ratio of the cycle is the pressure at point 2 (compressor discharge pressure) divided by the pressure at point 1 (compressor inlet pressure). In an ideal cycle,



GT23055A

Figure 4. Brayton cycle

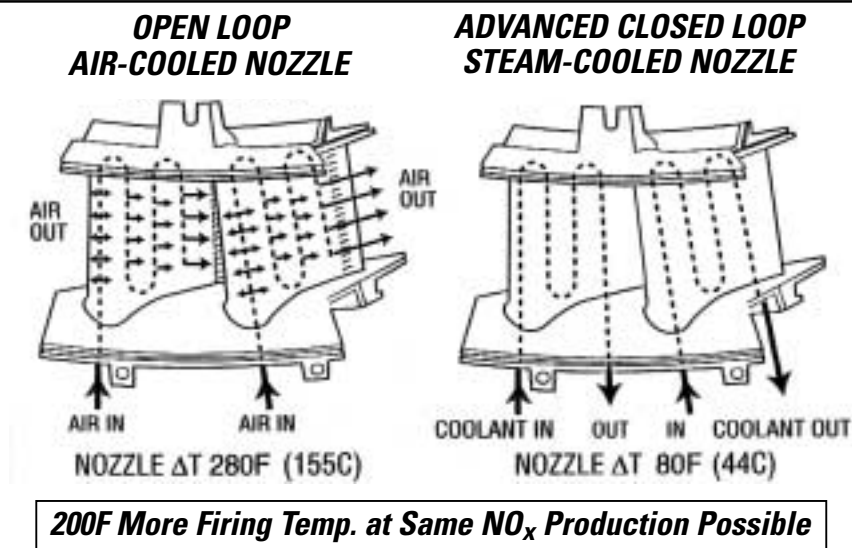
GE Gas Turbine Performance Characteristics

this pressure ratio is also equal to the pressure at point 3 divided by the pressure at point 4. However, in an actual cycle there is some slight pressure loss in the combustion system and, hence, the pressure at point 3 is slightly less than at point 2.

The other significant parameter, firing temperature, is thought to be the highest temperature reached in the cycle. GE defines firing temperature as the mass-flow mean total temperature

sented as firing temperature by point 3 in *Figure 4*.

Steam-cooled first stage nozzles do not reduce the temperature of the gas directly through mixing because the steam is in a closed loop. As shown in *Figure 5*, the firing temperature on a turbine with steam-cooled nozzles (GE's current "H" design) has an increase of 200 degrees without increasing the combustion exit temperature.



GT25134

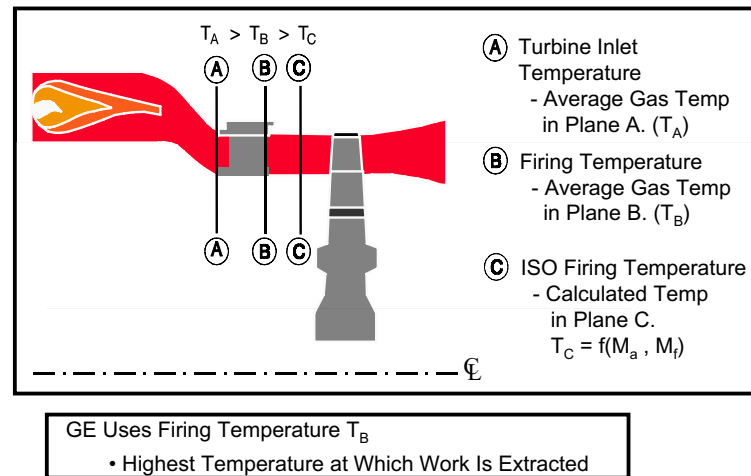
Figure 5. Comparison of air-cooled vs. steam-cooled first stage nozzle

at the stage 1 nozzle trailing edge plane. Currently all first stage nozzles are cooled to keep the temperatures within the operating limits of the materials being used. The two types of cooling currently employed by GE are air and steam.

Air cooling has been used for more than 30 years and has been extensively developed in aircraft engine technology, as well as the latest family of large power generation machines. Air used for cooling the first stage nozzle enters the hot gas stream after cooling down the nozzle and reduces the total temperature immediately downstream. GE uses this temperature since it is more indicative of the cycle temperature repre-

An alternate method of determining firing temperature is defined in ISO document 2314, "Gas Turbines – Acceptance Tests." The firing temperature here is a reference turbine inlet temperature and is not generally a temperature that exists in a gas turbine cycle; it is calculated from a heat balance on the combustion system, using parameters obtained in a field test. This ISO reference temperature will always be less than the true firing temperature as defined by GE, in many cases by 100 F/38 C or more for machines using air extracted from the compressor for internal cooling, which bypasses the combustor. *Figure 6* shows how these various temperatures are defined.

GE Gas Turbine Performance Characteristics



GT23056

Figure 6. Definition of firing temperature

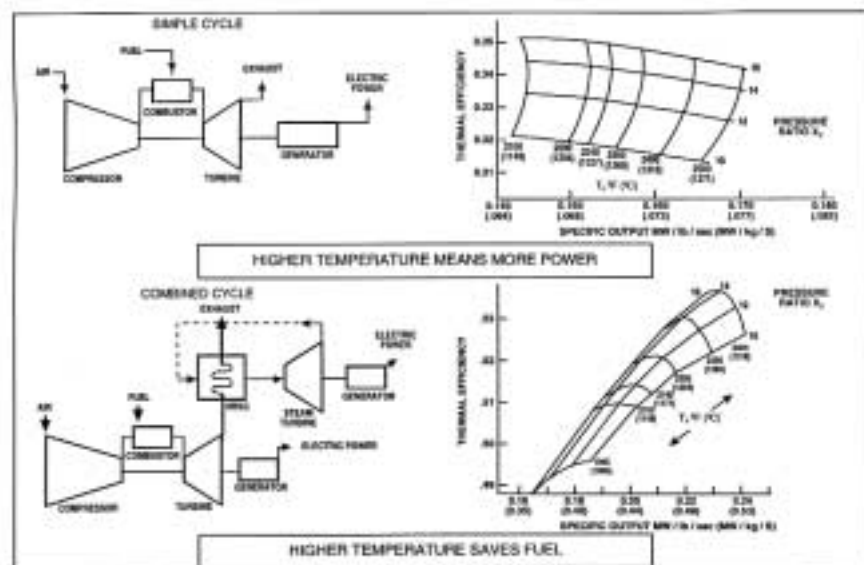
Thermodynamic Analysis

Classical thermodynamics permit evaluation of the Brayton cycle using such parameters as pressure, temperature, specific heat, efficiency factors and the adiabatic compression exponent. If such an analysis is applied to the Brayton cycle, the results can be displayed as a plot of cycle efficiency vs. specific output of the cycle.

Figure 7 shows such a plot of output and

efficiency for different firing temperatures and various pressure ratios. Output per pound of airflow is important since the higher this value, the smaller the gas turbine required for the same output power. Thermal efficiency is important because it directly affects the operating fuel costs.

Figure 7 illustrates a number of significant points. In simple-cycle applications (the top curve), pressure ratio increases translate into efficiency gains at a given firing temperature.



GT17983A

GE Gas Turbine Performance Characteristics

The pressure ratio resulting in maximum output and maximum efficiency change with firing temperature, and the higher the pressure ratio, the greater the benefits from increased firing temperature. Increases in firing temperature provide power increases at a given pressure ratio, although there is a sacrifice of efficiency due to the increase in cooling air losses required to maintain parts lives.

In combined-cycle applications (as shown in the bottom graph in *Figure 7*), pressure ratio increases have a less pronounced effect on efficiency. Note also that as pressure ratio increases, specific power decreases. Increases in firing temperature result in increased thermal efficiency. The significant differences in the slope of the two curves indicate that the optimum cycle parameters are not the same for simple and combined cycles.

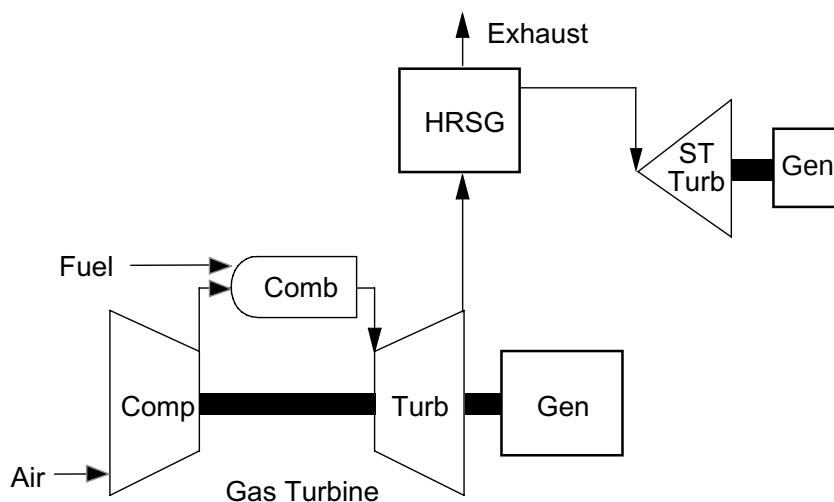
Simple-cycle efficiency is achieved with high pressure ratios. Combined-cycle efficiency is obtained with more modest pressure ratios and greater firing temperatures. For example, the MS7001FA design parameters are 2420 F/1316 C firing temperature and 15.7:1 pressure ratio;

while simple-cycle efficiency is not maximized, combined-cycle efficiency is at its peak. Combined cycle is the expected application for the MS7001FA.

Combined Cycle

A typical simple-cycle gas turbine will convert 30% to 40% of the fuel input into shaft output. All but 1% to 2% of the remainder is in the form of exhaust heat. The combined cycle is generally defined as one or more gas turbines with heat-recovery steam generators in the exhaust, producing steam for a steam turbine generator, heat-to-process, or a combination thereof.

Figure 8 shows a combined cycle in its simplest form. High utilization of the fuel input to the gas turbine can be achieved with some of the more complex heat-recovery cycles, involving multiple-pressure boilers, extraction or topping steam turbines, and avoidance of steam flow to a condenser to preserve the latent heat content. Attaining more than 80% utilization of the fuel input by a combination of electrical power generation and process heat is not unusual.



GT05363C

Figure 8. Combined cycle

GE Gas Turbine Performance Characteristics

Combined cycles producing only electrical power are in the 50% to 60% thermal efficiency range using the more advanced gas turbines. Papers dealing with combined-cycle applications in the GE Reference Library include: GER-3574F, “GE Combined-Cycle Product Line and Performance”; GER-3767, “Single-Shaft Combined-Cycle Power Generation Systems”; and GER-3430F, “Cogeneration Application Considerations.”

Factors Affecting Gas Turbine Performance

Air Temperature and Site Elevation

Since the gas turbine is an air-breathing engine, its performance is changed by anything that affects the density and/or mass flow of the air intake to the compressor. Ambient weather conditions are the most obvious changes from the reference conditions of 59 F/15 C and 14.7 psia/1.013 bar. *Figure 9* shows how ambient temperature affects the output, heat rate, heat consumption, and exhaust flow of a single-shaft MS7001. Each turbine model has its own temperature-effect curve, as it depends on the cycle

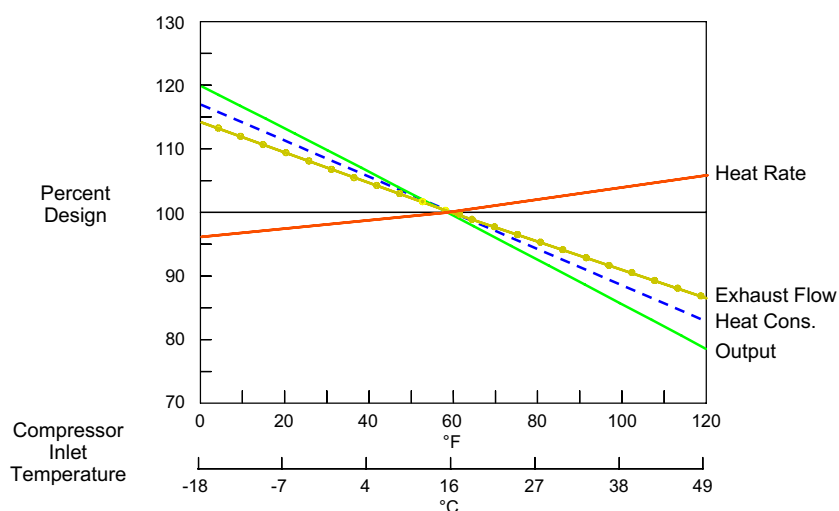
parameters and component efficiencies as well as air mass flow.

Correction for altitude or barometric pressure is more straightforward. The air density reduces as the site elevation increases. While the resulting airflow and output decrease proportionately, the heat rate and other cycle parameters are not affected. A standard altitude correction curve is presented in *Figure 10*.

Humidity

Similarly, humid air, which is less dense than dry air, also affects output and heat rate, as shown in *Figure 11*. In the past, this effect was thought to be too small to be considered. However, with the increasing size of gas turbines and the utilization of humidity to bias water and steam injection for NO_x control, this effect has greater significance.

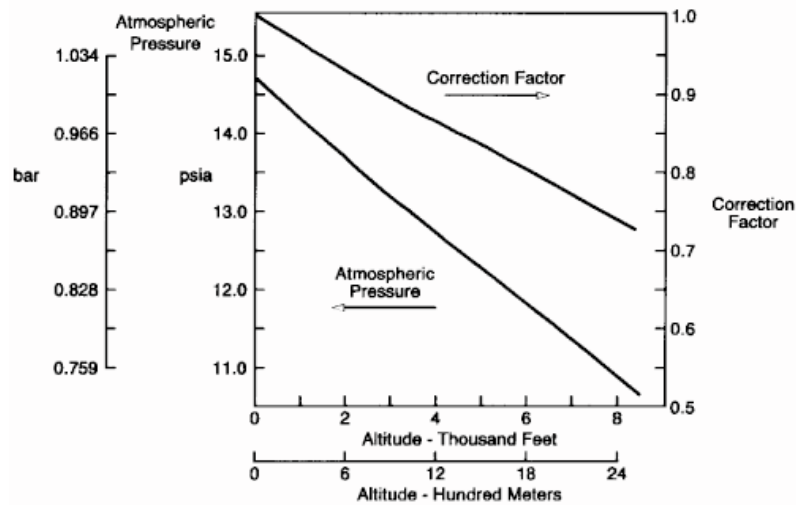
It should be noted that this humidity effect is a result of the control system approximation of firing temperature used on GE heavy-duty gas turbines. Single-shaft turbines that use turbine exhaust temperature biased by the compressor pressure ratio to the approximate firing temperature will reduce power as a result of



GT22045D

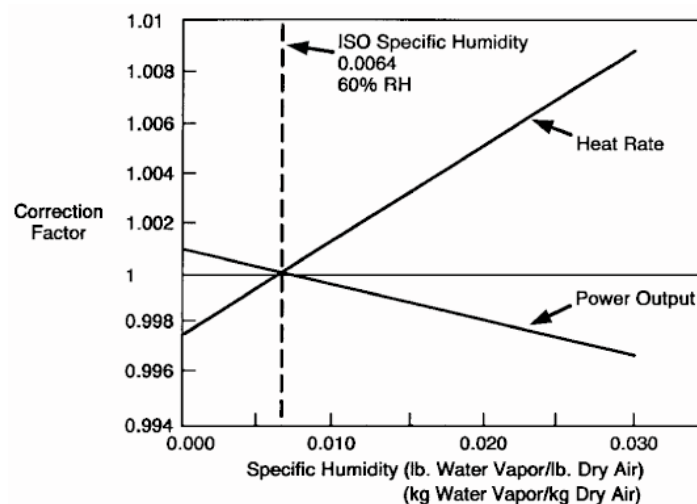
Figure 9. Effect of ambient temperature

GE Gas Turbine Performance Characteristics



GT18848B

Figure 10. Altitude correction curve



GT22046B

Figure 11. Humidity effect curve

increased ambient humidity. This occurs because the density loss to the air from humidity is less than the density loss due to temperature. The control system is set to follow the inlet air temperature function.

By contrast, the control system on aeroderivatives uses unbiased gas generator discharge temperature to approximate firing temperature. The gas generator can operate at different speeds from the power turbine, and the power will actually increase as fuel is added to raise the

moist air (due to humidity) to the allowable temperature. This fuel increase will increase the gas generator speed and compensate for the loss in air density.

Inlet and Exhaust Losses

Inserting air filtration, silencing, evaporative coolers or chillers into the inlet or heat recovery devices in the exhaust causes pressure losses in the system. The effects of these pressure losses are unique to each design. *Figure 12* shows

GE Gas Turbine Performance Characteristics

4 Inches (10 mbar) H₂O Inlet Drop Produces:

1.42% Power Output Loss

0.45% Heat Rate Increase

1.9 F (1.1 C) Exhaust Temperature Increase

4 Inches (10 mbar) H₂O Exhaust Drop Produces:

0.42% Power Output Loss

0.42% Heat Rate Increase

1.9 F (1.1 C) Exhaust Temperature Increase

GT18238C

Figure 12. Pressure drop effects (MS7001EA)

the effects on the MS7001EA, which are typical for the E technology family of scaled machines (MS6001B, 7001EA, 9001E).

Fuels

Work from a gas turbine can be defined as the product of mass flow, heat energy in the combusted gas (C_p), and temperature differential across the turbine. The mass flow in this equation is the sum of compressor airflow and fuel flow. The heat energy is a function of the elements in the fuel and the products of combustion.

Tables 1 and 2 show that natural gas (methane) produces nearly 2% more output than does distillate oil. This is due to the higher specific heat in the combustion products of natural gas, resulting from the higher water vapor content produced by the higher hydrogen/carbon ratio of methane. This effect is noted even though the mass flow (lb/h) of methane is lower than the mass flow of distillate fuel. Here the effects of specific heat were greater than and in opposition to the effects of mass flow.

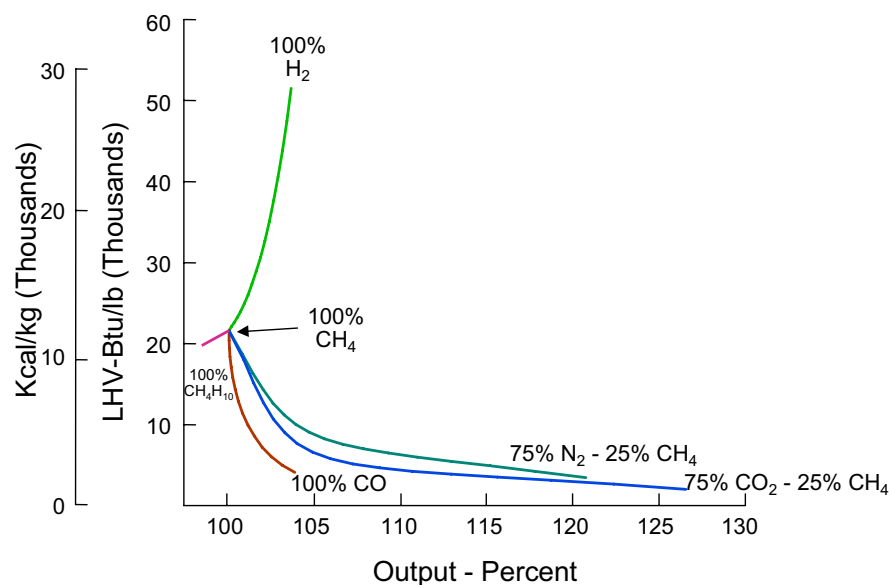
Figure 13 shows the total effect of various fuels on turbine output. This curve uses methane as the base fuel.

Although there is no clear relationship between fuel lower heating value (LHV) and output, it is

possible to make some general assumptions. If the fuel consists only of hydrocarbons with no inert gases and no oxygen atoms, output increases as LHV increases. Here the effects of C_p are greater than the effects of mass flow. Also, as the amount of inert gases is increased, the decrease in LHV will provide an increase in output. This is the major impact of IGCC type fuels that have large amounts of inert gas in the fuel. This mass flow addition, which is not compressed by the gas turbine's compressor, increases the turbine output. Compressor power is essentially unchanged. Several side effects must be considered when burning this kind of lower heating value fuels:

- Increased turbine mass flow drives up compressor pressure ratio, which eventually encroaches on the compressor surge limit
- The higher turbine power may exceed fault torque limits. In many cases, a larger generator and other accessory equipment may be needed
- High fuel volumes increase fuel piping and valve sizes (and costs). Low- or medium-Btu coal gases are frequently supplied at high temperatures, which further increases their volume flow

GE Gas Turbine Performance Characteristics



GT25842

Figure 13. Effect of fuel heating value on output

- Lower-Btu gases are frequently saturated with water prior to delivery to the turbine. This increases the combustion products heat transfer coefficients and raises the metal temperatures in the turbine section which may require lower operating firing temperature to preserve parts lives
- As the Btu value drops, more air is required to burn the fuel. Machines with high firing temperatures may not be able to burn low Btu gases
- Most air-blown gasifiers use air supplied from the gas turbine compressor discharge
- The ability to extract air must be evaluated and factored into the overall heat and material balances

As a result of these influences, each turbine model will have some application guidelines on flows, temperatures and shaft output to preserve

its design life. In most cases of operation with lower heating value fuels, it can be assumed that output and efficiency will be equal to or higher than that obtained on natural gas. In the case of higher heating value fuels, such as refinery gases, output and efficiency may be equal to or lower than that obtained on natural gas.

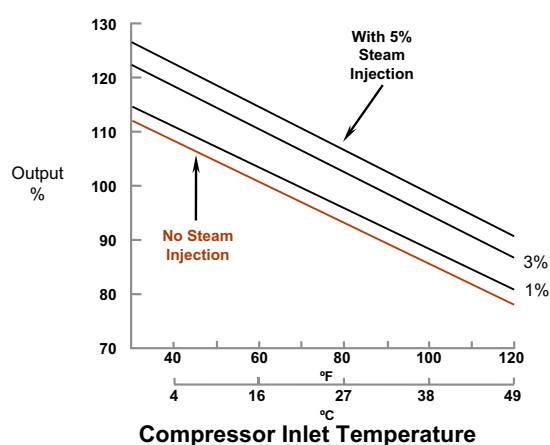
Fuel Heating

Most of the combined cycle turbine installations are designed for maximum efficiency. These plants often utilize integrated fuel gas heaters. Heated fuel results in higher turbine efficiency due to the reduced fuel flow required to raise the total gas temperature to firing temperature. Fuel heating will result in slightly lower gas turbine output because of the incremental volume flow decrease. The source of heat for the fuel typically is the IP feedwater. Since use of this energy in the gas turbine fuel heating system is thermodynamically advantageous, the combined cycle efficiency is improved by approximately 0.6%.

GE Gas Turbine Performance Characteristics

Diluent Injection

Since the early 1970s, GE has used water or steam injection for NO_x control to meet applicable state and federal regulations. This is accomplished by admitting water or steam in the cap area or “head-end” of the combustion liner. Each machine and combustor configuration has limits on water or steam injection levels to protect the combustion system and turbine section. Depending on the amount of water or steam injection needed to achieve the desired NO_x level, output will increase because of the



GT18851A

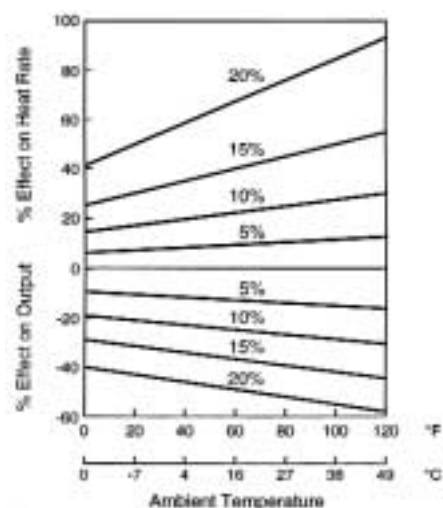
Figure 14. Effect of steam injection on output and heat rate

additional mass flow. Figure 14 shows the effect of steam injection on output and heat rate for an MS7001EA. These curves assume that steam is free to the gas turbine cycle, therefore heat rate improves. Since it takes more fuel to raise water to combustor conditions than steam, water injection does not provide an improvement in heat rate.

Air Extraction

In some gas turbine applications, it may be desirable to extract air from the compressor.

Generally, up to 5% of the compressor airflow can be extracted from the compressor discharge casing without modification to casings or on-base piping. Pressure and air temperature will depend on the type of machine and site conditions. Air extraction between 6% and 20% may be possible, depending on the machine and combustor configuration, with some modifications to the casings, piping and controls. Such applications need to be reviewed on a case-by-case basis. Air extractions above 20% will require extensive modification to the turbine casing and unit configuration. Figure 15



GT22048-1C

Figure 15. Effect of air extraction on output and heat rate

shows the effect of air extraction on output and heat rate. As a “rule of thumb,” every 1% in air extraction results in a 2% loss in power.

Performance Enhancements

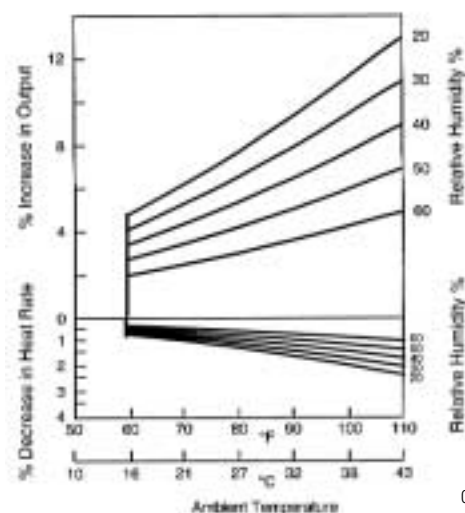
Generally, controlling some of the factors that affect gas turbine performance is not possible. The planned site location and the plant configuration (such as simple- or combined-cycle) determine most of these factors. In the event additional output is needed, several possibilities to enhance performance may be considered.

GE Gas Turbine Performance Characteristics

Inlet Cooling

The ambient effect curve (see *Figure 9*) clearly shows that turbine output and heat rate are improved as compressor inlet temperature decreases. Lowering the compressor inlet temperature can be accomplished by installing an evaporative cooler or inlet chiller in the inlet ducting downstream of the inlet filters. Careful application of these systems is necessary, as condensation or carryover of water can exacerbate compressor fouling and degrade performance. These systems generally are followed by moisture separators or coalescing pads to reduce the possibility of moisture carryover.

As *Figure 16* shows, the biggest gains from evaporative cooling are realized in hot, low-humidity climates. It should be noted that evaporative cooling is limited to ambient temperatures of 59 F/15 C and above (compressor inlet temperature >45 F/7.2 C) because of the potential for icing the compressor. Information contained in *Figure 16* is based on an 85% effective evaporative cooler. Effectiveness is a measure of how close the cooler exit temperature approaches the ambient wet bulb tempera-

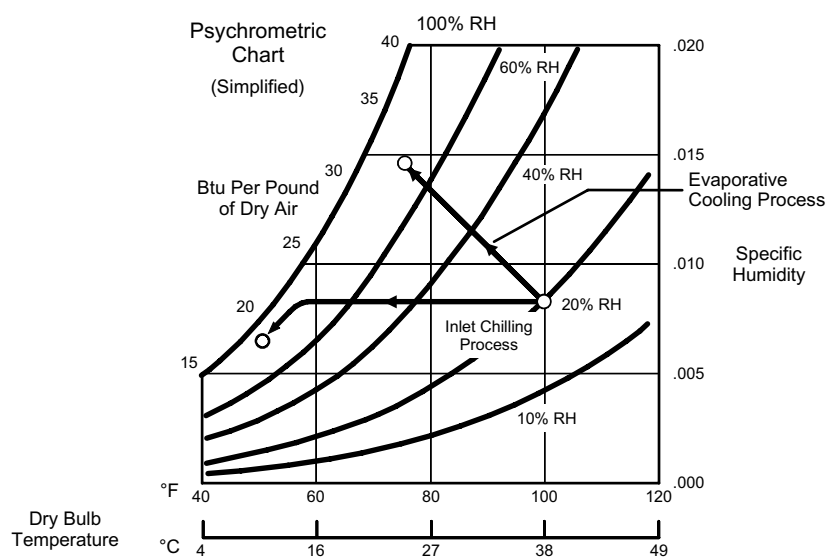


GT22419-1D

Figure 16. Effect of evaporative cooling on output and heat rate

ture. For most applications, coolers having an effectiveness of 85% or 90% provide the most economic benefit.

Chillers, unlike evaporative coolers, are not limited by the ambient wet bulb temperature. The achievable temperature is limited only by the capacity of the chilling device to produce coolant and the ability of the coils to transfer heat. Cooling initially follows a line of constant



GT21141D

Figure 17. Inlet chilling process

GE Gas Turbine Performance Characteristics

specific humidity, as shown in *Figure 17*. As saturation is approached, water begins to condense from the air, and mist eliminators are used. Further heat transfer cools the condensate and air, and causes more condensation. Because of the relatively high heat of vaporization of water, most of the cooling energy in this regime goes to condensation and little to temperature reduction.

Steam and Water Injection for Power Augmentation

Injecting steam or water into the head end of the combustor for NO_x abatement increases mass flow and, therefore, output. Generally, the amount of water is limited to the amount required to meet the NO_x requirement in order to minimize operating cost and impact on inspection intervals.

Steam injection for power augmentation has been an available option on GE gas turbines for over 30 years. When steam is injected for power augmentation, it can be introduced into the compressor discharge casing of the gas turbine as well as the combustor. The effect on output and heat rate is the same as that shown in *Figure 14*. GE gas turbines are designed to allow up to 5% of the compressor airflow for steam injection to the combustor and compressor discharge. Steam must contain 50 F/28 C superheat and be at pressures comparable to fuel gas pressures.

When either steam or water is used for power augmentation, the control system is normally designed to allow only the amount needed for NO_x abatement until the machine reaches base (full) load. At that point, additional steam or water can be admitted via the governor control.

Peak Rating

The performance values listed in *Table 1* are base load ratings. ANSI B133.6 Ratings and

Performance defines base load as operation at 8,000 hours per year with 800 hours per start. It also defines peak load as operation at 1250 hours per year with five hours per start.

In recognition of shorter operating hours, it is possible to increase firing temperature to generate more output. The penalty for this type of operation is shorter inspection intervals. Despite this, running an MS5001, MS6001 or MS7001 at peak may be a cost-effective way to obtain more kilowatts without the need for additional peripheral equipment.

Generators used with gas turbines likewise have peak ratings that are obtained by operating at higher power factors or temperature rises. Peak cycle ratings are ratings that are customized to the mission of the turbine considering both starts and hours of operation. Firing temperatures between base and peak can be selected to maximize the power capabilities of the turbine while staying within the starts limit envelope of the turbine hot section repair interval. For instance, the 7EA can operate for 24,000 hours on gas fuel at base load, as defined. The starts limit to hot section repair interval is 800 starts.

For peaking cycle of five hours per start, the hot section repair interval would occur at 4,000 hours, which corresponds to operation at peak firing temperatures. Turbine missions between five hours per start and 800 hours per start may allow firing temperatures to increase above base but below peak without sacrificing hours to hot section repair. Water injection for power augmentation may be factored into the peak cycle rating to further maximize output.

Performance Degradation

All turbomachinery experiences losses in performance with time. Gas turbine performance degradation can be classified as recoverable or non-recoverable loss. Recoverable loss is usually

GE Gas Turbine Performance Characteristics

associated with compressor fouling and can be partially rectified by water washing or, more thoroughly, by mechanically cleaning the compressor blades and vanes after opening the unit. Non-recoverable loss is due primarily to increased turbine and compressor clearances and changes in surface finish and airfoil contour. Because this loss is caused by reduction in component efficiencies, it cannot be recovered by operational procedures, external maintenance or compressor cleaning, but only through replacement of affected parts at recommended inspection intervals.

Quantifying performance degradation is difficult because consistent, valid field data is hard to obtain. Correlation between various sites is impacted by variables such as mode of operation, contaminants in the air, humidity, fuel and diluent injection levels for NO_x. Another problem is that test instruments and procedures vary widely, often with large tolerances.

Typically, performance degradation during the first 24,000 hours of operation (the normally recommended interval for a hot gas path inspection) is 2% to 6% from the performance test measurements when corrected to guaranteed conditions. This assumes degraded parts are not replaced. If replaced, the expected performance degradation is 1% to 1.5%. Recent field experience indicates that frequent off-line water washing is not only effective in reducing recoverable loss, but also reduces the rate of non-recoverable loss.

One generalization that can be made from the data is that machines located in dry, hot climates typically degrade less than those in humid climates.

Verifying Gas Turbine Performance

Once the gas turbine is installed, a performance test is usually conducted to determine

power plant performance. Power, fuel, heat consumption and sufficient supporting data should be recorded to enable as-tested performance to be corrected to the condition of the guarantee. Preferably, this test should be done as soon as practical, with the unit in new and clean condition. In general, a machine is considered to be in new and clean condition if it has less than 200 fired hours of operation.

Testing procedures and calculation methods are patterned after those described in the ASME Performance Test Code PTC-22-1997, "Gas Turbine Power Plants." Prior to testing, all station instruments used for primary data collection must be inspected and calibrated. The test should consist of sufficient test points to ensure validity of the test set-up. Each test point should consist of a minimum of four complete sets of readings taken over a 30-minute time period when operating at base load. Per ASME PTC-22-1997, the methodology of correcting test results to guarantee conditions and measurement uncertainties (approximately 1% on output and heat rate when testing on gas fuel) shall be agreed upon by the parties prior to the test.

Summary

This paper reviewed the thermodynamic principles of both one- and two-shaft gas turbines and discussed cycle characteristics of the several models of gas turbines offered by GE. Ratings of the product line were presented, and factors affecting performance were discussed along with methods to enhance gas turbine output.

GE heavy-duty gas turbines serving industrial, utility and cogeneration users have a proven history of sustained performance and reliability. GE is committed to providing its customers with the latest in equipment designs and advancements to meet power needs at high thermal efficiency.

GE Gas Turbine Performance Characteristics

List of Figures

- Figure 1. Heavy-duty gas turbine model designation
- Figure 2. Simple-cycle, single-shaft gas turbine
- Figure 3. Simple-cycle, two-shaft gas turbine
- Figure 4. Brayton cycle
- Figure 5. Comparison of air-cooled vs. steam-cooled first stage nozzle
- Figure 6. Definition of firing temperature
- Figure 7. Gas turbine thermodynamics
- Figure 8. Combined cycle
- Figure 9. Effect of ambient temperature
- Figure 10. Altitude correction curve
- Figure 11. Humidity effect curve
- Figure 12. Pressure drop effects (MS7001EA)
- Figure 13. Effect of fuel heating value on output
- Figure 14. Effect of steam injection on output and heat rate
- Figure 15. Effect of air extraction on output and heat rate
- Figure 16. Effect of evaporative cooling on output and heat rate
- Figure 17. Inlet chilling process

List of Tables

- Table 1. GE gas turbine performance characteristics - Generator drive gas turbine ratings
- Table 2. GE gas turbine performance characteristics - Mechanical drive gas turbine ratings



GE Power Systems Gas Turbine

Unit Operation/Turbine (Gas)

(Applicability MS 5001P, 6001B, 7001EA, 7001FA, 9001E Non Dry Low NOx)

I. REFERENCE DATA AND PRECAUTIONS

A. Operator Responsibility

It is essential that the turbine operators be familiar with the information contained in the following operation text, the Control Specification drawings (consult the Control System Settings drawing for the index of Control Specification drawings), the Piping Schematic drawings including the Device Summary (consult the Control System Settings Drawing for the index by model list and drawing number of applicable schematics), the SPEEDTRONIC® control sequence program and the SPEEDTRONIC® Mark V Users' Manual (GEH 5979). The operator must also be aware of the power plant devices which are tied into the gas turbine mechanically and electrically and could affect normal operation. No starts should be attempted whether on a new turbine or a newly overhauled turbine until the following conditions have been met:

1. Requirements listed under CHECKS PRIOR TO OPERATION have been met.
2. Control systems have been functionally checked for proper operation before restarting.
3. All GENERAL OPERATING PRECAUTIONS have been noted.

It is extremely important that gas turbine operators establish proper operating practices. We emphasize adherence to the following:

1. Respond to Annunciator Indicators — Investigate and correct the cause of the abnormal condition. This is particularly true for the protection systems, such as low oil pressure, overtemperature, vibration, overspeed etc.
2. Check of Control Systems — After any type of control maintenance is completed, whether repair or replacement of parts, functionally check control systems for proper operation. This should be done prior to restart of the turbine. It should not be assumed that reassembly, "as taken apart" is adequate without the functional test.
3. Monitor Exhaust Temperature During All Phases of Startup — The operator is alerted to the following:

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes the matter should be referred to the GE Company.

CAUTION

Overtemperature can damage the turbine hot gas path parts.

Monitor exhaust temperature for proper control upon first startup and after any turbine maintenance is performed. Trip the turbine if the exhaust temperature exceeds the normal trip level, or increases at an unusual rate. A particularly critical period for overtemperature damage to occur is during the startup phase before the turbine reaches governing speed. At this time air flow is low and the turbine is unable to accelerate away from excess fuel.

B. General Operating Precautions**1. Temperature Limits**

Refer to the Control Specifications for actual exhaust temperature control settings. It is important to define a “baseline value” of exhaust temperature spread with which to compare future data. This baseline data is established during steady state operation after each of the following conditions:

- a. Initial startup of unit
- b. Before and after a planned shut-down
- c. Before and after planned maintenance

An important point regarding the evaluation of exhaust temperature spreads is not necessarily the magnitude of the spread, but the change in spread over a period of time. The accurate recording and plotting of exhaust temperatures daily can indicate a developing problem. Consult Control Specification-Settings Drawings for maximum allowable temperature spreads and wheelspace temperature operating limits.

The wheelspace thermocouples, identified together with their nomenclature, are on the Device Summary. A bad thermocouple will cause a “High Wheelspace Differential Temperature” alarm. The faulty thermocouple should be replaced at the earliest convenience.

When the average temperature in any wheelspace is higher than the temperature limit set forth in the table, it is an indication of trouble. High wheelspace temperature may be caused by any of the following faults:

1. Restriction in cooling air lines
2. Wear of turbine seals
3. Excessive distortion of the turbine stator
4. Improper positioning of thermocouple
5. Malfunctioning combustion system
6. Leakage in external piping
7. Excessive distortion of exhaust inner diffuser

Check wheelspace temperatures very closely on initial startup. If consistently high, and a check of the external cooling air circuits reveals nothing, it is permissible to increase the size of the cooling air orifices slightly. Consult with a GE Company field representative to obtain recommendations as to the size that an orifice should be increased. After a turbine overhaul, all orifices should be changed back to their original size, assuming that all turbine clearances are returned to normal and all leakage paths are corrected.

CAUTION

Wheelspace temperatures are read on the <I> CRT. Temperatures in excess of the maximum are potentially harmful to turbine hot-gas-path parts over a prolonged period of time. Excessive temperatures are annunciated but will not cause the turbine to trip. High wheelspace temperature readings must be reported to the GE technical representative as soon as possible.

2. Pressure Limits

Refer to the Device Summary for actual pressure switch settings. Lube oil pressure in the bearing feed header is a nominal value of 25 psig (172.36 kPa). The turbine will trip at 8 psig (55.16 kPa). Pressure variations between these values will result from entrapped particulate matter within the lube oil filtering system.

3. Vibration Limits

The maximum overall vibration velocity of the gas turbine should never exceed 1.0 inch (2.54 cm) per second in either the vertical or horizontal direction. Corrective action should be initiated when the vibration levels exceed 0.5 inch (1.27 cm) per second as indicated on the SPEEDTRONIC® <I> CRT.

If doubt exists regarding the accuracy of the reading or if more accurate and specific vibration readings are desired a vibration check is recommended using vibration test equipment.

4. Load Limit

The maximum load capability of the gas turbine is given in the control specification. For the upper limits of generator capability, refer to the Reactive Capability Curve.

5. Overloading of Gas Turbine, Facts Involved and Policy

It is GE practice to design gas turbines with margins of safety to meet the contract commitments and to secure long life and trouble-free operation.

So that maximum trouble-free operation can be secured, GE designs these machines with more than ample margins on turbine bucket thermal and dynamic stresses, compressor and turbine wheel stresses, generator ventilation, coolers, etc. As a result, these machines are designed somewhat better than is strictly necessary, because of the importance of reliability of these turbines to our customers and to the electrical industry.

It cannot be said, therefore, that these machines cannot be safely operated beyond the load limits. Such operation, however, always encroaches upon the design margins of the machines with a conse-

quent reduction in reliability and increased maintenance. Accordingly, any malfunction that occurs as a result of operation beyond contract limits cannot be the responsibility of the GE Company.

The fact that a generator operates at temperature rises below the 185F° (85C°) for the rotor and 140F° (60C°) for the stator permitted by the AIEE Standards does not mean that it can be properly run with full safety up to these values by overloading beyond the nameplate rating. These standards were primarily set up for the protection of insulation from thermal deterioration on small machines. The imbedded temperature detectors of the stator register a lower temperature than the copper because of the temperature drop through the insulation from the copper to the outside of the insulation, where the temperature detectors are located. There are also conditions of conductor expansion, insulation stress, etc., which impose limitations. These factors have been anticipated in the “Vee” curves and reactive capability curves which indicate recommended values consistent with good operating practice. The “Vee” curves and reactive capability curves form part of the operating instructions for the generator and it is considered unwise to exceed the values given.

The gas turbine-generator sets may require gearing between the gas turbine and the generator. Where a reduction (or speed-increasing) gear is required between the gas turbine and generator, the gear is rated at the maximum capability of the gas turbine, or the maximum kVa capability of the generator, whichever is less. If the gas turbine-generator set is operated beyond the maximum rating of the gear, the gear will also be overloaded with corresponding increased maintenance and reduced length of life.

The gas turbines are mechanically designed so that (within prescribed limits), advantage can be taken of the increased capability over nameplate rating, which is available at lower ambient temperatures (because of increased air density), without exceeding the maximum allowable turbine inlet temperature.

The load limit of the gas turbine-generator must not be exceeded, even when the ambient temperature is lower than that at which the load limit of the gas turbine is reached. Under these conditions, the gas turbine will operate at this load with a lower turbine inlet temperature and the design stresses on the load coupling and turbine shaft will not be exceeded.

If the turbine is overloaded so that the turbine exhaust temperature schedule is not followed for reasons of malfunctioning or improper setting of the exhaust temperature control system, the maximum allowable turbine inlet temperature or the maximum allowable exhaust temperature, or both, will be exceeded and will result in a corresponding increase in maintenance and, in extreme cases, might result in failure of the turbine parts.

The exhaust temperature control system senses the turbine exhaust temperature and introduces proper bias to limit the fuel flow so that neither the maximum allowable turbine inlet temperature nor the maximum allowable turbine exhaust temperature is exceeded.

6. Fire Protection System Operating Precautions

The fire protection system, when actuated, will cause several functions to occur in addition to actuating the media discharge system. The turbine will trip, an audible alarm will sound, and the alarm message will be displayed on the <I> CRT. The ventilation openings in the compartments will be closed by a pressure-operated latch and the damper in the turbine shell cooling discharge will be actuated.

The annunciator audible alarm may be silenced by clicking on the alarm SILENCE target. The alarm message can be cleared from the ALARM list on the <I> CRT after the ACKNOWLEDGE target and the ALARM RESET target are actuated, but only after the situation causing the alarm has been corrected.

The fire protection system *must be replenished and reset* before it can automatically react to another fire. Reset must be made after each activation of the fire protection system which includes an initial discharge followed by an extended discharge period of the fire protection media.

Fire protection system reset is accomplished by resetting the pressure switch located on the fire protection system.

Ventilation dampers, automatically closed by a signal received from the fire protection system, must be reopened manually in all compartments before restarting the turbine.

CAUTION

Failure to reopen compartment ventilation dampers will severely shorten the service life of major accessory equipment. Failure to reopen the load coupling compartment dampers will materially reduce the performance of the generator.

7. Combustion System Operating Precautions

* * * WARNING * * *

Sudden emission of black smoke may indicate a possibility of outer casing failure or other serious combustion problems. In such an event :

- a. Immediately shut down the turbine.
- b. Allow no personnel inside the turbine compartment until turbine is shut down.
- c. Caution all personnel against standing in front of access door openings into pressurized compartments.
- d. Perform a complete combustion system inspection.

To reduce the possibility of combustion outer casing failure, the operator should adhere to the following:

- a. During operation, exhaust temperatures are monitored by the SPEEDTRONIC® control system. The temperature spread is compared to allowable spreads with alarms and/or protective trips resulting if the allowable spread limits are exceeded.
- b. After a trip from 75% load or above, observe the exhaust on startup for black or abnormal smoke and scan the exhaust thermocouples for unusually high spreads. Record temperature spread during a normal startup to obtain base line signature for comparison. Excessive tripping should be investigated and eliminated.
- c. Adhere to recommended inspection intervals on combustion liners, transition pieces and fuel nozzles.

Operating a turbine with non-operational exhaust thermocouples increases the risk of turbine overfiring and prevents diagnosis of combustion problems by use of temperature differential readings.

To prevent the above described malfunctions the operator should keep the number of non-operational exhaust thermocouples to a maximum of two but no more than *one* of any three adjacent thermocouples.

CAUTION

Operation of the gas turbine with a single faulty thermocouple should not be neglected, as even one faulty thermocouple will increase the risk of an invalid “combustion alarm” and/or “Trip”. The unit should not be shut down just for replacement of a single faulty thermocouple. However, every effort should be made to replace the faulty thermocouples when the machine is down for any reason.

Adherence to the above criteria and early preventive maintenance should reduce distortions of the control and protection functions and the number of unnecessary turbine trips.

8. Cooldown/Shutdown Precautions

CAUTION

In the event of an emergency shutdown in which internal damage of any rotating equipment is suspected, do not turn the rotor after shutdown. Maintain lube oil pump operation, since lack of circulating lube oil following a hot shutdown will result in rising bearing temperatures which can result in damaged bearing surfaces. If the malfunction that caused the shutdown can be quickly repaired, or if a check reveals no internal damage affecting the rotating parts, reinstate the cooldown cycle.

If there is an emergency shutdown and the turbine is not turned with the rotor turning device, the following factors should be noted:

- a. Within 20 minutes, maximum, following turbine shutdown, the gas turbine may be started without cooldown rotation. Use the normal starting procedure.
- b. After a shutdown of between 20 minutes and 48 hours, a restart should not be attempted unless the gas turbine rotor has been turned from one to two hours prior to the startup attempt.
- c. If the unit has been shut down and not turned at all, it must be shut down for approximately 48 hours before it can be restarted without danger of shaft bow.

CAUTION

Where the gas turbine has not been on rotor turning operation after shutdown and a restart is attempted, as under conditions (a) and (b) above, the operator should maintain a constant check on vibration velocity as the unit is brought up to its rated speed. If the vibration velocity exceeds one inch per second at any speed, the unit should be shut down and the shaft rotated for at least one hour before a second starting attempt is made. If seizure occurs during the turning operation of the gas turbine, the turbine should be shut down and remain idle for at least 30 hours, or until the rotor is free. The turbine may be rotated at any time during the 30-hour period if it is free; however, audible checks should be made for rubs.

NOTE

The vibration velocity must be measured at points near the gas turbine bearing caps.

II. PREPARATIONS FOR NORMAL LOAD OPERATION**A. Standby Power Requirements**

Standby AC power insures the immediate startup capability of particular turbine equipment and related control systems when the start signal is given. Functions identified by asterisk are also necessary for unit environmental protection and should not be turned off except for maintenance work on that particular function. Standby AC power is required for:

1. Lube oil heaters, which when used in conjunction with the lube oil pumps, heat and circulate turbine lube oil at low ambient temperatures to maintain proper oil viscosity.
2. *Control panel heating.
3. *Generator heating.
4. Lube oil pumps. Auxiliary pump should be run at periodic intervals to prevent rust formation in the lube oil system.
5. Fuel oil heaters, where used. These heaters used in conjunction with the fuel oil pumps, heat and circulate fuel oil at low ambient temperatures to maintain proper fuel oil viscosity.
6. Compartment heating.
7. *Operation of control compartment air conditioner during periods of high ambient temperature to maintain electrical equipment insulation within design temperature limits.
8. *Battery charging (where applicable).
9. Heating diesel engine cooling water to assure quick starting capability. (Applicable to diesel engine starting only.)

If a black start is required, it is recommended that the turbine be started and loaded within one hour of losing AC power.

B. Checks Prior to Operation

The following checks are to be made before attempting to operate a new turbine or an overhauled turbine. It is assumed that the turbine has been assembled correctly, is in alignment and that calibration of the SPEEDTRONIC® system has been performed per the Control Specifications. A standby inspection of the turbine should be performed with the lube oil pump operating and emphasis on the following areas:

1. Check that all piping and turbine connections are securely fastened and that all blinds have been removed. Most tube fittings incorporate a stop collar which insures proper torquing of the fittings at initial fitting make up and at reassembly. These collars fit between the body of the fitting and the nut and contact in tightening of the fitting. The stop collar is similar to a washer and can be rotated freely on unassembled fittings. During initial assembly of a fitting with a stop collar, tighten the nut until it bottoms on the collar. The fitting has to be sufficiently tightened until the collar cannot be rotated by hand. This is the inspection for a proper fitting assembly. For each remake of the fitting, the nut should again be tightened until the collar cannot be rotated.
2. Inlet and exhaust plenums and associated ducting are clean and rid of all foreign objects. All access doors are secure.
3. Where fuel, air or lube oil filters have been replaced check that all covers are intact and tight.
4. Verify that the lube oil tank is within the operating level and if the tank has been drained that it has been refilled with the recommended quality and quantity of lube oil. If lube oil flushing has been conducted verify that all filters have been replaced and any blinds if used, removed.
5. Check operation of auxiliary and emergency equipment, such as lube oil pumps, water pumps, fuel forwarding pumps, etc. Check for obvious leakage, abnormal vibration (maximum 3 mils), noise or overheating.
6. Check lube oil piping for obvious leakage. Also using provided oil flow sights, check visually that oil is flowing from the bearing drains. The turbine should not be started unless flow is visible at each flow sight.
7. Check condition of all thermocouples and/or resistance temperature detectors (RTDs) on the <I> CRT. Reading should be approximately ambient temperature.
8. Check spark plugs for proper arcing.

*** * * WARNING * * ***

<i>Do not test spark plugs where explosive atmosphere is present.</i>

If the arc occurs anywhere other than directly across the gap at the tips of the electrodes, or if by blowing on the arc it can be moved from this point, the plug should be cleaned and the tip clearance adjusted. If necessary, the plug should be replaced. Verify the retracting piston for free operation.

9. Devices requiring manual lubrication are to be properly serviced.
10. Determine that the cooling water system has been properly flushed and filled with the recommended coolant. Any fine powdery rust, which might form in the piping during short time exposure to atmosphere, can be tolerated. If there is evidence of a scaly rust, the cooling system should be power flushed until all scale is removed. If it is necessary to use a chemical cleaner, most automobile cool-

ing system cleaners are acceptable and will not damage the carbon and rubber parts of the pump mechanical seals or rubber parts in the piping.

Refer to “Cooling Water Recommendations for Combustion Gas Turbine Closed Cooling Systems” included under tab titled Fluid Specifications. Note the following regarding antifreeze.

CAUTION

Do not change from one type antifreeze to another without first flushing the cooling system very thoroughly. Inhibitors used may not be compatible and can cause formation of gums, in addition to destroying effectiveness as an inhibitor. Consult the antifreeze vendor for specific recommendations.

Following the water system refill ensure that water system piping, primarily pumps and flexible couplings, do not leak. It is wise not to add any corrosion inhibitors until after the water system is found to be leak free.

11. Turbines having a diesel engine starting means should have the engine tested using the diesel test pushbutton in the accessory compartment.
12. The use of radio transmitting equipment in the vicinity of open control panels is not recommended. Prohibiting such use will assure that no extraneous signals are introduced into the control system that might influence the normal operation of the equipment.
13. Check the Cooling and Sealing Air Piping against the assembly drawing and piping schematic, to ensure that all orifice plates are of designated size and in designated positions.
14. At this time all annunciated ground faults should be cleared. It is recommended that units not be operated when a ground fault is indicated. Immediate action should be taken to locate all grounds and correct the problems.

C. Checks During Start Up and Initial Operation

The following is a list of important checks to be made on a new or newly overhauled turbine with the OPERATION SELECTOR in various modes. The Control Specifications — Control Systems Adjustments should be reviewed prior to operating the turbine.

CAUTION

Where an electric motor is used as the starting means refer to the Control Specifications for maximum operating time.

When a unit has been overhauled those parts or components that have been removed and taken apart for inspection/repair should be critically monitored during unit startup and operation. This inspection should include: leakage check, vibration, unusual noise, overheating, lubrication.

1. Crank

- a. Listen for rubbing noises in the turbine compartment and in the reduction gear compartment especially in the load tunnel area. A soundscope or some other listening type device is suggested. Shutdown and investigate if unusual noise occurs.

- b. Check for unusual vibration.
- c. Inspect for water system leakage.

2. Fire

*** * * WARNING * * ***

Due to the complexity of gas turbine fuel systems, it is imperative for everyone to exercise extreme caution in and near any turbine compartment, fuel handling system, or any other enclosures or areas containing fuel piping or fuel system components.

Do not enter the turbine compartment unless absolutely necessary. When it is necessary, exercise caution when opening and entering the compartment. Be aware of the possibility of fuel leaks, and be prepared to shut down the turbine and take action if a leak is discovered.

At any time, if/when entering the turbine compartment or when in the vicinity of the fuel handling system or other locations with fuel piping, fuel system components, or fuel system connections, while the turbine is operating, implement the following:

Conduct an environmental evaluation of the turbine compartment, fuel handling system, or specific area. Pay particular attention to all locations where fuel piping/components/connections exist.

Follow applicable procedures for leak testing. If fuel leaks are discovered, exit the area quickly, shut the turbine down, and take appropriate actions to eliminate the leak(s).

Require personnel entering the turbine compartment to be fitted with the appropriate personal protective equipment, i.e., hard hat, safety glasses, hearing protection, harness/manline (optional depending on space constraints), heat resistant/flame retardant coveralls and gloves.

Establish an attendant to maintain visual contact with personnel inside the turbine compartment and radio communications with the control room operator.

During the first start-up after a disassembly, visually check all connections for fuel leaks. Preferably check the fittings during the warm-up period when pressures are low. Visually inspect the fittings again at full speed, no load, and at full load. Do not attempt to correct leakage problems by tightening fittings and/or bolting while lines are fully pressurized. Note area in question and, depending on severity of leak, repair at next shutdown, or if required shut unit down immediately. Attempts to correct leakage problem on pressurized lines could lead to sudden and complete failure of component and resulting damage to equipment and personnel injury.

- a. Bleed fuel oil filters, if appropriate. Then check entire fuel system and the area immediately around the fuel nozzle for leaks. In particular check for leaks at the following points:

Turbine Compartment

- (1) Fuel piping/tubing to fuel nozzle
- (2) Fuel check valves
- (3) Atomizing air manifold and associated piping (when used)
- (4) Gas manifold and associated piping (when used)

Accessory Compartment or Fuel Module

- (1) Flow divider (when used)
- (2) Fuel and water pumps
- (3) Filter covers and drains

CAUTION

Elimination of fuel leakage in the turbine compartment is of extreme importance as a fire preventive measure.

- b. Monitor FLAME status on the <I> processor to verify all flame detectors are correctly indicating flame. Two sight glasses are included as part of the unit startup kit. Use of sight glasses to be limited to initial startup and special requirements, as opposed to normal operation. Following initial startup remove sight glasses and plug opening.
- c. Monitor the turbine control system readings on the <I> processor for unusual exhaust thermocouple temperature, wheelspace temperature, lube oil drain temperature, highest to lowest exhaust temperature spreads and “hot spots” i.e. combustion chamber(s) burning hotter than all the others.
- d. Listen for unusual noises and rubbing.
- e. Monitor for excessive vibration.

3. Automatic, Remote

On initial startup, permit the gas turbine to operate for a 30 to 60 minute period in a full speed, no load condition. This time period allows for uniform and stabilized heating of the parts and fluids. Tests and checks listed below are to supplement those recorded in Control Specification — Control System Adjustments. Record all data for future comparison and investigation.

- a. Continue monitoring for unusual rubbing noises and shutdown immediately if noise persists.
- b. Monitor lube oil tank, header and bearing drain temperatures continually during the heating period. Refer to the Schematic Piping Diagram — Summary Sheets for temperature guidelines. Adjust VTRs if required.

- c. At this time a thorough vibration check is recommended, using vibration test equipment such as IRD equipment (IRD Mechanalysis, Inc.) or equivalent with filtered or unfiltered readings. It is suggested that horizontal, vertical and axial data be recorded for the:
 - (1) accessory gear (when used) forward and aft sides
 - (2) all accessible bearing covers on the turbine
 - (3) turbine forward compressor casing
 - (4) turbine support legs
 - (5) reduction gear (when used) forward and aft sides, gear and pinion
 - (6) bearing covers on the load equipment
- d. Check wheelspace, exhaust and control thermocouples for proper indication on the <I> CRT. Record these values for future reference.
- e. Flame detector operation should be tested per the Control Specification — Control System Adjustments.
- f. Utilize all planned shutdowns in testing the Overspeed Trip System per the Control Specifications — Control System Adjustments. Refer to Special Operations section of this text.
- g. Monitor <I> CRT display data for proper operation.

III. OPERATING PROCEDURES

A. General

The following instructions pertain to the operation of a model series 5001, 6001, 7001EA or 9001E gas turbine unit designed for generator drive application. These instructions are based on use of Mark V SPEEDTRONIC® turbine control panels.

Functional description of the <I> CRT Main Display follows; however, panel installation, calibration, and maintenance are not included.

Operational information includes startup and shutdown sequencing in the AUTO mode of operation. The most common causes of alarm messages can be found in the concluding section.

It is not intended to cover initial turbine operation herein; rather, it will be assumed that initial startup, calibration and checkouts have been completed. The turbine is in the cooldown or standby mode ready for normal operation with AC and DC power available for all pumps, motors, heaters, and controls and all annunciator drops are cleared.

Refer to the Control Specifications in this volume, and the previously furnished Control Sequence Program (CSP) for additional operating sequence information and related diagrams.

B. Start-Up

1. General

Operation of a single turbine/generator unit may be accomplished either locally or remotely.

The following description lists operator, control system and machine actions or events in starting the gas turbine.

Reference the section “Description of Panels and Terms — Turbine Control Panel” for description of turbine panel devices. The following assumes that the unit is off of cooldown, and in a ready to start condition.

2. Starting Procedure

- a. Using the cursor positioning device, select “MAIN” display from the DEMAND DISPLAY menu.

- (1) The display will indicate speed, temperature, various conditions etc. Three lines displayed on the <I> CRT will read:

SHUTDOWN STATUS
OFF COOLDOWN
OFF

- b. Select “AUTO” and “EXECUTE”

- (1) The <I> CRT display will change to:

STARTUP STATUS
READY TO START
AUTO

- c. Select “START” and “EXECUTE”

- (1) Unit auxiliaries will be started including a motor driven lube oil pump used to establish lube oil pressure. The <I> CRT message SEQ IN PROGRESS will appear.
 - (2) If the starting clutch is not engaged, the rotor turning device will operate until the clutch engages. With the clutch engaged, the lube oil pressure and all other permissives satisfied, the master protective logic (L4) will be satisfied. The CRT display will change to:

STARTUP STATUS
STARTING
AUTO;
START

- (3) Where a diesel engine is utilized as starting equipment, the starting diesel will start and run at idle for two minutes to warm up. At the end of the diesel warmup period, the rotor turning device will operate continuously and the diesel will accelerate. Where an electric motor is utilized as starting equipment, the motor will start immediately.

- (4) The turbine shaft will begin to rotate and accelerate. When the unit reaches approximately 10 rpm, the turning device will be turned off. The <I> CRT display will change to START-UP STATUS/CRANKING. The zero speed signal "14HR" will be displayed.
- (5) When the unit reaches approximately 20% speed, the minimum speed signal "14HM" will be displayed on the <I> CRT. (For machines with cooling water fan motors receiving power from the generator terminals via the UCAT transformer, field flashing will be initiated to build up generator voltage to power the fans; otherwise, field flashing to build up generator voltage will occur at operating speed.)
- (6) If the unit configuration requires purging of the gas path prior to ignition, the starting device will crank the gas turbine at purge speed for a period of time determined by the setting of the purge timer. See Control Specifications-Settings Drawing for purge timer settings.
- (7) FSR will be set to firing value. (FSR, Fuel Stroke Reference, is the electrical signal that determines the amount of fuel delivered to the turbine combustion system.) Ignition sequence is initiated. The <I> CRT display will change to START UP STATUS/FIRING.
- (8) When flame is established, the <I> CRT display will indicate flame in those combustors equipped with flame detectors.
- (9) FSR is set back to warm-up value, and the <I> CRT display will indicate STARTUP STATUS/WARMING UP. If the flame goes out during the 60 second firing period, FSR will be reset to firing value. (At the end of the ignition period, if flame has not been established, the unit will remain at firing speed.) At this time the operator may shut the unit down or attempt to fire again. To fire again select CRANK on the Main Display. The purge timer and firing timer are reinitialized. The purge timer will begin to time. Reselecting AUTO will cause the ignition sequence to repeat itself after the purge timer has timed out. If the unit is being operated remotely (REMOTE having previously been selected on the Main Display), and no fire has been established at the end of the ignition period, the unit will be purged of unburned fuel. At the end of the purge period (normally 1 to 2 minutes) ignition will be attempted again. If flame is not established at this time, the starting sequence will be terminated and the unit will shutdown.

At the end of the warmup period, with flame established, FSR will begin increasing. The <I> CRT will indicate STARTUP STATUS/ACCELERATING and the turbine will increase in speed. At approximately 50% speed, the accelerating speed signal "14HA" will be displayed on the <I> CRT.

- (10) The turbine will continue to accelerate. When it reaches about 60% speed, the starting device will disengage and shutdown (if the starting device is a diesel engine, it will cooldown at idle speed before shutting down). The <I> CRT will indicate the change in status from STARTUP CONTROL to SPEED CONTROL at approximately 60% speed.
- (11) When the turbine reaches operating speed, the operating speed signal "14HS" will be displayed on the <I> CRT. The motor-driven lube oil pump will shutdown, since lube oil is being supplied by the shaft driven pump. Field flashing is terminated. If the synchronizing selector switch (43S) on the generator control panel is in the OFF position and REMOTE is not selected on the <I> CRT, as the turbine reaches operating speed, <I> CRT will now read:

RUN STATUS
FULL SPEED NO LOAD
AUTO; START

If the synchronizing selector switch on the generator panel is in the AUTO position or REMOTE is selected on the <I> CRT automatic synchronizing is initiated. The <I> CRT will read SYNCHRONIZING.

The turbine speed is matched to the system (to less than 1/3 Hz difference) and when the proper phase relationship is achieved the generator breaker will close. The machine will load to Spinning Reserve unless a load control point BASE, PEAK or PRESELECTED LOAD has been selected.

The <I> CRT will display SPINNING RESERVE, once the unit has reached this load point.

C. Synchronizing

When a gas turbine-driven synchronous generator is connected into a power transmission system, the phase angle of the generator going on-line must correspond to the phase angle of the existing line voltage at the moment of its introduction into the system. This is called synchronizing.

CAUTION

Before initiating synchronization procedures, be sure that all synchronization equipment is functioning properly, and that the phase sequence of the incoming unit corresponds to the existing line phase sequence and the potential transformers are connected correctly to proper phases. Initial synchronization and checkout after performing maintenance to synchronizing equipment should be performed with the breaker racked out.

NOTE

Synchronizing cannot take place unless AUTO or REMOTE has been selected on the <I> CRT Main Display and the turbine has reached full speed.

Generator synchronization can be accomplished either automatically or manually. Manual synchronization is accomplished by the following procedure:

1. Place the synchronizing selector switch on the generator panel (43S) in the MANUAL position.
2. Select AUTO on the <I> CRT Main Display.
3. Select START and EXECUTE on the <I> CRT Main Display. This will start the turbine and accelerate it to full speed as previously described. At this point the CRT will indicate RUN STATUS, FULL SPEED NO LOAD.
4. Compare the generator voltage with the line voltage. (These voltmeters are located on the generator control panel.)
5. Make any necessary voltage adjustment by operating the RAISE- LOWER (90R4) switch on the generator panel until the generator voltage equals the line voltage.

6. Compare the generator and line frequency on the synchroscope (located on the generator control panel). If the pointer is rotating counterclockwise, the generator frequency is lower than the line frequency and should be raised by increasing the turbine-generator speed. The brightness of the synchronizing lights will change with the rotation of the synchroscope. When the lights are their dimmest the synchroscope will be at the 12 o'clock position. The lights should not be used to synchronize but only to verify proper operation of the synchroscope.
7. Adjust the speed until the synchroscope rotates clockwise at approximately five seconds per revolution or slower.
8. The generator circuit breaker "close" signal should be given when it reaches a point approximately one minute before the 12 o'clock position. This allows for a time lag for the breaker contacts to close after receiving the close signal.

Automatic synchronization is accomplished by the following steps:

1. Place the synchronizing selector switch (43S) in the AUTO position.
2. Select AUTO on the <I> CRT Main Display.
3. Select START on the <I> CRT Main Display.

This procedure will start the turbine, and upon attainment of "complete sequence", match generator voltage to line voltage (if equipped with optional voltage matching), synchronize the generator to the line frequency, and load the generator to the preselected value. A "breaker closed" indicator will actuate when the generator circuit breaker has closed placing the synchronized unit on-line.

Once the generator has been connected to the power system, the turbine fuel flow may be increased to pick up load, and the generator excitation may be adjusted to obtain the desired KVAR value.

*** * * WARNING * * ***

Failure to synchronize properly may result in equipment damage and/or failure, or the creation of circumstances which could result in the automatic removal of generating capacity from the power system.

In those cases where out-of-phase breaker closures are not so serious as to cause immediate equipment failure or system disruption, cumulative damage may result to the on-coming generator. Repeated occurrences of out-of-phase breaker closures can eventually result in generator failure because of the stresses created at the time of closure. Gear damage may result on load packages with a reduction gear in the gas turbine-generator train. Such damage may occur separately or in conjunction with generator damage from out-of-phase breaker closure. Damage may be to the gear teeth or to the quill shaft (if there is a quill shaft).

Out-of-phase breaker closure of a magnitude sufficient to cause either immediate or cumulative equipment damage mentioned above will usually result in annunciator drops to notify the operator of the problem. The following alarms have been displayed at various occurrences of known generator breaker mal-closures:

1. High vibration trip
2. Loss of excitation

3. Various AC undervoltage drops

Out-of-phase breaker closure will result in abnormal generator noise and vibration at the time of closure. If there is reason to suspect such breaker malclosure, the equipment should be immediately inspected to determine the cause of the malclosure and for any damage to the generator and/or reduction gear.

Refer to the “Control and Protection” section of this volume for additional information on the synchronizing system.

D. Normal Load Operation

1. Manual Loading

Manual loading is accomplished by clicking on the SPEED SP RAISE/SPEED SP LOWER targets on the <I> CRT Main Display.

Manual loading can also be accomplished by means of the governor control switch (70R4/CS) on the generator control panel. Holding the switch to the right will increase the load; holding it to the left will decrease the load.

Manual loading beyond the selected temperature control point BASE or PEAK is not possible. The manual loading rate is shown in the Control Specification-Settings Drawing.

NOTE

When manually loading with the governor control switch (70R4/CS) for load changes greater than 25% of full load, the operator should not change more than 25% of full load in one minute.

2. Automatic Loading

On startup if no load point is selected, the unit will load to the SPINNING RESERVE load point. The SPINNING RESERVE load point is slightly greater than no load, typically 8% of base rating.

An intermediate load point, PRE-SELECTED load, and temperature control load points BASE and PEAK can be selected anytime after a start signal has been given. The selection will be displayed on the <I> CRT. The unit will load to the selected load point. PRESELECTED LOAD is a load point greater than SPINNING RESERVE and less than BASE, typically 50%. The auto loading rate is shown in Control Specification-Settings Drawing.

E. Remote Operation

To transfer turbine control from the control compartment to remotely located equipment, select REMOTE on the <I> CRT Main Display. The turbine may then be started, automatically synchronized, and loaded by the remote equipment.

If manual synchronization is to be performed at the remote location, the synchronizing selector switch (43S) mounted on the generator control panel must be placed in the OFF/REMOTE position.

F. Shutdown and Cooldown

1. Normal Shutdown

Normal shutdown is initiated by selecting STOP on the <I> CRT Main Display. The shutdown procedure will follow automatically through generator unloading, turbine speed reduction, fuel shutoff at part speed and initiation of the cooldown sequence as the unit comes to rest.

2. Emergency Shutdown

Emergency shutdown is initiated by depressing the EMERGENCY STOP pushbutton. An emergency shutdown can also be mechanically initiated by pushing the manual emergency trip valve on the gauge cabinet assembly, or the manual trip button on the overspeed trip mechanism mounted on the side of the accessory gear. Cooldown operation after emergency shutdown is also automatic provided the permissives for this operation are met.

3. Cooldown

Immediately following a shutdown, after the turbine has been in the fired mode, the rotor is turned to provide uniform cooling. Uniform cooling of the turbine rotor prevents rotor bowing, resultant rubbing and imbalance, and related damage that might otherwise occur when subsequent starts are attempted without cooldown. The turbine can be started and loaded at any time during the cooldown cycle.

The cooldown cycle may be accelerated using the starting device; in which case it will be operated at cranking speed. On units having an electric motor as the starting device, the operator must heed instructions regarding the length of time the motor can be operated without overheating. Refer to the control specifications.

The device furnished for cooldown rotation on MS 5001P, MS 6001B, and MS 7001EA units is the hydraulic ratchet which is mounted as part of the torque converter. The ratchet cycles once every 3.0 minutes to turn the rotor 47°. A description of rotor turning operation and servicing can be found in the Starting System tab. The MS 9001E is a continuous turning gear system at 6.0 rpm.

The minimum time required for turbine cooldown depends mainly on the turbine ambient temperature. Other factors, such as wind direction and velocity in outdoor installations and air drafts in indoor installations, can have an affect on the time required for cooldown. The cooldown times recommended in the following paragraphs are the result of GE Company operating experience in both factory and field testing of GE gas turbines. The purchaser may find that these times can be modified as experience is gained in operation of the gas turbine under his particular site conditions.

Cooldown times should not be accelerated by opening up the turbine compartment doors or the lagging panels since uneven cooling of the outer casings may result in excessive stress.

The unit must be on rotor turning operation immediately following a shutdown for at least 24 hours to ensure minimum protection against rubs and unbalance on a subsequent starting attempt. The GE Company, however, recommends that the rotor turning operation continue for 48 hours after shutdown to ensure uniform rotor cooling.

To terminate the cooldown sequence, prior to timer timeout select the Auxiliary Control Display on the <I> CRT. Select “RATCHET OFF”. This will cause the cooldown auxiliaries to be turned off. Similarly, by selecting the “RATCHET ON” target, the cooldown auxiliaries can be reinstated.

G. Special Operations

1. Black Start Operation

(Optional with Gas Turbines equipped with a diesel engine starting device)

a. General

Gas turbine operation under “black start” conditions is defined as a requirement to start and run the turbine when an external AC power source is not available. Diesel engines are normally utilized as starting equipment with other compatible steam or gas starting means optional.

The prime DC controlling power for the turbine control system is derived from the unit battery.

Ignition and internal AC control power is obtained through DC conversion circuitry within the SPEEDTRONIC® power supply system.

b. Operation

When the turbine is started, the DC emergency lube pump will supply adequate lubrication until the accessory gear-driven main lube oil pump pressure is established. The emergency pump continues to run until the accelerating speed signal (14HA) indicates that the unit has accelerated to 50% speed. The emergency pump then shuts down if lube oil pressure switch (63QL) indicates adequate pressure.

Black start operation also requires the addition of the 88HR DC hydraulic ratchet pump assembly. This unit furnishes the required hydraulic control oil pressure for operation of the starting clutch and ratchet assembly.

For liquid fuel machines, fuel pressure delivered to the input of the turbine gear driven fuel pump is provided by a dc/ac powered fuel forwarding pump. The DC motor drives the pump until AC power is available to drive the AC motor. The turbine high pressure fuel oil requirements are satisfied by the normal accessory gear driven fuel pump.

Gas turbine AC powered cooling system fan drive motors are operated from partial to full power by driven load generator output, as the gas turbine is brought up to operational speed level.

During turbine shutdown and cooldown periods, the operational lube supply is again furnished by the emergency DC lube pump and the 88HR DC hydraulic ratchet supply pump assembly mentioned previously operates to turn the rotor.

Refer to the Lube Oil and Hydraulic Oil Supply Schematic Piping Diagrams; and the SPEEDTRONIC® Control instructions of this service manual for further related information.

2. Fuel Transfer (Gas-Distillate Option)

Fuel transfer is initiated using the Fuel Mixture Display on the <I> CRT. When transferring from one fuel to the other, there is a thirty second delay before the transfer begins. For the gas-to-distillate transfer, the delay allows for filling the liquid fuel lines. For the distillate-to-gas transfer, the delay allows time for the speed ratio valve (and gas control valve) to modulate the inter volume gas pressure before the transfer begins. Once started, fuel transfer takes approximately thirty seconds. The transfer can be stopped at any fuel mixture proportion within limits as specified in the Control Specification-Settings Drawing by setting the FUEL MIX SETPOINT and then selecting MIX. Fuel transfer should be initiated prior to ignition or after the unit reaches operating speed.

3. Automatic Fuel Transfer On Low Gas Pressure (Gas-Distillate Option)

In the event of low fuel gas pressure the turbine will transfer to liquid fuel. The transfer will occur with no delay for line filling. To return to gas fuel operation after an automatic transfer, manually reselect gas fuel.

4. Diesel Testing (Optional on MS 5001 and MS 6001 Units)

The starting diesel may be tested either with the turbine operating or while shutdown. To test the diesel, first select the Auxiliary Control Display on the <I> CRT. Select the "DIESEL TEST ON" target. The diesel can now be tested by operating the diesel test pushbutton located on the accessory base. The diesel will run at idle speed as long as the pushbutton is held in. (Do not exceed two (2) minutes.)

5. Jogging Turbine Rotor (MS 5001 and MS 6001 Units)

A pushbutton (43HR) located on the accessory base is provided for manual jogging of the turbine shaft by means of the hydraulic ratchet.

6. Testing the Emergency DC Lube Pump

The DC emergency pump may be tested using the test pushbutton on the motor starter.

7. Overspeed Trip Checks

Overspeed trip system testing should be performed on an annual basis on peaking and intermittently used gas turbines. On continuously operated units, the test should be performed at each scheduled shutdown and after each major overhaul. All units should be tested after an extended shutdown period of two or more months unless otherwise specified in the Control Specifications-Adjustments Drawing.

NOTE

The turbine should be operated for at least 30 minutes at rated speed before checking the overspeed settings. This will allow determination of the actual trip speed, which might be higher or lower than the "cold" trip speed depending upon several contributing factors, such as oil temperature and vibration.

8. Electrical Overspeed

Turbine speed is controlled by the turbine speed reference signal TNR. The maximum speed called for by TNR is limited by the high speed stop control constant. This value is nominally set at 107% of rated speed. It will be necessary to enter a new constant value for the high speed stop constant that will allow the speed to increase above the electrical overspeed trip setting. New constants can be entered with the Control Constant Adjust display activated and via the <I> keypad. Reference the control specification and the SPEEDTRONIC® Mark V Maintenance Manual (GEH 5980) for details. For security, an identification code must be entered via the keypad in order to make any changes to the control system constants. With the high speed stop constant adjusted to be higher than the electrical overspeed trip speed, raise unit speed gradually by using the SPEED SP RAISE target on the <I> Main Display and observe speed at which the unit trips against the value tabulated in the Control Specifications — Setting drawing.

CAUTION

1. Do not exceed the maximum search speed as defined in the Control Specifications.
2. Return all constants to their normal value after coastdown of unit.

9. Mechanical Overspeed (if applicable)

In order to test the mechanical overspeed bolt it is necessary to change the electrical overspeed trip setting constant to be greater than the mechanical overspeed bolt overspeed setting. After changing the required constants raise unit speed gradually by using the SPEED SP RAISE target on the <I> Main Display and observe speed at which the unit trips against the value tabulated in the Control Specifications — Settings drawing.

CAUTION

1. Do not exceed the maximum search speed as defined in the Control Specifications.
2. Return all constants to their normal values following tests.
3. Reset mechanical overspeed trip mechanism on unit accessory gear.

Record all trip speeds. Mechanical testing should also include the emergency trip button on the turbine control panel and the manual overspeed mechanical trip located on the right side of the accessory gear. Successful completion of the above tests will assure that all shutdown devices are operating correctly.

To reduce the possibility of overspeed bolt trip system degradation where the trip speed becomes excessively high, especially after long periods of inactivity, it is recommended that the mechanical bolt be tested periodically by carefully overspeeding the turbine and noting the speed at which the trip occurs. If the trip does not occur within the limits, as defined in the Control Specifications, the bolt should be sparingly oiled in place with a lightweight machine oil, stroked by manually depressing the plunger several times through its stroke limits, and retested. The overspeed bolt should then be tripped three successive times within 1% of nominal trip speed and within 1% repeatability unless defined otherwise in the Control Specifications.

CAUTION

1. Do not exceed the maximum search speed as defined in the Control Specifications.
2. The turbine should not be operated unless the overspeed bolt, the overspeed trip mechanisms, the fuel stop valves and other shutdown devices are in reliable condition.

If a trip does not occur within reliable limits, refer to the adjustment instructions in the Service Manual, Protection System, Overspeed Bolt Assembly. If three successive trips do not occur within acceptable repeatability limits, see instructions for Maintenance and Replacement or contact your Field Service Representative for assistance.

10. Steam Injection Operation (Optional)

Before operating the steam injection system for the first time following an overhaul or periods of extended shutdown, it is important that the following checks be made:

- a. Steam supply is within design parameters
- b. Instrument air supply is at required pressure
- c. Steam line orifice size is correct

a. Pre-Operation Checks

Prior to operation, check for the following conditions:

- a. <I> CRT controls are in non-select positions (Steam Injection OFF)
- b. Manual stop valve is open
- c. All hand valves in line of flow are open
- d. All valves to temperature or pressure gauges are open
- e. Steam supply pressure and temperature are in operating range

b. Startup

The automatic control system, in conjunction with logic circuits of the microcomputer of the SPEEDTRONIC® control system, operates the steam injection system control valving and assures that the proper amount of steam injection is provided to the turbine combustion system during operation.

To initiate steam injection the operator must first select the Steam Injection Overview Display on the <I> CRT. Selecting the STM INJ ON target initiates the steam injection control. At this point the automatic steam control circuits will take over, initiate the drain and stop valve sequences and control the system. When steam conditions are correct, the steam control valve releases steam into the combustion system at the proper steam-to-fuel flow ratio.

The startup and operating sequence of the steam injection system is described and explained in the Steam Injection control system text of the Control and Protection Tab.

c. Trouble Shooting

The purpose of the system is to provide steam to the turbine combustion system at the desired pressure, temperature and flow. If this does not happen, the following problems may be the cause:

- (1) Steam supply exhausted
- (2) Insufficient supply pressure
- (3) Control valve closed
- (4) Stop valve closed

The following should be checked:

- (1) Adequate steam supply
- (2) Check steam supply system
- (3) Check control valve actuator and drain valve operation
- (4) Check that instrument air supply pressure is sufficient and/or check solenoid control valve operation.

Alarm and shutdown conditions of the steam injection system are detected by a protection program built into Control Sequence Program. Alarm and trip indications are displayed on the <I> CRT. An alarm condition is initiated by high or low pressure levels and by high or low temperatures. See Control Specifications for alarm and trip point values.

The computer program is designed to trip the steam stop valve and prevent steam flow if steam temperature becomes too high or too low. It can trip the system on temperature or pressure to protect against loss of superheat and carry over of condensate. Steam at too high a pressure can cause damage to valve stem packing and system seals. A steam injection trip only shuts down the steam injection system. It does not trip the turbine.

11. Water Washing System Operation (Optional)**a. General**

Water washing should be scheduled during a normal shutdown, if possible. This will allow enough time for the internal machine temperature to drop to the required levels for the washing. The time required to cool the machine can be shortened by maintaining the unit at crank speed. During this cooling of the turbine, the wash water is to be heated to the proper level.

b. Mandatory Precautions

Before water washing of the compressor begins, the turbine blading temperature must be low enough so that the water does not cause thermal shock.

CAUTION

The differential temperature between the wash water and the interstage wheel-space temperature must not be greater than 120°F (48.9°C) to prevent thermal shock to the hot gas parts. For wash water of 180°F (82.2°C), the maximum wheelspace temperature must be no greater than 300°F (148.9°C) as measured by the digital thermocouple readout system on the turbine control panel.

To reduce this difference, the wash water may be heated and the turbine kept on crank until the wheelspace temperatures drop to an acceptable level. The wheelspace temperatures are read in the control room on the <I> CRT.

CAUTION

If, during operation, there has been an increase in exhaust temperature spread above the normal 15°F to 30°F (8.3°C to 16.6°C), the thermocouples in the exhaust plenum should be examined. If they are coated with ash, the ash should be removed.

Radiation shields should also be checked. If they are not radially oriented relative to the turbine, they should be repositioned per the appropriate drawing. If the thermocouples are coated with ash, or if the radiation shields are not properly oriented, a correct temperature reading will not be obtained.

If neither of the above conditions exists and there is no other explanation for the temperature spread, consult the GE Installation and Service Engineering representative.

*** * * WARNING * * ***

The water wash operation involves water under high pressure. Caution must be exercised to ensure the proper positioning of all valves during this operation. Since the water may also be hot, necessary precautions should be taken in handling valves, pipes, and potentially hot surfaces.

NOTE

Before water washing the compressor, inspect the inlet plenum and gas turbine bellmouth for large accumulations of atmospheric contaminants which could be washed into the compressor. These deposits can be removed by washing with a garden hose.

c. Water Wash Procedures

Refer to cleaning publication included in this section for details on procedures.

12. Standby Gas Turbines on Extended Shutdown

The GE Company recommends the following procedures for gas turbines subject to extended shutdowns.

- a. The turbine rotor should be operated on turning gear or ratchet for one hour each day to prevent the buildup of corrosive deposits in the turbine wheel dovetails, OR
- b. The gas turbine should be operated at full speed, no load for one hour per week to dry the turbine out and thereby preventing moisture condensation in the turbine wheel dovetail crevices.

IV. DESCRIPTION OF PANELS AND TERMS

A. Turbine Control Panel (TCP)

The turbine control panel contains the hardware and software required to operate the turbine.

EMERGENCY STOP (5E) — This red pushbutton is located on the front of the TCP. Operation of this pushbutton immediately shuts off turbine fuel.

BACKUP OPERATOR INTERFACE (BOI) — This interactive display is mounted on the front of the TCP. All operator commands can be issued from this module. In addition, alarm management can be performed and turbine parameters can be monitored from the <BOI>.

B. <I> CRT

The <I> CRT is a personal computer that directly interfaces to the turbine control panel. This is the primary operator station. All operator commands can be issued from the <I> CRT. Alarm management can be performed and turbine parameters can be monitored. With the proper password, editing can also be accomplished.

1. Main Display

Operator selector targets and master control selector targets can be actuated from the main display by using the cursor positioning device (CPD). Operator selector targets include:

OFF — Inhibits a start signal.

CRANK — With crank selected, a start signal will bring the machine to cranking speed (14HM).

FIRE — With FIRE selected, a START signal will bring the machine to minimum speed and establish flame in the combustors. Selecting FIRE while the machine is on CRANK will initiate the firing sequence and establish flame in the combustors.

AUTO — With AUTO selected, a START signal will bring the machine to operating speed. Changing selections from FIRE to AUTO will allow the machine to accelerate to operating speed.

REMOTE — With REMOTE selected, control for the unit is transferred to the remote control equipment.

Master control selector targets include:

START — A START selection will cause the unit to start. With AUTO selected, the unit will load to the SPINNING RESERVE load point.

FAST START - A FAST START selection will cause the unit to start. With AUTO selected, the unit will load to the PRESELECTED load point. The machine will load at the manual loading rate.

STOP - A STOP selection will cause the unit to initiate a normal shutdown.

All operator selector switches and master control selector targets are green and are located on the right side of the display. All green targets are the AUTO/EXECUTE type, which means that the target must be selected with the CPD and then, within three seconds, the EXECUTE target at the bottom of the display must also be selected in order to actuate that command.

2. Load Control Display

Load selector targets can be actuated from the load control display by using the cursor positioning device (CPD). Load selector targets include:

PRESEL - Select the preselected load point.

BASE - Select base temperature control load point.

***PEAK** - Select peak temperature control load point.

3. *Fuel Mixture Display

Fuel selector targets are used to select the desired fuel by using the cursor positioning device (CPD). Fuel selector targets include:

GAS SELECT - 100% gas fuel operation.

DIST SELECT - 100% distillate fuel operation.

MIX SELECT - Selecting MIX while on 100% single fuel will cause the machine to transfer to mixed fuel operation at a preset mixture.

4. *Isochronous Setpoint Display

Governor selector targets are used to select the desired type of speed control by using the cursor positioning device (CPD). Governor selector targets include:

DROOP SELECT - Used to select droop speed control.

ISOCH SELECT - Used to select isochronous speed control.

5. *Inlet Guide Vane Control Display

The inlet guide vane (IGV) temperature control targets are IGV TEMP CNTL ON and IGV TEMP CNTL OFF. The IGV AUTO target selects normal operation of the IGVs. The IGV MANUAL target allows the maximum IGV angle to be manually set by the operator (not normally used while on-line).

*Optional equipment

6. Alarm Display

This screen displays the current un-reset alarms, the time when each alarm occurred, the alarm drop number and a word description of the alarm. An “*” indicates that the alarm has not been acknowledged. The “*” disappears after the alarm has been acknowledged. For more information, see the Mark V Users’ Manual (GEH 5979).

7. Auxiliary Display

COOLDOWN ON and COOLDOWN OFF can be selected from this display. The DIESEL TEST ON and DIESEL TEST OFF targets (if diesel starting means is used) can also be selected from this display. Selecting the DIESEL TEST ON target enables the permissive which allows the Diesel Test Pushbutton to be manually operated.

8. *Mechanical Overspeed Test Display

After selecting the ENABLE SOFTSW’s target, the OVERSPEED TEST HP target can be selected. This will adjust the electrical overspeed setpoint to allow testing of the mechanical overspeed equipment.

9. Manual Reset Target

Selecting the manual reset target resets the Master Reset Lockout function. This target must be selected so that the unit can be restarted following a trip.

C. Definition of Terms

SPINNING RESERVE - The minimum load control point based on generator output. The spinning reserve magnitude in MWs can be found in the control specifications (5–10% of rating is a typical value).

PRESELECTED LOAD - A load control point based on generator output. The preselected load point is adjustable within a range designated in the Control Specification. The preselected load point is normally set below the base load point (50–60% of rating is a typical value).

BASE LOAD - This is the normal maximum loading for continuous turbine operation as determined by turbine exhaust temperature levels.

PEAK LOAD (Optional) - This is the maximum allowable output permitted for relatively long-duration, emergency power requirement situations consistent with acceptable turbine parts life. Peak loading duration is based on turbine exhaust temperature levels.

D. Generator Control Panel (Typical)

SYNCHRONIZING LAMPS — Rough indication of the speed and phase relationship between the generator and the bus.

FREQUENCY METER — Indicates generator frequency.

INCOMING VOLTMETER — Indicates generator voltage.

RUN VOLTMETER — Indicates bus voltage.

SYNCHROSCOPE — Indicates the phase relationship between the generator and bus voltage.

GENERATOR AMMETER — Indicates generator phase current. The phase current to be read is selected on the three position ammeter selector switch.

GENERATOR WATTMETER — Indicates the generator output in megawatts.

GENERATOR VAR METER — Indicates the generator reactive output in megavars.

GENERATOR TEMPERATURE METER — (Traditionally included on the Generator Control Panel, but actually displayed in Mark V SPEEDTRONIC® systems on the <I> CRT.) Reads the generator Resistance Temperature Detector (RTD) selected by the temperature meter selector switch.

EXCITER VOLTMETER — Indicates generator field voltage (if used).

GENERATOR FIELD AMMETER — Indicates generator field amperes (if used).

AMMETER SELECTOR SWITCH — See Generator Ammeter (above).

SYNCHRONIZING SELECTOR SWITCH (43S/CS) — Three position switch used to select the synchronizing mode.

Manual — Selects manual synchronizing mode. In this position the generator frequency and voltage, bus voltage, and phase relationship will be displayed to facilitate manual synchronizing.

Off/Remote — Used when the unit is being controlled from the remote control equipment.

Auto — Used for local automatic synchronizing.

VOLTMETER SWITCH (VS) — Used to select the phase of the bus voltage to be displayed on the run voltmeter.

TEMPERATURE METER SELECTOR SWITCH — Traditionally included on the Generator Control Panel, but actually displayed in Mark V SPEEDTRONIC® systems on the <I> CRT.

VOLTAGE/VAR CONTROL SWITCH (90R4/CS) — Controls generator voltage when the unit is off the line, and controls voltage/vars when the machine is on the line. (Increase — Right; Decrease — Left; spring return to normal.)

GENERATOR BREAKER CONTROL SWITCH (52G/CS) — Used to open or close the generator breaker. The indicator lights above the switch indicate Open (Green) and Closed (Red).

NOTE

Using this switch, the generator breaker should be closed only when proper synchronizing techniques are used or when the system onto which the generator is being brought is not energized.

GENERATOR DIFFERENTIAL LOCK-OUT SWITCH (86G) — Manual reset lockout switch which operates in the event of a generator fault.

GOVERNOR RAISE/LOWER CONTROL SWITCH (70R4/CS) — Used to control turbine speed when the generator is off the line (i.e. for manual synchronizing); generator load when the generator is on the line; and frequency when the generator is running isolated and on DROOP speed control.

TRANSFORMER DIFFERENTIAL LOCK-OUT SWITCH (86T) — Manual reset lockout switch which operates in the event of a transformer fault.

WATTHOUR METER — Measures the watthour output of the generator.

E. Motor Control Center

The turbine is provided with a motor control center for the control of the electrical auxiliaries. The motor control center includes AC and DC distribution systems.

Motor controllers are used for auxiliaries such as motors and heaters. Each motor controller normally consists of a breaker, control power transformer, control circuit, power contactor, selector switch and indicator lights. The selector switch is normally left in AUTO. Each motor control center is also provided with AC and DC distribution panel boards with circuit breakers.

F. Supervisory Remote Equipment

Supervisory equipment is normally functionally the same as the equipment described in the cable connected master panel. However, it may differ somewhat in metering and indications. Refer to the supervisory manufacturer's instruction manual for details.

G. Annunciator System

The attached alarm list is a maxcase of alarms that may be available. All alarms may not be used on this project.

Alarms are displayed on the <I> CRT when the ALARM Display mode is selected. Before clearing an alarm, action should be taken to determine the cause and perform the necessary corrective action. The following is a list of annunciator messages along with suggested operator action.

NOTE

The alarm messages can be categorized as either "trip" or "alarm". The "trip" messages contain the word TRIP in the message. The "alarm" messages do not indicate TRIP. For those alarms associated with permissive to start and trip logics latched up through the MASTER RESET function, it will be necessary to call up the <I> CRT Display with the Master Reset target in order to unlatch and clear these alarms.

Tab 22

ECH. / SCALE	DATE	31-Mar-2003	11-Mar-2003	31-Mar-2003
	NOM / NAME	TECHNICREA LM	JOST JEAN-MICHEL	JEZEQUEL MAELIG
FORMAT/SIZE A4	VISA	TECHNICREA LM	JOST JEAN-MICHEL	JEZEQUEL MAELIG
		REDIGE / MADE	VERIFIE / CHECKED	APPROUVE/APPROVED

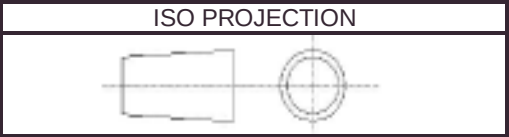
TITRE/TITLE

NOMENCLATURE.APP.CONTROLE

DEVICE SUMMARY

Ce document, propriete exclusive de <i>GE Energy Products France SNC</i> est strictement confidentiel. Il ne peut etre communique, copie ou reproduit sans son autorisation ecrite prealable. This document, exclusive property of <i>GE Energy Products France SNC</i> is strictly confidential. It must not be communicated, copied or reproduced without our previous written consent.	<i>GE Energy Products - Europe</i>	REVISION
	 <i>GE Energy Products France SNC</i>	D
	N° 379A9706	INSTRUCTION DE MODIFICATION IM-2003002135
SHT.N		Section Doc. GRD F

SIZE A	DWG NO 379A9706	SH	REV D



EACH SECTION SHALL BE REVISED IN ITS ENTIRETY. ALL SHEETS OF EACH SECTION ARE THE SAME REVISION LEVEL AS INDICATED IN THE REVISION BLOCK.

REV	DESCRIPTION		DATE	SIGNATURES
A	First Issue	Maëlig JEZEQUEL	11 Sep 02	
		Jean-Michel JOST	11 Sep 02	
		Jean-François COURTOT	11 Sep 02	
B	IM-2003001001	TECHNICREA	13 FEV 03	N. G.
		JOST J-M	13 FEV 03	J. J-M
		JEZEQUEL M.	13 FEV 03	J. M.
C	IM-2003001097	TECHNICREA DD	19 FEV 03	
		JOST J-M	19 FEV 03	
		JEZEQUEL M.	19 FEV 03	
D	IM-2003002135	TECHNICREA LM	27 MAR 03	
		JOST J-M.	27 MAR 03	
		JEZEQUEL M.	27 MAR 03	

SECTION	NO. OF SHEETS	REV
INDEX	1 to 3	D
01F	4 to 11	D
01E	12 to 19	D

Ce document, propriété exclusive de
GE Energy Products France SNC
est strictement confidentiel. Il ne peut être communiqué,
copié ou reproduit sans notre autorisation
écrite préalable.

This document, exclusive property of
GE Energy Products France SNC
is strictly confidential. It must not be communicated,
copied or reproduced without our prior written consent.

ITEM	DESCRIPTION	DWG. NO.
LIST OF COMPLEMENTARY DOCUMENTS		
First made for : 9E		ITEM : 0414

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MM [INCHES] TOLERANCES ON: 1[2] PL DECIMALS ± 2[3] PL DECIMALS ± ANGLES ± FRACTIONS ± WEIGHT : 0000 kg	DRAWN M. JEZEQUEL	DATE 11 Sep. 02	GENERAL ELECTRIC COMPANY g <i>GE Energy Products – Europe</i>
	CHECKED JM. JOST		NOMENCLATURE DES APPAREILS DE CONTROLE DIAGRAM. SCHEMA. P.P. – DEVICE SUMMARY FIRST MADE FOR : Item 0414, 9E
	APPROVED JF. COURTOT		
			SIZE A CAGE CODE DWG NO 379A9706 INDEX
	SIM TO: -		SCALE SHEET 1



SIZE A	DWG NO 379A9706	SH 2	REV D

Désignations	Abréviations / Abbreviations	Descriptions
Niveau d'énergie zéro absolu, aucune puissance, pas d'huile, aucune vitesse, aucune température	Normal	Means absolute zero energy level, such as no power, no oil, no speed, no temperature
Normalement ouvert	NO	Normaly open
Normalement fermé	NC	Normaly closed
Croissant	INC.	Increasing
Décroissant	DEC.	Decreasing
Simple contact, simple pôle	SPST	Single pole, single throw
Simple contact, double pôle	SPDT	Single pole, double throw
Double contact, double pôle	DPDT	Double pole, double throw
Transmetteur de position linéaire différentiel	LVDT	Linear variable differential transformer
Pression aval filtre principal huile	AMF	Lube Oil Filter Downstream Pressure
Pression aval filtre huile contrôle	ACF	Control Filter Downstream Pressure
Egouttures d'eau	WD	Water Drain
Alimentation d'eau	WF	Water Feed
Retour d'eau	WR	Water Return
Air d'atomisation	AA	Atomizing Air
Air sortie compresseur	AD	Compressor Discharge Air
Air d'extraction	AE	Extraction Air
Manomètre – Pression différentielle	DPG	Differential Pressure Gauge
Combustible gazeux	GF	Gas Fuel
Event de gaz	GFV	Gas Fuel Vent
Fuite aux garnitures vanne combinée gaz	GPL	Gas Valve Stem Packaging Leakoff
Huile de régulation HP	OH	Control Oil High Pressure
Huile de sécurité HP	OHT	Trip Oil High Pressure
Huile de graissage	OL	Lube Oil
Event d'huile de graissage	OLV	Lube Oil Event
Huile de graissage modulée	OR	Regulated Lube Oil
Raccordement client	PC	Purchaser Connexion
Retour d'huile	OD	Oil Drain
Retour d'huile au-dessus du niveau cuve à huile	OD ┆ ┆ ┆	Oil drain above oil tank level
Retour d'huile au-dessous du niveau cuve à huile	OD ┆ ┆ ┆	Oil drain below oil tank level

GENERAL ELECTRIC COMPANY		SIZE	CAGE CODE	DWG NO
 GE Energy Products - Europe		A		379A9706
DRAWN	M. JEZEQUEL			SECTION INDX
			SCALE	SHEET 2



SIZE A	DWG NO 379A9706	SH 3	REV D

Nomenclature des Schémas et des Tuyauteries	Device Summary - Piping Systems Schematic	Items	Sys.	Référence
Schéma appareils de protection T.G.	Diagram . Cont. Devices - Turbines	0415	CD	91-313097
Schéma tuyauterie huile de lubrification	Diagram . Schem P. P. Lube Oil	0416	LO	202D8321
Schéma Tuyauterie Air refroidissement et étanchéité.	Diagram. Schem. P. P. - Slg Air	0417	CSA	360B1321
Schéma tuyauterie huile de déclenchement	Diagram. Schem. P. P. Trip Oil	0418	TO	91-315584
Schéma tuyauterie eau de refroidissemet	Diagram. Schem. P. P. Cooling Water	0420	CW	356B3088
Schéma système de lancement	Diagram. Schem P. P. Strating Means	0421	SM	356B2630
Schéma tuyauterie combustible gaz	Diagram. Schem P. P. Fuel Gas	0422	GF	360B1202
Schéma tuyauterie combustible liquide	Diagram. Schem P. P. Liq. Fuel	0424	LF	239C7407
Schéma tuyauterie air atomisation	Diagram. Schem P. P. Atomizing Air	0425	AA	91-317615
Schéma protection incendie	Diagram. Schem. P. P. Fire Protect	0426	FP	360B1239
Schéma injection vapeur	Diagram. Schem. P. P. Steam Injection	0431	SI	N/A
Schéma tuyauterie réchauffement air aspiration	Diagram. Schem. P. P. Inlet Air heating	0432	IAR	N/A
Schéma tuyauterie alimentation huile HP	Diagram. Schem. P. P. Hydr. Supply	0434	HS	356B2697
Schéma chauffage et ventilation compartiments	Diagram. Flow Heating - Vent	0436	HV	205D4462
Schéma lavage compresseur turbine	Diagram. Schem. P. P. Turb. – CPRSR WSHG	0442	TCW	356B3388
Schéma tuyauterie système inje ction	Diagram. Schem. P. P. Water Inj. System	0462	WI	356B3359
Schéma commande aubes variables	Diagram. Schem. P. P. I.G.V.	0469	IGV	91-242B9854
Schéma détection gaz	Diagram. Schem. Hazardous Gas Detector	0474	GD	202D8322
Schéma balayage tuyauterie combustible	Diagram. Schem. P. P. Fuel Purge	0477	FPU	91-315618
Schéma compresseur performance monitoring	Diagram. Schem. Performance Monitor	0492	PM	356B2419

GENERAL ELECTRIC COMPANY		SIZE	CAGE CODE	DWG NO
 GE Energy Products - Europe		A		379A9706
DRAWN	M. JEZEQUEL			SECTION INDX
		SCALE		SHEET 3



SIZE A	DWG NO 379A9706	SH 4	REV D

Item PID	Appareils	Item TG	Désignation	Réglages
0425	20AA-1	0983	Electrovanne Air Atomisation Normal : 1 vers 3 ouvert ; 2 fermé.	-
0425	20AB-1	0922	Electrovanne Air Atomisation suppres seur de démarrage Normal : 1 vers 3 ouvert ; 2 fermé.	-
0417	20CB-1	1071	Electrovanne Commande Vanne Anti pompage compresseur Normal : B vers C ouvert ; A fermée	-
0424	20CF-1	0601	Embrayage Electromagnetique Pompe a Fuel Normal : désexcité et libéré	-
0418	20FG-1	1019	Electrovanne Arret Combustible Gaz Normal : ouvert	-
0418	20FL-1	1019	Electrovanne Arret Combustible Liquide Normal : ouvert	-
0477	20PG-1	0918	Electrovanne balayage purge combustible gaz Normal : 1 vers 3 ouvert ; 2 fermé.	-
0477	20PG-2	0918	Electrovanne balayage purge combustible gaz Normal : 1 vers 3 ouvert ; 2 fermé.	-
0477	20PL-1	918T	Electrovanne Purge Combustible liquide Normal : 1 vers 3 ouvert ; 2 fermé.	-
0421	20TU-1	0605	Electrovanne d'Appoint / Décharge du Convertisseur de Couple	-
0418	20TV-1	1019	Electrovanne Commande des Aubes à Ouvertures Variables Normal : ouvert	-
0442	20TW-1	0953	Vanne Motorisée Lavage compres seur (Off Line) Caractéristiques : 92 W 115 V 50/60 Hz 1 PH	-
0442	20TW-3	0953	Vanne Motorisée Lavage compres seur (On Line) Caractéristiques : 92 W 115 V 50/60 Hz 1 PH	-
0422	20VG-1	0911	Electrovanne Event Combustible Gaz Normal : NO	-
0477	20VG-2	0918	Electrovanne event combustible gazeux Normal : ouvert	-
0462	20WN-2	A035	Electrovanne transfert injection d'eau VC5-1	-
0462	20WN-4	A035	Electrovanne d'arrêt injection eau	-
0425	23AB-1	1047	Résistance anticondensation moteur 88AB-1 Caractéristiques : 0,05 kW 230 V 50 Hz 1 PH	-
0436	23BT-1	En d.	Résistance anticondensation du moteur 88BT-1 Caractéristiques : 0,05 kW 230 V 50 Hz 1 PH	-
0436	23BT-2	En d.	Résistance anticondensation du moteur 88BT-2 Caractéristiques : 0,05 kW 230 V 50 Hz 1 PH	-
0421	23CR-1	0603	Réchauffage Moteur de Lancement Caractéristiques : 0,15 kW 240 V 50 Hz 1 PH	-
0421	23CR-2	0603	Réchauffage Moteur de Lancement Caractéristiques : 0,15 kW 240 V 50 Hz 1 PH	-
0421	23CR-3	0603	Réchauffage Moteur de Lancement Caractéristiques : 0,15 kW 240 V 50 Hz 1 PH	-
0436	23HA	En d.	Chauffage compartiment auxiliaire Caractéristiques : 18 kW 230 V 50 Hz 1 PH	-
0434	23HQ-1	0628	Résistance chauffantes de pompe à huile Caractéristiques : 0,05 kW -230 V 50- Hz 1 PH	-
0436	23HT	En d.	Chauffage enceinte acoustique TG Caractéristiques : 18 kW 230 V 50 Hz 1 PH	-
0416	23QA-1	1006	Résistance anticondensation du moteur 88QA-1 Caractéristiques : 0,05 kW 230 V 50 Hz 1 PH	-
0416	23QT-1	0938	Résistance de chau ffrage cuve à huile Caractéristiques : 10,2 kW 400 V 50 Hz 1 PH	-
0416	23QT-2	0938	Résistance de chau ffrage cuve à huile Caractéristiques : 10,2 kW 400 V 50 Hz 1 PH	-
0416	23QV-1	A098	Résistance anticondensation du moteur 88QV-1 Caractéristiques : 0,05 kW 230 V 50 Hz 1 PH	-
0421	23TG-1	0538	Réchauffage Moteur de Virage Caractéristiques : 0,05 kW 230 V 50 Hz 1 PH	-
0417	23TK-1	1233	Résistance anticondensation du moteur 88TK-1 Caractéristiques : 0,05 kW 230 V 50 Hz 1 PH	-
0417	23TK-2	1233	Résistance anticondensation du moteur 88TK-2 Caractéristiques : 0,05 kW 230 V 50 Hz 1 PH	-
0436	23VG-1	En d.	Résistance anticondensation moteur 88VG-1 Caractéristiques : 0,05 kW 230 V 50 Hz 1 PH	-

GENERAL ELECTRIC COMPANY		SIZE A	CAGE CODE	DWG NO 379A9706	
 GE Energy Products - Europe				SECTION 01F	
DRAWN M. JEZEQUEL		SCALE		SHEET	4



SIZE A	DWG NO 379A9706	SH 5	REV D

Item PID	Appareils	Item TG	Désignation	Réglages
0436	23VG-2	En d.	Résistance anticondensation moteur 88VG-2 Caractéristiques : 0,05 kW 230 V 50 Hz 1 PH	-
0421	26CR-1	0603	Capteur de Température Haute Bobinage Stator - Ph1	-
0421	26CR-2	0603	Capteur de Température Haute Bobinage Stator - Ph2	-
0421	26CR-3	0603	Capteur de Température Haute Bobinage Stator - Ph3	-
0436	26HA	En d.	Thermostat, température base dans compartiment auxiliaire	-
0436	26HT	En d.	Thermostat, température base dans enceinte acoustique	-
0415	28FD-10	1121	Détecteur de flamme Chambre de combustion 10	-
0415	28FD-11	1121	Détecteur de flamme Chambre de combustion 11	-
0415	28FD-4	1121	Détecteur de flamme Chambre de combustion 4	-
0415	28FD-5	1121	Détecteur de flamme Chambre de combustion 5	-
0436	33BT-1	En d.	Fin de course à l'entrée d'air de l'enceinte acoustique TG	-
0436	33BT-2	En d.	Fin de course à l'entrée d'air de l'enceinte acoustique TG	-
0417	33CB-1	1022	Fin de Course Vanne anti - pompage (11 ème étage)	Vanne ouverte : fin de course actionné, contact fermé
0417	33CB-2	1022	Fin de Course Vanne anti - pompage (11 ème étage)	Vanne ouverte : fin de course actionné, contact fermé
0417	33CB-3	1022	Fin de Course Vanne anti - pompage (11 ème étage)	Vanne ouverte : fin de course actionné, contact fermé
0417	33CB-4	1022	Fin de Course Vanne anti - pompage (11 ème étage)	Vanne ouverte : fin de course actionné, contact fermé
0424	33FL-1	0511	Fin de course Vanne Arrêt Combustible Liquide	Vanne fermée : fin de course actionne, contact fermé
0424	33FL-2	0511	Fin de course Vanne Arrêt Combustible Liquide	Vanne ouverte : fin de course actionne, contact fermé
0477	33PG-1	0918	Fin de course vanne purge combustible gaz	Vanne fermée : fin de course actionne, contact fermé
0477	33PG-2	0918	Fin de course vanne purge combustible gaz	Vanne ouverte : fin de course actionne, contact fermé
0477	33PG-3	0918	Fin de course vanne purge combustible gaz	Vanne fermée : fin de course actionne, contact fermé
0477	33PG-4	0918	Fin de course vanne purge combustible gaz	Vanne ouverte : fin de course actionne, contact fermé
0421	33TC-1	0605	Fin de Course Position Electrovanne Convertisseur de Couple	Fin de course activé pour 20TU-1 au repos - Contact fermé
0421	33TM-5	0605	Fin de Course Couple Bas Convertisseur de Couple	Réglage préliminaire à 2 tr (échelle 0-31 tr)
0421	33TM-6	0605	Fin de Course Couple Haut Convertisseur de Couple	Réglage préliminaire à 28 tr (échelle 0-31 tr)
0422	33VG-1	0911	Fin de course Vanne Event Gaz (20VG-1)	Désactivé quand la vanne d'event 20VG-1 est ouverte.
0436	33VG-1	En d.	Fin de course clapet anti-retour de la ventilation compartiment puissance	-
0436	33VG-2	En d.	Fin de course clapet anti-retour de la ventilation compartiment puissance	-
0462	33WN-1	A035	Fin de course vanne controle VC4-1 normal = no-SPST	Actionne et contact ferme quand vanne est pleine ouverture
0462	33WN-3	A035	Fin de course vanne transfert VC5-1 normal = no-SPST	Actionne et contact ferme quand vanne est pleine ouverture
0462	33WN-6	A035	Fin de course vanne contrôle VC4-1 normal = no-SPST	Actionne et contact ferme quand vanne est fermée
0462	33WN-7	A035	Fin de crouse vanne transfert VC5-1 normal = no-SPST	Actionne et contact ferme quand vanne est fermée
0415	39V-1A	1218	Capteur de vibration palier 1	-
0415	39V-1B	1218	Capteur de vibration palier 1	-
0415	39V-2A	1218	Capteur de vibration palier 2	-
0415	39V-3A	1218	Capteur de vibration palier 3	-
0415	39V-3B	1218	Capteur de vibration palier 4	-
0426	43CP-1	En d.	Bris de glace compartiment auxiliaire	N/A
0426	43CP-2	En d.	Bris de glace compartiment turbine	N/A
0426	43CP-3	En d.	Bris de glace compartiment auxiliaire	N/A
0426	43CP-4	En d.	Bris de glace compartiment turbine	N/A
0426	43CP-5	En d.	Bris de glace compartiment Load	N/A
0442	43TW-1 /PB	1105	Bouton poussoir Commande vanne (20TW-1)	N/A
0426	45FA-1A	1104	Détecteur thermostatique incendie Compartiment auxiliaire	163 ± 14 °C
0426	45FA-1B	1104	Détecteur thermostatique incendie Compartiment auxiliaire	163 ± 14 °C
0426	45FA-2A	1104	Détecteur thermostatique incendie Compartiment auxiliaire	163 ± 14 °C
0426	45FA-2B	1104	Détecteur thermostatique incendie Compartiment auxiliaire	163 ± 14 °C
0426	45FT-1A	1103	Détecteur thermostatique incendie Compartiment turbine	316 ± 14°C
0426	45FT-1B	1103	Détecteur thermostatique incendie Compartiment turbine	316 ± 14°C
0426	45FT-2A	1154	Détecteur thermostatique incendie Compartiment turbine	316 ± 14°C
0426	45FT-2B	1154	Détecteur thermostatique incendie Compartiment turbine	316 ± 14°C
0426	45FT-3A	1154	Détecteur thermostatique incendie Compartiment turbine	316 ± 14°C
0426	45FT-3B	1154	Détecteur thermostatique incendie Compartiment turbine	316 ± 14°C
0426	45FT-8A	1160	Détecteur thermostatique incendie Compartiment load	385 ± 14°C
0426	45FT-8B	1160	Détecteur thermostatique incendie Compartiment load	385 ± 14°C
0426	45FT-9A	1160	Détecteur thermostatique incendie Compartiment load	385 ± 14°C

GENERAL ELECTRIC COMPANY		SIZE A	CAGE CODE	DWG NO 379A9706	
g GE Energy Products - Europe				SECTION 01F	
DRAWN M. JEZEQUEL					
		SCALE			SHEET 5



SIZE A	DWG NO 379A9706	SH 6	REV D				
Item PID	Appareils	Item TG	Désignation	Réglages			
0426	45FT-9B	1160	Détecteur thermostatique incendie Compartiment load	385 ± 14°C			
0474	45HA-1	1153	Detecteur Gaz Compartiment Auxiliaire 0 – 20 % LIE	-			
0474	45HA-2	1153	Detecteur Gaz Compartiment Auxiliaire 0 – 20 % LIE	-			
0474	45HA-3	1153	Detecteur Gaz Compartiment Auxiliaire. 0 – 20 % LIE	-			
0474	45HA-4	1153	Detecteur Gaz Module Cabane gaz. 0 – 20 % LIE	-			
0474	45HA-5	1153	Detecteur Gaz Module Cabane gaz. 0 – 20 % LIE	-			
0474	45HA-6	1153	Detecteur Gaz Module Cabane gaz. 0 – 20 % LIE	-			
0474	45HT-1	1154	Detecteur Gaz Compartiment Turbine 0 – 20 % LIE	-			
0474	45HT-2	1154	Detecteur Gaz Compartiment Turbine 0 – 20 % LIE	-			
0474	45HT-3	1154	Detecteur Gaz Compartiment Turbine 0 – 20 % LIE	-			
0474	45HT-4	1154	Detecteur Gaz dans gaine de ventilation Compartiment Turbine 0 – 20 % LIE	-			
0474	45HT-5	1154	Detecteur Gaz dans gaine de ventilation Compartiment Turbine 0 – 20 % LIE	-			
0474	45HT-6	1154	Detecteur Gaz dans gaine de ventilation Compartiment Turbine 0 – 20 % LIE	-			
0426	5E-1	1104	Bouton d'arrêt d'urgence compartiment auxiliaire	-			
0426	5E-2	1104	Bouton d'arrêt d'urgence compartiment auxiliaire	-			
0424	63FL-2	0926	Manostat Pression Fuel Amont Vanne Arrêt Fuel	DEC ouvert = 2,41 +/- 0,14 bars INC fermé = 2,75 +/- 0,17 bars			
0434	63HF-1	0926	Manostat Différentiel Filtre Alimentation Hydraulique	DEC fermé = 2,75 +/- 1,03 bars INC ouvert = 4,13 +/- 0,20 bars			
0418	63HG-1	0926	Manostat Pression Huile de déclenchement pour vanne d'arrêt Combustible Gaz	Seuil Ouverture descendante : 1,40 ± 0,07 bars (Pour Info Fermeture montante : 1,65 ± 0,14 bars)			
0418	63HG-2	0926	Manostat Pression Huile de déclenchement pour vanne d'arrêt Combustible Gaz	Seuil Ouverture descendante : 1,40 ± 0,07 bars (Pour Info Fermeture montante : 1,65 ± 0,14 bars)			
0418	63HG-3	0926	Manostat Pression Huile de déclenchement pour vanne d'arrêt Combustible Gaz	Seuil Ouverture descendante : 1,40 ± 0,07 bars (Pour Info Fermeture montante : 1,65 ± 0,14 bars)			
0418	63HL-1	0926	Manostat Pression Huile de déclenchement pour vanne d'arrêt combustible liquide	Seuil Ouverture descendante : 1,40 ± 0,07 bars (Pour Info Fermeture montante : 1,65 ± 0,14 bars)			
0418	63HL-2	0926	Manostat Pression Huile de déclenchement pour vanne d'arrêt combustible liquide	Seuil Ouverture descendante : 1,40 ± 0,07 bars (Pour Info Fermeture montante : 1,65 ± 0,14 bars)			
0418	63HL-3	0926	Manostat Pression Huile de déclenchement pour vanne d'arrêt combustible liquide	Seuil Ouverture descendante : 1,40 ± 0,07 bars (Pour Info Fermeture montante : 1,65 ± 0,14 bars)			
0434	63HQ-1	0926	Manostat de pression basse alimentation huile HP	INC fermé = 100 +/- 3,1 bars DEC ouvert = 93,1 +/- 1,7 bars			
0424	63LF-3	0992	Manostat de pression différentielle filtre fuel principal	INC ouvert = 1 +/- 0,07 bars D			
0477	63PG-1	0918	Manostat de pression système vanne de purge	DEC ouvert = 2,75 +/- 0,13 bars INC fermé = 3,1 +/- 0,13 bars			
0477	63PL-21	0918T	Manostat Pression Air Purge	INC fermé = 7 +/- 0,25 bars DEC ouvert = 5,6 +/- 0,25 bars			
0416	63QA-2	0926	Manostat Basse Pression Huile Graissage Paliers (alarme)	INC fermé = 3,1 +/- 0,14 bars DEC ouvert = 2,8 +/- 0,07 bars			
0416	63QQ-1	0926	Manostat Différentiel Filtre Huile de graissage	DEC fermé = 0,9 +/- 0,2 bars INC ouvert = 1,03 +/- 0,07 bars			
0416	63QQ-8	0916	Manostat de pression différentielle filtre convertisseur de couple	INC ouvert = 1,5 bars			
0416	63QT-2A	ALT/ GEN.	Manostat Basse pression Huile Lubrification (Partie Alternateur)	INC fermé = 0,62 +/- 0,04 bars DEC ouvert = 0,55 +/- 0,02 bars			
0416	63QV-1	A098	Manostat de pression différentielle filtre d'huileur	NO Seuil Fermeture montante : 10 ± 0,25 mbar (Pour Info Ouverture descendante : 6,8 ± 0,25 mbar)			
0417	63TK-1	A053	Manostat de pression air refroidissement corps turbine et cadre échappement	Fermé : au dessus de 381 +/- 76 mm H2O			
0417	63TK-2	A053	Manostat de pression air refroidissement corps turbine et cadre échappement	Fermé : au dessus de 381 +/- 76 mm H2O			

GENERAL ELECTRIC COMPANY			SIZE A	CAGE CODE	DWGNO 379A9706
g GE Energy Products - Europe					
DRAWN M. JEZEQUEL			SECTION 01F		
			SCALE		SHEET 6



SIZE A	DWG NO 379A9706	SH 7	REV D

Item PID	Appareils	Item TG	Désignation	Réglages
0436	63VL	En d.	manostat pression compartiment gaz	
0424	65FP	0533	Servo-van ne (Bypass) Pompe a Fuel	-
0422	65GC	0541	Servo-van ne Controle Gaz	-
0416	71QH-1	1038	Detecteur de Niveau Niveau Haut Huile de Graissage	Voir schéma huile de graissage : Item 416
0416	71QL-1	1038	Detecteur de Niveau Niveau Bas Huile de Graissage	Voir schéma huile de graissage : Item 416
0424	77FD-1	0992	Capteur de Vitesse magnetique Diviseur de Debit	Jeux : 0,38 +/- 0,05 mm
0424	77FD-2	0992	Capteur de Vitesse magnetique Diviseur de Debit	Jeux : 0,38 +/- 0,05 mm
0424	77FD-3	0992	Capteur de Vitesse magnetique Diviseur de Debit	Jeux : 0,38 +/- 0,05 mm
0415	77HT-1	0546	Capteur de Vitesse Magnetique Survitesse Ligne d'arbre	Jeux : 1,27 +/- 0,12 mm
0415	77HT-2	0546	Capteur de Vitesse Magnetique Survitesse Ligne d'arbre	Jeux : 1,27 +/- 0,12 mm
0415	77HT-3	0546	Capteur de Vitesse Magnetique Survitesse Ligne d'arbre	Jeux : 1,27 +/- 0,12 mm
0415	77NH-1	0546	Capteur de Vitesse Magnetique Ligne d'arbre	Jeux : 1,27 +/- 0,12 mm
0415	77NH-2	0546	Capteur de Vitesse Magnetique Ligne d'arbre	Jeux : 1,27 +/- 0,12 mm
0415	77NH-3	0546	Capteur de Vitesse Magnetique Ligne d'arbre	Jeux : 1,27 +/- 0,12 mm
0462	77WN-1T3	A 035	Débitmètre circuit commun injection d'eau	-
0425	88AB-1	1047	Moteur compresseur de démarrage air atomisation Caractéristiques : 15 kW 2925 tr/min 400 V 50 Hz 3 PH	-
0436	88BT-1	En d.	Moteur électrique Ventilateur refroidissement enceinte acoustique Caractéristiques : 15 kW 1460 tr/min 400 V 50 Hz 3 PH	-
0436	88BT-2	En d.	Moteur électrique Ventilateur refroidissement enceinte acoustique Caractéristiques : 15 kW 1460 tr/min 400 V 50 Hz 3 PH	-
0421	88CR-1	0603	Moteur Electrique de Lancement Caractéristiques : 1000 kW 2973 tour/min 6 kV 50 Hz 3 PH	-
0424	88FM	0613	Moteur Electrique Demarrage Repartiteur de Debit Combustible Liquide Caractéristiques : 0,37 kW 1400 tr/min 6,6 kV 50 Hz 3 PH	-
0436	88HA	En d.	Ventilateur interne au 23HA-1 Caractéristiques : 400 V 50 Hz 3 PH	-
0434	88HQ-1	0628	Moteur pompe auxiliaire huile HP Caractéristiques : 15 kW 1455 tr/min 400 V 50 Hz 3 PH	-
0436	88HT	En d.	Ventilateur interne au 23HT Caractéristiques : 400 V 50 Hz 3 PH	-
0416	88QA-1	1006	Moto-pompe auxiliaire huile de graissage Caractéristiques : 90 kW 2960 tr/min 400 V 50 Hz 3 PH	-
0416	88QE-1	1007	Moto-pompe de secours huile de graissage Caractéristiques : 7,5 kW 1750 tr/min 125 V - DC	-
0416	88QV-1	A 098	Moteur Electrique du Deshuileur Caractéristiques : 7,5 kW 3000 tr/min 400 V 50 Hz 3 PH	-
0421	88TG-1	0538	Moteur Electrique de Virage Caractéristiques : 30 kW 733 tr/min 400 V 50 Hz 3 PH	-
0417	88TK-1	1233	Ventilateur centrifuge + Moteur Electrique Groupe Moto Ventilateur Refroidissement Corps TG Caractéristiques : 45 kW 2900 tr/min 400 V 50 Hz 3 PH	-
0417	88TK-2	1233	Ventilateur centrifuge + Moteur Electrique Groupe Moto Ventilateur Refroidissement Corps TG Caractéristiques : 45 kW 2900 tr/min 400 V 50 Hz 3 PH	-
0421	88TM-1	0605	Moteur convertisseur de couple Caractéristiques : 1,5 kW 3000 tr/min 400 V 50 Hz 3 PH	-
0436	88VG-1	En d.	Moteur électrique Ventilateur refroidissement compartiment puissance TG Caractéristiques : 7,5 kW 1450 tour/min 400 V 50 Hz 3 PH	-
0436	88VG-2	En d.	Moteur électrique Ventilateur refroidissement compartiment puissance TG Caractéristiques : 7,5 kW 1450 tour/min 400 V 50 Hz 3 PH	-
0436	88VL-1	En d.	Moteur électrique Ventilateur refroidissement compartiment gaz Caractéristiques : 3 kW - tr/min 400 V 50 Hz 3 PH	-
0436	88VL-2	En d.	Moteur électrique Ventilateur refroidissement compartiment gaz Caractéristiques : 3 kW - tr/min 400 V 50 Hz 3 PH	-

GENERAL ELECTRIC COMPANY		SIZE A	CAGE CODE	DWG NO 379A9706	
 GE Energy Products - Europe				SECTION 01F	
DRAWN M. JEZEQUEL					
			SCALE		SHEET 7



SIZE A	DWG NO 379A9706	SH 8	REV D

Item PID	Appareils	Item TG	Désignation	Réglages
0462	88WN-1	A035	Moteur pompe injection d'eau Caractéristiques : 75 kW 3000 tr/min 400 V 50 Hz 3 PH	-
0422	90SR-1	0541	Servo-vanne Arrêt et Régulation Gaz	-
0469	90TV-1	0540	Servovalve IGV Compresseur	N/A
0462	90WN-1	A035	Servovalve pour vanne VC5-1	-
0415	95SP-13	1214	Bougies Allumage Chambre de Combustion n°13	-
0415	95SP-14	1214	Bougies Allumage Chambre de Combustion n°14	-
0415	95TR-13	1213	Transformateur pour bougie d'allumage	-
0415	95TR-14	1213	Transformateur pour bougie d'allumage	-
0425	96AD-1	0926	Transmetteur de Pression Différentiel Air Atomisation	4 mA pour 0 bar 20 mA pour 6 bar
0492	96AP-1A	0559	Transmetteur de pression atmosphérique	4 mA +/- 0,02 mA pour 0,745 bar 20 mA +/- 0,10 mA pour 1,250 bar
0492	96AP-1B	0559	Transmetteur de pression atmosphérique	4 mA +/- 0,02 mA pour 0,745 bar 20 mA +/- 0,10 mA pour 1,250 bar
0492	96AP-1C	0559	Transmetteur de pression atmosphérique	4 mA +/- 0,02 mA pour 0,745 bar 20 mA +/- 0,10 mA pour 1,250 bar
0492	96BD-1	0559	Transmetteur de pression	4 mA +/- 0,02 mA pour 0,000 bar 20 mA +/- 0,10 mA pour 0,345 bar
0417	96CD-1A	0557	Transmetteur de Pression sortie Compresseur	4 ± 0,5 mA pour 0 bar 20 ± 0,5 mA pour 20 bar
0417	96CD-1B	0557	Transmetteur de Pression sortie Compresseur	4 ± 0,5 mA pour 0 bar 20 ± 0,5 mA pour 20 bar
0417	96CD-1C	0557	Transmetteur de Pression sortie Compresseur	4 ± 0,5 mA pour 0 bar 20 ± 0,5 mA pour 20 bar
0492	96CS-1	0559	Transmetteur de pression différentiel entrée air / pression atmosphérique	4 mA +/- 0,02 mA pour 0,0000 bar 20 mA +/- 0,10 mA pour 0,0274 bar
0422	96FG-2A	0557	Transmetteur de la Pression Gaz inter-vanne	0 - 5 ± 0,05 V 0 - 34,5 bars
0422	96FG-2B	0557	Transmetteur de la Pression Gaz inter-vanne	0 - 5 ± 0,05 V 0 - 34,5 bars
0422	96FG-2C	0557	Transmetteur de la Pression Gaz inter-vanne	0 - 5 ± 0,05 V 0 - 34,5 bars
0422	96FG-3	0557	Transmetteur de pression Entrée Module Gaz	4 - 20 mA 0 - 35 bars
0422	96FM-1	0639	Transmetteur de débit massique gaz	
0422	96GC-1,2	0509	Transmetteur de Position Lineaire Différentiel (LVDT) Vanne Contrôle Gaz	
0416	96QA-2	0926	Transmetteur de Pression Huile de Lubrification sortie VRP2	4 ± 0,5 mA pour 0 b 20 ± 0,5 mA pour 7 b
0416	96QT-2A	ALT/ GEN.	Transmetteur de Pression Huile de Lubrification côté Alternateur	4 ± 0,5 mA pour 0 b 20 ± 0,5 mA pour 5 b
0422	96SR-1,2	0507	Transmetteur de Position Lineaire Différentiel (LVDT) Vanne arrêt Gaz (VSR-1)	Vanne complètement fermée : 0.7 VAC +/- 0.1 VRMS Au milieu: 2.1 VAC +/- 0.1 VRMS Vanne complètement ouverte : 3.5VAC +/- 0.1 VRMS
0421	96TM-1	0605	Transmetteur de Position IGV Convertisseur de Couple	N/A
0469	96TV-1	0548	Transmetteur de Position Linéaire Différentiel (LVDT) Contrôle Aubes Variables Entrée Compresseur	Voir l'Instruction Liaison IGV et l'Instruction Ajustement LVDT dans l'Ensemble Système Commande IGV (MLI 0548).
0469	96TV-2	0548	Transmetteur de Position Linéaire Différentiel (LVDT) Commande Aubes Variables Entrée Compresseur	Voir l'Instruction Liaison IGV et l'Instruction Ajustement LVDT dans l'Ensemble Système Commande IGV (MLI 0548).
0462	96WN-1	A035	Transmetteur pression absolue entrée skid injection eau	-
0462	96WN-3	A035	Transmetteur pression relatif sortie pompe injection eau	-
0462	96WN-4	A035	Transmetteur de pression différentiel filtres skid injection eau	-
0425	AAT-1A	0637	Thermocouple Aval Réfrigérant Air Atomisation	-
0425	AAT-2A	0637	Thermocouple Aval Réfrigérant Air Atomisation	-
0434	AH1-1	0502	Accumulateur sur huile de contrôle	-
0434	AH1-2	0502	Accumulateur sur huile de contrôle	-
0436	AT-LC-1	0637	Résistance thermométrique compartiment puissance	-
0436	AT-TC-1	0637	Résistance thermométrique compartiment turbine	-
0462	AW-1	A035	Accumulateur sur circuit commun injection d'eau	-
0425	CA1	0607	Compresseur air atomisation principal	-
0425	CA2	1047	Compresseur de démarrage air atomisation	-

GENERAL ELECTRIC COMPANY		SIZE A	CAGE CODE	DWG NO 379A9706	
 GE Energy Products - Europe				SECTION 01F	
DRAWN M. JEZEQUEL					
			SCALE		SHEET 8



SIZE	DWG NO	SH	REV
A	379A9706	9	D

Item PID	Appareils	Item TG	Désignation	Réglages
0415	CT-DA-1	0637	Thermocouple Echappement Compresseur	-
0415	CT-DA-2	0637	Thermocouple Echappement Compresseur	-
0415	CT-IF-1	0637	Thermocouple entrée compresseur	-
0415	CT-IF-2	0637	Thermocouple entrée compresseur	-
0477	FA3-1	0918T	Filtre Purge Injecteur Liquide	-
0425	FA4-1	0983	Filtre contrôle air atomisation	-
0477	FA6-1	1015	Filtre air atomisation circuit purge gaz	-
0462	FA90-1	A035	Filtre sur circuit d'alimentation en air de commande	-
0424	FD1-1	0613	Répartiteur de débit	-
0424	FF2-1	1014	Filtre fuel HP	-
0434	FH2-1	0908	Filtre Alimentation Hydraulique	-
0434	FH2-2	0908	Filtre Alimentation Hydraulique	-
0424	FH3-1	0992	Filtre Hydraulique Servo vanne Fuel Liquide	-
0469	FH6-1	0548	Filtre alimentation bloc de commande hydraulique IGV	-
0422	FH7-1	0911	Filtre Hydraulique du circuit d'alimentation des servo valve de la VGC et VSR	-
0462	FM1-1	A035	Débitmètre injection d'eau circuit commun	-
0422	FT-MG-1/R	0639	Résistance température device connecté au 96FM-1	-
0462	FW1-1	A035	Filtre basse pression injection d'eau	-
0462	FW2-1	A035	Filtre haute pression injection d'eau	-
0462	FW3-1	A035	Filtre haute pression aval debimetre injection eau	-
0469	HM3-1	0548	Ensemble actionneur Système Aubes Variables	-
0425	HX1-1	1003	Réfrigérant Air Atomisation	-
0416	LT-B1D-1 A,1B	0637	Thermocouple Retour Huile Palier n°1	-
0416	LT-B2D-1 A,1B	0637	Thermocouple Retour Huile Palier n°2	-
0416	LT-B3D-1 A,1B	0637	Thermocouple Retour Huile Palier n°3	-
0416	LT-BT1D-1 A,1B	0637	Thermocouple Retour Huile Butée Palier n°1	-
0416	LT-G1D	ALT/ GEN.	Thermocouple retour d'huile palier n°4	-
0416	LT-G2D	ALT/ GEN.	Thermocouple Retour Huile Palier n°5 Alternateur	-
0416	LT-OT-1A	0938	RTD Temperature Basse Cuve a Huile	-
0416	LT-OT-2A	0938	RTD Temperature Normale Cuve a Huile	-
0416	LT-TH-1A,1B	0637	Thermocouple Temperature Collecteur Turbine Huile Lubrification	-
0416	LT-TH-2A,2B	0637	Thermocouple Temperature Collecteur Turbine Huile Lubrification	-
0416	LT-TH-3A,3B	0637	Thermocouple Temperature Collecteur Turbine Huile Lubrification	-
0422	MG1	0512	Injecteur Combustible Gaz	-
0422	MG2-1	0639	Diaphragme de mesure de débit gaz	-
0424	PF1	0611	Pompe Principale Combustible Liquide	-
0434	PH1	0627	Pompe Hydraulique Principale	-
0434	PH2	0627	Pompe auxiliaire huile HP	-
0426	SLI-1	1104	Avertisseur lumineux compartiment auxiliaire	-
0426	SLI-1A	En d.	Feu flash d'alarme incendie	-
0426	SLI-1B	En d.	Feu flash d'alarme incendie	-
0426	SLI-1C	En d.	Combiné sonore et lumineux d'alarme incendie	-
0426	SLI-2	1104	Avertisseur lumineux compartiment auxiliaire	-
0426	SLI-2C	En d.	Combiné sonore et lumineux d'alarme incendie	-
0426	SLI-3C	En d.	Combiné sonore et lumineux d'alarme incendie	-
0415	TT-1B-1	0637	thermocouple tunnel palier 3	-
0415	TT-WS1A0-1	0637	Thermocouple Temperature 1ere Roue Turbine (extérieure)	-
0415	TT-WS1A0-2	0637	Thermocouple Temperature 1ere Roue Turbine (extérieure)	-
0415	TT-WS1FI-1	0637	Thermocouple Temperature Avant 1ere Roue Turbine (Intérieur)	-
0415	TT-WS1FI-2	0637	Thermocouple Temperature Avant 1ere Roue Turbine (Intérieur)	-
0415	TT-WS2A0-1	0637	Thermocouple Temperature après 2eme Roue Turbine (Extérieur)	-
0415	TT-WS2A0-2	0637	Thermocouple Temperature après 2eme Roue Turbine (Extérieur)	-
0415	TT-WS2F0-1	0637	Thermocouple Temperature Avant 2eme Roue Turbine (Extérieur)	-

GENERAL ELECTRIC COMPANY		SIZE A	CAGE CODE	DWG NO 379A9706	
 GE Energy Products - Europe				SECTION 01F	
DRAWN M. JEZEQUEL					
		SCALE		SHEET	9



SIZE A	DWG NO 379A9706	SH 10	REV D

Item PID	Appareils	Item TG	Désignation	Réglages
0415	TT-WS2F0-2	0637	Thermocouple Temperature Avant 2 eme Roue Turbine (Exterieur)	-
0415	TT-WS3A0-1	0637	Thermocouple Temperature après 3eme Roue Turbine (Exterieur)	-
0415	TT-WS3A0-2	0637	Thermocouple Temperature après 3eme Roue Turbine (Exterieur)	-
0415	TT-WS3F0-1	0637	Thermocouple Temperature avant 3eme Roue Turbine (Exterieur)	-
0415	TT-WS3F0-2	0637	Thermocouple Temperature avant 3eme Roue Turbine (Exterieur)	-
0415	TT-XD-1	0623	Thermocouple Temperature Echappement Turbine	-
0415	TT-XD-10	0623	Thermocouple Temperature Echappement Turbine	-
0415	TT-XD-11	0623	Thermocouple Temperature Echappement Turbine	-
0415	TT-XD-12	0623	Thermocouple Temperature Echappement Turbine	-
0415	TT-XD-13	0623	Thermocouple Temperature Echappement Turbine	-
0415	TT-XD-14	0623	Thermocouple Temperature Echappement Turbine	-
0415	TT-XD-15	0623	Thermocouple Temperature Echappement Turbine	-
0415	TT-XD-16	0623	Thermocouple Temperature Echappement Turbine	-
0415	TT-XD-17	0623	Thermocouple Temperature Echappement Turbine	-
0415	TT-XD-18	0623	Thermocouple Temperature Echappement Turbine	-
0415	TT-XD-19	0623	Thermocouple Temperature Echappement Turbine	-
0415	TT-XD-2	0623	Thermocouple Temperature Echappement Turbine	-
0415	TT-XD-20	0623	Thermocouple Temperature Echappement Turbine	-
0415	TT-XD-21	0623	Thermocouple Temperature Echappement Turbine	-
0415	TT-XD-22	0623	Thermocouple Temperature Echappement Turbine	-
0415	TT-XD-23	0623	Thermocouple Temperature Echappement Turbine	-
0415	TT-XD-24	0623	Thermocouple Temperature Echappement Turbine	-
0415	TT-XD-3	0623	Thermocouple Temperature Echappement Turbine	-
0415	TT-XD-4	0623	Thermocouple Temperature Echappement Turbine	-
0415	TT-XD-5	0623	Thermocouple Temperature Echappement Turbine	-
0415	TT-XD-6	0623	Thermocouple Temperature Echappement Turbine	-
0415	TT-XD-7	0623	Thermocouple Temperature Echappement Turbine	-
0415	TT-XD-8	0623	Thermocouple Temperature Echappement Turbine	-
0415	TT-XD-9	0623	Thermocouple Temperature Echappement Turbine	-
0477	VA13-1	0918	Vanne système purge combustible gaz	-
0477	VA13-2	0918	Vanne système purge combustible gaz	-
0424	VA17-1	1026	Vanne Purge carter des chambres Faux Depart Normal = ouvert	-
0424	VA17-2	1026	Vanne purge cadre échappement faux départ Normal = ouvert	-
0424	VA17-5	1026	Vanne Purge caisson échappement Faux Depart Normal = ouvert	-
0425	VA18-1	1070	Vanne recirculation Air Atomisation Normal = fermé	-
0477	VA19-1	0918T	Vanne Purge Injecteur Fuel Liquide Normal : C vers L ouvert ; U fermé	-
0417	VA2-1	1022	Vanne anti - pompage 11ème étage	-
0417	VA2-2	1022	Vanne anti - pompage 11ème étage	-
0417	VA2-3	1022	Vanne anti - pompage 11ème étage	-
0417	VA2-4	1022	Vanne anti - pompage 11ème étage	-
0425	VA22-1	0922	Vanne d'isolation surpresseur air atomisation Normal = ouvert	-
0434	VAB1	0947	Purge Air Sur Circuit Hydraulique principal	-
0434	VAB2	0947	Purge air sur circuit hydraulique auxiliaire	-
0424	VC3-1	0516	Vanne de dérivation de contrôle débit fuel	-
0462	VC4-1	A 035	Vanne contrôle de débit injection d'eau circuit primaire	-
0462	VC5-1	A 035	Vanne transfert injection d'eau manifold grand débit	-
0424	VCK1-1T14	0961	Clapet antiretour sur injecteur pour combustible fuel	Tarage : 8,27 +/- 0,34 bars
0477	VCK2-1T14	0918T	Clapet antiretour sur injecteur pour combustible fuel	Tarage : 0,34 +/- 0,069 bars
0434	VCK3-1	0947	Clapet antiretour Hydraulique Pompe Principale	-
0434	VCK3-2	0947	Clapet Hydraulique Pompe auxiliaire	-
0417	VCK7-1	A 053	Clapet Circuit Air Refroidissement Corps Turbine	-
0417	VCK7-2	A 053	Clapet Circuit Air Refroidissement Corps Turbine	-
0422	VGC	0509	Vanne Gaz de Contrôle	-

GENERAL ELECTRIC COMPANY		SIZE A	CAGE CODE	DWG NO 379A9706	
 GE Energy Products - Europe				SECTION 01F	
DRAWN M. JEZEQUEL					
			SCALE		SHEET 10



SIZE A	DWG NO 379A9706	SH 11	REV D

Item PID	Appareils	Item TG	Désignation	Réglages
0422	VH12	0509	Vanne de décharge de sécurité de la VGC	-
0469	VH3-1	0540	Vanne de déclenchement hydraulique IG V	-
0422	VH5	0507	Vanne de décharge de sécurité de la VSR	-
0416	VPR2-1	1023	Vanne de Régulation Collecteur Huile Palier	Tarage : 1,72 +0,13/-0 bars
0434	VPR3-1	1005	Compensateur de pression pompe hydraulique	Tarage : 103,4 +/- 1,37 bars
0477	VPR44-1	0918	Vanne de régulation pression air combustible gaz	Tarage : 2,3 +0/-0,2 bars
0477	VPR44-2	0918	Vanne de régulation pression air combustible gaz	Tarage : 2,3 +0/-0,2 bars
0477	VPR54-1	918T	Vanne de régulation Pression Purge injecteurs Combustible Liquide	Tarage : 3,27 +1,7/-0 bars
0425	VPR68-1	0922	Vanne de régulation de pression pour isolation surpresseur AA	Tarage : 3,79 +/- 0,13 bars
0462	VPR90-1	A 035	Regulateur pression air vanne controle VC4-1 injection eau	-
0462	VPR90-2	A 035	Regulateur pression air vanne controle VC5-1 injection eau	-
0416	VR1	1016	Vanne de décharge pompe principale huile de lubrification	Tarage : 6,89 +0,13/-0 bars
0434	VR21	0947	Vanne de décharge pompe principale huile HP	Tarage : 113,7 +/- 1,37 bars
0434	VR22	0947	Vanne de décharge pompe auxiliaire huile HP	Tarage : 113,7 +/- 1,37 bars
0424	VR27	0992	Vanne de décharge sur tuyauterie combustible liquide	Tarage : 6 +/- 0,2 bars
0424	VR4	0992	Vanne de décharge pompe à fuel	Tarage : 82,7 +/- 1,72 bars
0424	VS1	0511	Vanne Arrêt fuel	-
0422	VSR	0507	Vanne d'Arrêt et Réglage Gaz	-
0420	VTR1	1035	Vanne Thermostatique réfrigérant huile de graissage avant palier Normal = B vers E ouvert, C fermé	début de fermeture B vers E à 54 ± 1,6 °C
0420	VTR2-1	1027	Vanne thermostatique-réfrigérant air atomisation amont compresseur Normal = B vers E ouvert, C fermé	Réglage à 102 ± 5 °C
0420	WT-TL-1	0637	RTD Temperature pattes turbine	
0420	WT-TL-2	0637	RTD Temperature pattes turbine	-

GENERAL ELECTRIC COMPANY		SIZE A	CAGE CODE	DWG NO 379A9706	
 GE Energy Products - Europe				SECTION 01F	
DRAWN M. JEZEQUEL					
		SCALE		SHEET	11



SIZE A	DWG NO 379A9706	SH 12	REV D

Item PID	Devices	Item TG	Designation	Settings
0425	20AA-1	0983	Atomizing air solenoid valve Normal : désexcité et libéré	-
0425	20AB-1	0922	Atomizing booster air solenoid valve Normal : 1 to 3 open ; 2 closed.	-
0417	20CB-1	1071	Compressor Bleed Solenoid Valve Normal : B to C Open ; A closed	-
0424	20CF-1	0601	Fuel pump clutch solenoid Normal : de-energized and disengaged	-
0418	20FG-1	1019	Gas fuel stop valve solenoid Normal : open	-
0418	20FL-1	1019	Liquid fuel stop gas solenoid Normal : open	-
0477	20PG-1	0918	Gas fuel system purge valve solenoid Normal : 1 to 3 open ; 2 closed.	-
0477	20PG-2	0918	Gas fuel system purge valve solenoid Normal : 1 to 3 open ; 2 closed.	-
0477	20PL-1	918T	Liquid fuel system purge valve solenoid Normal : 1 to 3 open ; 2 closed.	-
0421	20TU-1	0605	Torque Converter Fill / Drain Solenoid Valve	-
0418	20TV-1	1019	Turbine compressor IGV solenoid valve Normal : open	-
0442	20TW-1	0953	Off line compressor wash motor inj sol (motor) valve Characteristics : 92 W 115 V 50/60 Hz 1 PH	-
0442	20TW-3	0953	On line compressor wash motor inj sol (motor) valve Characteristics : 92 W 115 V 50/60 Hz 1 PH	-
0422	20VG-1	0911	Fuel Gaz Vet solenoid Valve Normal : NO	-
0477	20VG-2	0918	Gas fuel vent solenoid valve Normal : open	-
0462	20WN-2	A035	Water injection transfert valve VC5-1 control solenoid valve	-
0462	20WN-4	A035	Water flow stop solenoid valve	-
0425	23AB-1	1047	Motor space heater for 88AB-1 Characteristics : 0,05 kW 230 V 50 Hz 1 PH	-
0436	23BT-1	En d.	Anti-condensation heater for motor 88BT-1 Characteristics : 0,05 kW 230 V 50 Hz 1 PH	-
0436	23BT-2	En d.	Anti-condensation heater for motor 88BT-2 Characteristics : 0,05 kW 230 V 50 Hz 1 PH	-
0421	23CR-1	0603	Cranking Motor Space Heater Characteristics : 180 W 240 V 50 Hz 1 PH	-
0421	23CR-2	0603	Cranking Motor Space Heater Characteristics : 0,15 kW 240 V 50 Hz 1 PH	-
0421	23CR-3	0603	Cranking Motor Space Heater Characteristics : 0,15 kW 240 V 50 Hz 1 PH	-
0436	23HA	En d.	Accessory compartment heater Characteristics : 0,15 kW 230 V 50 Hz 1 PH	-
0434	23HQ-1	0628	Heater hydraulic oil pump motor Characteristics : : 0,05 kW 230 V 50 Hz 1 PH	-
0436	23HT	En d.	Acoustic TG enclosure Heater Characteristics : 18 kW 230 V 50 Hz 1 PH	-
0416	23QA-1	1006	Anti-condensation heater for motor 88QA-1 Characteristics : 0,05 kW 230 V 50 Hz 1 PH	-
0416	23QT-1	0938	Immersion heater lube oil tank Characteristics : 10,2 kW 400 V 50 Hz 1 PH	-
0416	23QT-2	0938	Immersion heater lube oil tank Characteristics : 10,2 kW 400 V 50 Hz 1 PH	-
0416	23QV-1	A098	Anti-condensation heater for motor 88QV-1 Characteristics : 0,05 kW 230 V 50 Hz 1 PH	-
0421	23TG-1	0538	Tuning Gear Motor Space Heater Characteristics : 0,05 W 230 V 50 Hz 1 PH	-
0417	23TK-1	1233	Anti-condensation heater for motor 88TK-1 Characteristics : 0,05 kW 230 V 50 Hz 1 PH	-
0417	23TK-2	1233	Anti-condensation heater for motor 88TK-2 Characteristics : 0,05 kW 230 V 50 Hz 1 PH	-
0436	23VG-1	En d.	Motor space heater for 88VG-1 Characteristics : 0,05 kW 230 V 50 Hz 1 PH	-

GENERAL ELECTRIC COMPANY		SIZE A	CAGE CODE	DWG NO 379A9706
 GE Energy Products - Europe				SECTION 01E
DRAWN M. JEZEQUEL		SCALE		SHEET 12



SIZE A	DWG NO 379A9706	SH 13	REV D

Item PID	Devices	Item TG	Designation	Settings
0436	23VG-2	En d.	Motor space heater for 88VG-2 Characteristics : 0,05 kW 230 V 50 Hz 1 PH	-
0421	26CR-1	0603	Stator Winding High Temperature Sensor - Ph1	-
0421	26CR-2	0603	Stator Winding High Temperature Sensor - Ph2	-
0421	26CR-3	0603	Stator Winding High Temperature Sensor - Ph3	-
0436	26HA	En d.	Thermostat, lower temperature in accessory compartment	-
0436	26HT	En d.	Thermostat, lower temperature in acoustic enclosure	-
0415	28FD-10	1121	Flame detector-combustion chamber n° 10	-
0415	28FD-11	1121	Flame detector-combustion chamber n° 11	-
0415	28FD-4	1121	Flame detector-combustion chamber n° 4	-
0415	28FD-5	1121	Flame detector-combustion chamber n° 5	-
0436	33BT-1	En d.	Position control of GT enclosure air inlet damper	-
0436	33BT-2	En d.	Position control of GT enclosure air inlet damper	-
0417	33CB-1	1022	11 stage compressor Bleed Valve Limit Switch	Valve open : limit switch activated, contact closed
0417	33CB-2	1022	11 stage compressor Bleed Valve Limit Switch	Valve open : limit switch activated, contact closed
0417	33CB-3	1022	11 stage compressor Bleed Valve Limit Switch	Valve open : limit switch activated, contact closed
0417	33CB-4	1022	11 stage compressor Bleed Valve Limit Switch	Valve open : limit switch activated, contact closed
0424	33FL-1	0511	Liquid fuel stop valve limit switch (bc)	Valve closed : switch activated, contact closed
0424	33FL-2	0511	Liquid fuel stop valve limit switch	Valve opened : switch activated, contact closed
0477	33PG-1	0918	Gas fuel system purge valve limit switch	Valve closed : switch activated, contact closed
0477	33PG-2	0918	Gas fuel system purge valve limit switch	Valve opened : switch activated, contact closed
0477	33PG-3	0918	Gas fuel system purge valve limit switch	Valve closed : switch activated, contact closed
0477	33PG-4	0918	Gas fuel system purge valve limit switch	Valve opened : switch activated, contact closed
0421	33TC-1	0605	Torque Converter Solenoid Valve Limit Switch	Switch activated with 20TU-1 desenergized - Contact closed
0421	33TM-5	0605	Torque Converter Low Torque Limit Switch	Preliminary Setup at 2 tr (range 0-31 tr)
0421	33TM-6	0605	Torque Converter High Torque Limit Switch	Preliminary Setup at 28 tr (range 0-31 tr)
0422	33VG-1	0911	Limit Switch on Solenoid Valve 20VG-1	De-energized when vent valve 20VG-1 is opened
0436	33VG-1	En d.	Position control of load compartment ventilation .Fan non return valve	
0436	33VG-2	En d.	Position control of load compartment ventilation .Fan non return valve	
0462	33WN-1	A035	VC4-1 control valve limit switch normal = no-spst	Switch actuated and contact closed when control valve full open
0462	33WN-3	A035	VC5-1 transfert valve limit switch normal = no-spst	Switch actuated and contact closed when transfer valve full open
0462	33WN-6	A035	VC4-1 control valve limit switch normal = no-spst	Switch actuated and contact closed when control valve close
0462	33WN-7	A035	VC5-1 transfert valve limit switch normal = no-spst	Switch actuated and contact closed when transfer valve close
0415	39V-1A	1218	Vibration sensor turbine bearing 1	
0415	39V-1B	1218	Vibration sensor turbine bearing 1	
0415	39V-2A	1218	Vibration sensor turbine bearing 2	
0415	39V-3A	1218	Vibration sensor turbine bearing 3	
0415	39V-3B	1218	Vibration sensor turbine bearing 4	
0426	43CP-1	En d.	Break glass unit accessory compartment Normal open	
0426	43CP-2	En d.	Break glass unit GT compartment	
0426	43CP-3	En d.	Break glass unit accessory compartment	
0426	43CP-4	En d.	Break glass unit GT compartment	
0426	43CP-5	En d.	Break glass unit load compartment	
0442	43TW-1 /PB	1105	Push button (20TW-1)	
0426	45FA-1A	1104	Thermostatic fire detector Accessory compartment	163 ± 14 °C
0426	45FA-1B	1104	Thermostatic fire detector Accessory compartment	163 ± 14 °C
0426	45FA-2A	1104	Thermostatic fire detector Accessory compartment	163 ± 14 °C
0426	45FA-2B	1104	Thermostatic fire detector Accessory compartment	163 ± 14 °C
0426	45FT-1A	1103	Thermostatic fire detector Turbine compartment	316 ± 14°C
0426	45FT-1B	1103	Thermostatic fire detector Turbine compartment	316 ± 14°C
0426	45FT-2A	1154	Thermostatic fire detector Turbine compartment	316 ± 14°C
0426	45FT-2B	1154	Thermostatic fire detector Turbine compartment	316 ± 14°C
0426	45FT-3A	1154	Thermostatic fire detector Turbine compartment	316 ± 14°C
0426	45FT-3B	1154	Thermostatic fire detector Turbine compartment	316 ± 14°C
0426	45FT-8A	1160	Thermostatic fire detector Load compartment	385 ± 14°C
0426	45FT-8B	1160	Thermostatic fire detector Load compartment	385 ± 14°C

GENERAL ELECTRIC COMPANY		SIZE A	CAGE CODE	DWG NO 379A9706
 GE Energy Products - Europe				
DRAWN M. JEZEQUEL				SECTION 01E
		SCALE		SHEET 13



SIZE A	DWG NO 379A9706	SH 14	REV D

Item PID	Devices	Item TG	Designation	Settings
0426	45FT-9A	1160	Thermostatic fire detector Load compartment	385 ± 14°C
0426	45FT-9B	1160	Thermostatic fire detector Load compartment	385 ± 14°C
0474	45HA-1	1153	Gas detector Gas Auxiliarie compartment 0 – 20 % LIE	-
0474	45HA-2	1153	Gas detector in Auxiliarie Compartmente 0 – 20 % LIE	-
0474	45HA-3	1153	Gas detector Gas in Auxiliarie Compartment. 0 – 20 % LIE	-
0474	45HA-4	1153	Gas detector Gas in Gas cabinet Module. 0 – 20 % LIE	-
0474	45HA-5	1153	Gas detector Gas in Gas cabinet Module. 0 – 20 % LIE	-
0474	45HA-6	1153	Gas detector Gas in Gas cabinet Module. 0 – 20 % LIE	-
0474	45HT-1	1154	Gas detector Turbine Compartment 0 – 20 % LIE	-
0474	45HT-2	1154	Gas detector Turbine Compartment 0 – 20 % LIE	-
0474	45HT-3	1154	Gas detector Turbine Compartment 0 – 20 % LIE	-
0474	45HT-4	1154	Gas detector Turbine Compartment ventilation duct 0 – 20 % LIE	-
0474	45HT-5	1154	Gas detector Turbine Compartment ventilation duct 0 – 20 % LIE	-
0474	45HT-6	1154	Gas detector Turbine Compartment ventilation duct 0 – 20 % LIE	-
0426	5E-1	1104	Emergency Stop Button accessory compartment	-
0426	5E-2	1104	Emergency Stop Button accessory compartment	-
0424	63FL-2	0926	Liquid fuel pressure upstream of stop valve	DEC opened = 35 +/- 1 psig INC closed = 40 +/- 2 psig
0434	63HF-1	0926	Hyd. filter diff. press. alarm	DEC closed = 40 +/- 15 psig INC opened = 60 +/- 3 psig
0418	63HG-1	0926	Hydraulic Trip Oil Pressure sw gas stop valve	Dec. Open : 1,40 ± 0,07 bars (20 ± 1 psig) (For Information Inc. Close : 1,65 ± 0,14 bars (24 ± 2 psig))
0418	63HG-2	0926	Hydraulic Trip Oil Pressure sw gas stop valve	Dec. Open : 1,40 ± 0,07 bars (20 ± 1 psig) (For Information Inc. Close : 1,65 ± 0,14 bars (24 ± 2 psig))
0418	63HG-3	0926	Hydraulic Trip Oil Pressure sw gas stop valve	Dec. Open : 1,40 ± 0,07 bars (20 ± 1 psig) (For Information Inc. Close : 1,65 ± 0,14 bars (24 ± 2 psig))
0418	63HL-1	0926	Hydraulic Trip Oil Pressure - Liquid Fuel System	Dec. Open : 1,40 ± 0,07 bars (20 ± 1 psig) (For Information Inc. Close : 1,65 ± 0,14 bars (24 ± 2 psig))
0418	63HL-2	0926	Hydraulic Trip Oil Pressure - Liquid Fuel System	Dec. Open : 1,40 ± 0,07 bars (20 ± 1 psig) (For Information Inc. Close : 1,65 ± 0,14 bars (24 ± 2 psig))
0418	63HL-3	0926	Hydraulic Trip Oil Pressure - Liquid Fuel System	Dec. Open : 1,40 ± 0,07 bars (20 ± 1 psig) (For Information Inc. Close : 1,65 ± 0,14 bars (24 ± 2 psig))
0434	63HQ-1	0926	Low hydraulic supply press. aux hyd. pump start	INC closed = 1450 +/- 45 psig DEC opened = 1350 +/- 25 psig
0424	63LF-3	0992	Fuel filter differential pressure alarm	INC opened = 15 +/- 1 psid
0477	63PG-1	0918	Gas fuel sys. purge pressure switch	DEC opened = 40 +/- 2 psig INC closed = 45 +/- 2 psig
0477	63PL-21	0918T	Purge air pressure	INC closed = 101 +/- 4 psig DEC opened = 81 +/- 4 psig
0416	63QA-2	0926	Low lube oil pressure auxiliary pump start	INC closed = 45 +/- 2 psig DEC opened = 40,6 +/- 1 psig
0416	63QQ-1	0926	Main lube oil filter differential press. alarm	DEC closed = 12,7 +/- 3 psig INC opened = 15 +/- 1 psig
0416	63QQ-8	0916	Torque adjuster filter differential pressure	INC opened = 21,75 psig
0416	63QT-2A	ALT/ GEN.	Low lube oil pressure generator side	INC closed = 9 +/- 0,5 psig DEC opened = 8 +/- 0,3 psig

GENERAL ELECTRIC COMPANY		SIZE	CAGE CODE	DWG NO	
 GE Energy Products - Europe		A		379A9706	
DRAWN M. JEZEQUEL				SECTION 01E	
			SCALE		SHEET 14



SIZE A	DWG NO 379A9706	SH 15	REV D

Item PID	Devices	Item TG	Designation	Settings
0416	63QV-1	A 098	Oil mist eliminator differential pressure	NO Inc. Close : $4 \pm 0,1$ InH2O (For Information Dec. Open : $2,73 \pm 0,1$ InH2O)
0417	63TK-1	A 053	Turb. Shell and exhaust frame blower discharge pressure switch	Closed : above 15 +/- 3 inch H2O
0417	63TK-2	A 053	Turb. Shell and exhaust frame blower discharge pressure switch	Closed : above 15 +/- 3 inch H2O
0436	63VL	En d.	Gaz valve compt. pressure switch	
0424	65FP	0533	Liquid fuel pump (by pass valve) servo valve	-
0422	65GC	0541	Gas control valve servo valve	-
0416	71QH-1	1038	High lube oil level alarm	See lube oil schematic : item 416
0416	71QL-1	1038	Low lube oil level alarm	See lube oil schematic : item 416
0424	77FD-1	0992	Flow divider magnetic pickup	Gap : 0,015 +/- 0,002 in
0424	77FD-2	0992	Flow divider magnetic pickup	Gap : 0,015 +/- 0,002 in
0424	77FD-3	0992	Flow divider magnetic pickup	Gap : 0,015 +/- 0,002 in
0415	77HT-1	0546	High pressure set magnetic pickup location: n° 1 bearing	Gap : 0,05 +/- 0,005 in
0415	77HT-2	0546	High pressure set magnetic pickup location: n° 1 bearing	Gap : 0,05 +/- 0,005 in
0415	77HT-3	0546	High pressure set magnetic pickup location: n° 1 bearing	Gap : 0,05 +/- 0,005 in
0415	77NH-1	0546	High pressure set magnetic pickup location: n° 1 bearing	Gap : 0,05 +/- 0,005 in
0415	77NH-2	0546	High pressure set magnetic pickup location: n° 1 bearing	Gap : 0,05 +/- 0,005 in
0415	77NH-3	0546	High pressure set magnetic pickup location: n° 1 bearing	Gap : 0,05 +/- 0,005 in
0462	77WN-1T3	A 035	Water injection common circuit flow pick-up	-
0425	88AB-1	1047	Atomizing air booster motor Characteristics : 15 kW 2925 rpm 400 V 50 Hz 3 PH	-
0436	88BT-1	En d.	Cooling air fan motor - Acoustic enclosure Characteristics : 15 kW 1460 rpm 400 V 50 Hz 3 PH	-
0436	88BT-2	En d.	Cooling air fan motor - Acoustic enclosure Characteristics : 15 kW 1460 rpm 400 V 50 Hz 3 PH	-
0421	88CR-1	0603	Electrical Cranking Motor Characteristics : 1000 kW 2973 rpm 6 kV 50 Hz 3 PH	-
0424	88FM	0613	Flow divider starting motor Characteristics : 0,37 kW 1400 rpm 6,6 kV 50 Hz 3 PH	-
0436	88HA	En d.	Air fan of 23HA-1 Characteristics : 400 V 50 Hz 3 PH	-
0434	88HQ-1	0628	(auxiliary) hydraulic supply pump motor Characteristics : 15 kW 1455 rpm 400 V 50 Hz 3 PH	-
0436	88HT	En d.	Air fan of 23HT Characteristics : 400 V 50 Hz 3 PH	-
0416	88QA-1	1006	Auxiliary lube oil pump motor Characteristics : 90 kW 2960 rpm 400 V 50 Hz 3 PH	-
0416	88QE-1	1007	Emergency lube oil pump motor Characteristics : 7,5 kW 1750 rpm 125 V - DC	-
0416	88QV-1	A 098	Lube Oil Mist Eliminator Motor Characteristics : 7,5 kW 3000 rpm 400 V 50 Hz 3 PH	-
0421	88TG-1	0538	Tuning Gear Electrical Motor Characteristics : 30 kW 733 rpm 400 V 50 Hz 3 PH	-
0417	88TK-1	1233	Turbine Exhaust Frame Cooling Fan Vent Motor Characteristics : 45 kW 2900 rpm 400 V 50 Hz 3 PH	-
0417	88TK-2	1233	Turbine Exhaust Frame Cooling Fan Vent Motor Characteristics : 45 kW 2900 rpm 400 V 50 Hz 3 PH	-
0421	88TM-1	0605	Torque adjuster drive motor Characteristics : 1,5 kW 3000 rpm 400 V 50 Hz 3 PH	-
0436	88VG-1	En d.	Cooling air fan motor Load compartment. Characteristics : 7,5 kW 1450 rpm 400 V 50 Hz 3 PH	-
0436	88VG-2	En d.	Cooling air fan motor Load compartment. Characteristics : 7,5 kW 1450 rpm 400 V 50 Hz 3 PH	-
0436	88VL-1	En d.	Cooling air fan motor - Gas compt. Characteristics : 3 kW - rpm 400 V 50 Hz 3 PH	-
0436	88VL-2	En d.	Cooling air fan motor - Gas compt. Characteristics : 3 kW - rpm 400 V 50 Hz 3 PH	-
0462	88WN-1	A 035	Water injection syst. Pump motor Characteristics : 75 kW 3000 tr/min 400 V 50 Hz 3 PH	-
0422	90SR-1	0541	Speed ratio/stop valve servo valve	-
0469	90TV-1	0540	Inlet Guide Vane Servovalve	-
0462	90WN-1	A 035	Servovalve for VC5-1 control valve	-

GENERAL ELECTRIC COMPANY		SIZE A	CAGE CODE	DWG NO 379A9706
 GE Energy Products - Europe				
DRAWN	M. JEZEQUEL			SECTION 01E
		SCALE		SHEET 15



SIZE A	DWG NO 379A9706	SH 16	REV D

Item PID	Devices	Item TG	Designation	Settings
0415	95SP-13	1214	Spark plug-combustion chamber n°13	-
0415	95SP-14	1214	Spark plug-combustion chamber n°14	-
0415	95TR-13	1213	Ignition transformer for 95SP-13	-
0415	95TR-14	1213	Ignition transformer for 95SP-14	-
0425	96AD-1	0926	Atomizing air compressor differential pressure transmitter	4 mA for 0 bar 20 mA for 6 bar
0492	96AP-1A	0559	Atmospheric Pressure transmitter	4 mA +/- 0,02 mA for 0,745 bar (22 in of Hg) 20 mA +/- 0,10 mA for 1,250 bar (37 in of Hg)
0492	96AP-1B	0559	Atmospheric Pressure transmitter	4 mA +/- 0,02 mA for 0,745 bar (22 in of Hg) 20 mA +/- 0,10 mA for 1,250 bar (37 in of Hg)
0492	96AP-1C	0559	Atmospheric Pressure transmitter	4 mA +/- 0,02 mA for 0,745 bar (22 in of Hg) 20 mA +/- 0,10 mA for 1,250 bar (37 in of Hg)
0492	96BD-1	0559	Pressure transmitter	4 mA +/- 0,02 mA for 0,000 bar 20 mA +/- 0,10 mA for 0,345 bar (138,5 in of H2O)
0417	96CD-1A	0557	Compressor Discharge Pressure Transmitter	4 ± 0,5 mA for 0 bar 20 ± 0,5 mA for 20 bar
0417	96CD-1B	0557	Compressor Discharge Pressure Transmitter	4 ± 0,5 mA for 0 bar 20 ± 0,5 mA for 20 bar
0417	96CD-1C	0557	Compressor Discharge Pressure Transmitter	4 ± 0,5 mA for 0 bar 20 ± 0,5 mA for 20 bar
0492	96CS-1	0559	Air inlet / Atmospheric pressure differential pressure transmitter	4 mA +/- 0,02 mA for 0,0000 bar 20 mA +/- 0,10 mA for 0,0274 bar (11 in of H2O)
0422	96FG-2A	0557	Fuel Gas inter-valve Pressure Transmitter	0 - 5 ± 0,05 V 0 - 34,5 bars (0 - 500 psid)
0422	96FG-2B	0557	Fuel Gas inter-valve Pressure Transmitter	0 - 5 ± 0,05 V 0 - 34,5 bars (0 - 500 psid)
0422	96FG-2C	0557	Fuel Gas inter-valve Pressure Transmitter	0 - 5 ± 0,05 V 0 - 34,5 bars (0 - 500 psid)
0422	96FG-3	0557	Exhaust Pressure Transmitter	4 - 20 mA 0 - 35 bars (0 - 510 psid)
0422	96FM-1	0639	Mass flow transmitter	
0422	96GC-1,2	0509	Gas control valve LVDT	
0416	96QA-2	0926	Lube oil pressure transmitter VPR2 outlet	4 ± 0,5 mA for 0 bar 20 ± 0,5 mA for 7 bar
0416	96QT-2A	ALT/ GEN.	Low lube oil pressure transmitter generator side	4 ± 0,5 mA for 0 bar 20 ± 0,5 mA for 5 bar
0422	96SR-1,2	0507	Fuel Gas Control (VSR-1) LVDT	Full closed position : 0.7 VAC +/- 0.1 VRMS Full open position : 3.5 VAC +/- 0.1 VRMS
0421	96TM-1	0605	Torque Converter IGV Position Transmitter	N/A
0469	96TV-1	0548	Inlet Guide Vane LVDT	See Instruction IGV Linkage and LVDT Adjust Instruction in Actuator Arrangement IGV (MLI 0548).
0469	96TV-2	0548	Inlet Guide Vane Actuator LVDT (Linear variable displacement transmitter)	See Instruction IGV Linkage and LVDT Adjust Instruction in Actuator Arrangement IGV (MLI 0548).
0462	96WN-1	A035	Water injection skid inlet absolute pressure transmitter	
0462	96WN-3	A035	Water injection pump outlet relative pressure transmitter	
0462	96WN-4	A035	Water injection filters differential pressure transmitter	
0425	AAT-1A	0637	Atomizing air cooler discharge temp. thermocouple K type	
0425	AAT-2A	0637	Atomizing air cooler discharge temp. thermocouple K type	
0434	AH1-1	0502	Control oil hydraulic accumulator	
0434	AH1-2	0502	Control oil hydraulic accumulator	
0436	AT-IC-1	0637	Load compartment temperature resistance thermometer detector	
0436	AT-TC-1	0637	Turbine compartment resistance thermometer detector	
0462	AW-1	A035	Water injection common circuit accumulator-hale	
0425	CA1	0607	Main atomizing air compressor centrifugal	
0425	CA2	1047	Atomizing air booster	
0415	CT-DA-1	0637	Compressor temperature discharge annulus	
0415	CT-DA-2	0637	Compressor temperature discharge annulus	
0415	CT-IF-1	0637	Compressor temperature inlet flange	
0415	CT-IF-2	0637	Compressor temperature inlet flange	
0477	FA3-1	0918T	Liquid fuel nozzle purge filter	
0425	FA4-1	0983	Atomizing air control filter	
0477	FA6-1	1015	Gas fuel system purge filter (atomizing air)	
0462	FA90-1	A035	Stainer on control air supply circuit	

GENERAL ELECTRIC COMPANY		SIZE A	CAGE CODE	DWG NO 379A9706
 GE Energy Products - Europe				
DRAWN	M. JEZEQUEL			SECTION 01E
		SCALE		SHEET 16



SIZE A	DWG NO 379A9706	SH 17	REV D

Item PID	Devices	Item TG	Designation	Settings
0424	FD1-1	0613	Flow divider	
0424	FF2-1	1014	HP fuel filter	
0434	FH2-1	0908	Hydraulic supply filter	
0434	FH2-2	0908	Hydraulic supply filter	
0424	FH3-1	0992	Hydraulic supply filter-liquid fuel servo	
0469	FH6-1	0548	IGV controller assembly hydraulic oil supply filter	
0422	FH7-1	0911	Servo hydraulic supply filter of Gas fuel control & stop valve	
0462	FM1-1	A035	Water injection common flow meter	
0422	FT-MG-1/R	0639	Resistive temperature device connected to 96FM-1	
0462	FW1 -1	A035	Water injection system low pressure stainer	
0462	FW2 -1	A035	Water injection system high pressure stainer	
0462	FW3 -1	A035	High pressure strainer downstream flowmeter water injection	
0469	HM3-1	0548	Actuator assembly, Inlet Guide Vane System	
0425	HX1-1	1003	Atomizing air cooler	
0416	LT-B1D-1 A,1B	0637	Lube oil temperature return bearing 1	
0416	LT-B2D-1 A,1B	0637	Lube oil temperature return bearing 2	
0416	LT-B3D-1 A,1B	0637	Lube oil temperature return bearing 3	
0416	LT-BT1D-1 A,1B	0637	Lube oil temperature thrust bearing 1	
0416	LT-G1 D	ALT/ GEN.	Lube temperature bearing 4 thermocouple K type	
0416	LT-G2 D	ALT/ GEN.	Lube temperature bearing 5 thermocouple K type	
0416	LT-OT-1A	0938	Lube oil tank temperature low resistance thermometer detector	
0416	LT-OT-2A	0938	Lube oil tank temperature normal resistance thermometer detector	
0416	LT-TH-1A,1B	0637	Lube oil temperature turbine header. thermocouple K type	
0416	LT-TH-2A,2B	0637	Lube oil temperature turbine header thermocouple K type	
0416	LT-TH-3A,3B	0637	Lube oil temperature turbine header thermocouple K type	
0422	MG1	0512	Gas fuel nozzle	
0422	MG2-1	0639	Gas fuel metering tube-orifice	-
0424	PF1	0611	Main fuel Pump	-
0434	PH1	0627	Main hydraulic supply pump	-
0434	PH2	0627	Auxiliary hydraulic supply pump	-
0426	SLI-1	1104	Light warning accessory compartment	
0426	SLI-1A	En d.	Fire alarm: flashing light unit	
0426	SLI-1B	En d.	Fire alarm: flashing light unit	
0426	SLI-1C	En d.	Fire alarm: horn and flashing light unit load	
0426	SLI-2	1104	Light warning accessory compartment	
0426	SLI-2C	En d.	Fire alarm: horn and flashing light unit load	
0426	SLI-3C	En d.	Fire alarm: horn and flashing light unit load	
0415	TT-1B-1	0637	Turbine temperature -inner barrel- 3 thermocouple K type	-
0415	TT-WS1A0-1	0637	Turbine temperature -wheel space 1 st stage aft -(outer)	-
0415	TT-WS1A0-2	0637	Turbine temperature -wheel space 1 st stage aft -(outer)	-
0415	TT-WS1FI-1	0637	Turbine temperature -wheel space 1 st stage fwd -(inner)	-
0415	TT-WS1FI-2	0637	Turbine temperature -wheel space 1 st stage fwd -(inner)	-
0415	TT-WS2A0-1	0637	Turbine temperature - wheel space 2nd stage aft -(outer)	-
0415	TT-WS2A0-2	0637	Turbine temperature - wheel space 2nd stage aft -(outer)	-
0415	TT-WS2F0-1	0637	Turbine temperature - wheel space 2nd stage fwd -(outer)	-
0415	TT-WS2F0-2	0637	Turbine temperature - wheel space 2nd stage fwd -(outer)	-
0415	TT-WS3A0-1	0637	Turbine temperature - wheel space 3rd stage aft -(outer)	-
0415	TT-WS3A0-2	0637	Turbine temperature - wheel space 3rd stage aft -(outer)	-
0415	TT-WS3F0-1	0637	Turbine temperature - wheel space 3rd stage fwd -(outer)	-
0415	TT-WS3F0-2	0637	Turbine temperature - wheel space 3rd stage fwd -(outer)	-
0415	TT-XD-1	0623	Turbine exhaust temperature thermocouple k type	-
0415	TT-XD-10	0623	Turbine exhaust temperature thermocouple k type	-
0415	TT-XD-11	0623	Turbine exhaust temperature thermocouple k type	-
0415	TT-XD-12	0623	Turbine exhaust temperature thermocouple k type	-
0415	TT-XD-13	0623	Turbine exhaust temperature thermocouple k type	-
0415	TT-XD-14	0623	Turbine exhaust temperature thermocouple k type	-
0415	TT-XD-15	0623	Turbine exhaust temperature thermocouple k type	-
0415	TT-XD-16	0623	Turbine exhaust temperature thermocouple k type	-
0415	TT-XD-17	0623	Turbine exhaust temperature thermocouple k type	-
0415	TT-XD-18	0623	Turbine exhaust temperature thermocouple k type	-

GENERAL ELECTRIC COMPANY		SIZE A	CAGE CODE	DWG NO 379A9706
 GE Energy Products - Europe				
DRAWN M. JEZEQUEL				SECTION 01E
		SCALE		SHEET 17



SIZE A	DWG NO 379A9706	SH 18	REV D

Item PID	Devices	Item TG	Designation	Settings
0415	TT-XD-19	0623	Turbine exhaust temperature thermocouple k type	-
0415	TT-XD-2	0623	Turbine exhaust temperature thermocouple k type	-
0415	TT-XD-20	0623	Turbine exhaust temperature thermocouple k type	-
0415	TT-XD-21	0623	Turbine exhaust temperature thermocouple k type	-
0415	TT-XD-22	0623	Turbine exhaust temperature thermocouple k type	-
0415	TT-XD-23	0623	Turbine exhaust temperature thermocouple k type	-
0415	TT-XD-24	0623	Turbine exhaust temperature thermocouple k type	-
0415	TT-XD-3	0623	Turbine exhaust temperature thermocouple k type	-
0415	TT-XD-4	0623	Turbine exhaust temperature thermocouple k type	-
0415	TT-XD-5	0623	Turbine exhaust temperature thermocouple k type	-
0415	TT-XD-6	0623	Turbine exhaust temperature thermocouple k type	-
0415	TT-XD-7	0623	Turbine exhaust temperature thermocouple k type	-
0415	TT-XD-8	0623	Turbine exhaust temperature thermocouple k type	-
0415	TT-XD-9	0623	Turbine exhaust temperature thermocouple k type	-
0477	VA13-1	0918	Gas fuel system purge valve air	-
0477	VA13-2	0918	Gas fuel system purge valve air	-
0424	VA17-1	1026	False start drain valve-combustion wrapper Normal = open	
0424	VA17-2	1026	False start drain valve-exhaust frame open = normal Normal = open	
0424	VA17-5	1026	False start drain valve-exhaust plenum Normal = open	
0425	VA18-1	1070	Atomizing air compressor by pass Normal = closed	
0477	VA19-1	0918T	Liquid fuel nozzle purge valve Normal : C to L opened ; U closed	
0417	VA2-1	1022	Compressor Bleed valve 11th stage Normal = open	
0417	VA2-2	1022	Compressor Bleed valve 11th stage Normal = open	
0417	VA2-3	1022	Compressor Bleed valve 11th stage	
0417	VA2-4	1022	Compressor Bleed valve 11th stage	
0425	VA22-1	0922	Atomizing air booster isolation valve Normal = open	
0434	VAB1	0947	Hydraulic system air bleed valve (main)	-
0434	VAB2	0947	Hydraulic system air bleed valve (aux.)	-
0424	VC3-1	0516	By pass control valve	-
0462	VC4-1	A035	Water injection flow control valve common circuit	-
0462	VC5-1	A035	Big flow manifold water injection transfer valve	-
0424	VCK1-1T14	0961	Liquid fuel nozzle check valve	Cracking press : 8,27 +/- 0,34 bars (120 +/- 5 psig)
0477	VCK2-1T14	0918T	Liquid fuel nozzle purge check valve	Cracking press : 4,93 +/- 1 psig
0434	VCK3-1	0947	Hydraulic pump check valve for main pump	-
0434	VCK3-2	0947	Hydraulic pump check valve for auxiliary pump	-
0417	VCK7-1	A053	Turbine Shell and Exhaust Frame Blower Check Valve	-
0417	VCK7-2	A053	Turbine Shell and Exhaust Frame Blower Check Valve	-
0422	VGC	0509	Gas control valve	
0422	VH12	0509	Vgc trip valve	-
0469	VH3-1	0540	Trip relay, hydraulic, IGV	
0422	VH5	0507	VSR security discharge valve	-
0416	VPR2-1	1023	Bearing header pressure regulator valve	25 +/- 0 psig
0434	VPR3-1	1005	Hydraulic supply pump (PH1) compensator	1500 +/- 20 psig
0477	VPR44-1	0918	Air pressure regulator-gas fuel purge valve	33,35 +/- 0/-2,9 psig
0477	VPR44-2	0918	Air pressure regulator-gas fuel purge valve	33,35 +/- 0/-2,9 psig
0477	VPR54-1	918T	Pressure regulator - purge control valve liquid manifold	47,5 +/- 2,5/0 psig
0425	VPR68-1	0922	Pressure reg. valve booster aa isolation valve	55 +/- 2 psig
0462	VPR90-1	A035	Water injection VC4-1 transfer valve air pressure regulation	-
0462	VPR90-2	A035	Water injection VC5-1 transfer valve air pressure regulation	-
0416	VR1	1016	Main lube oil pump pressure relief valve	100 +/- 0 psig
0434	VR21	0947	Main hydraulic supply pump pressure relief valve	1650 +/- 20 psig
0434	VR22	0947	uxiliary hydraulic supply pump pressure relief valve	1650 +/- 20 psig
0424	VR27	0992	Pressure relief valve on liq. fuel piping	87 +/- 2,9 psig
0424	VR4	0992	Main fuel pump pressure relief valve	1200 +/- 25 psig
0424	VS1	0511	Fuel oil stop valve	-
0422	VSR	0507	Fuel gas stop/speed ratio valve	

GENERAL ELECTRIC COMPANY		SIZE A	CAGE CODE	DWG NO 379A9706	
g GE Energy Products - Europe				SECTION 01E	
DRAWN M. JEZEQUEL			SCALE		SHEET 18

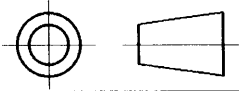


SIZE A	DWG NO 379A9706	SH 19	REV D

Item PID	Devices	Item TG	Designation	Settings
0420	VTR1	1035	Brg header temperature regu- valve Normal = B to E opened, C closed	Start to close B to E at 129,2 ± 2,88 °F
0420	VTR2-1	1027	Atmg air precooler air discharge temp rgltr valve turbine Normal = B to E opened, C closed	setting at 215 ± 9 °F
0420	WT-TL-1	0637	Resistance themometer detector water system temperature turbine	-
0420	WT-TL-2	0637	Water temperature for cooling turbine support	-

GENERAL ELECTRIC COMPANY		SIZE A	CAGE CODE	DWG NO 379A9706	
 GE Energy Products - Europe				SECTION 01E	
DRAWN M. JEZEQUEL		SCALE			SHEET 19



SIZE A DWG NO.	INDEX SH. 1 REV. G	THIRD ANGLE PROJECTION				REVISIONS			
						REV	DESCRIPTION	DATE	APPROVED
						G	MP51920 S. A. WOOLLING	99-03-24 SAW	RWH DBH
THIS DRAWING TO BE REVISED ON FORMTEK ONLY									
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PL DECIMALS ± 3 PL DECIMALS ± ANGLES ± FRACTIONS ±		SIGNATURES DRAWN N.D. PEAMYER CHECKED N.D. PEAMYER ENGRG K.D.C. ISSUED		DATE 76-11-10 76-11-10 76-11-10 76-11-11		 GE Power Generation GENERAL ELECTRIC COMPANY GAS TURBINE Greenville, SC			
APPLIED PRACTICES		FIRST MADE FOR GAS TURBINE		SYMBOLS, PIPING					
SIMILAR TO: NONE		SIZE A		CAGE CODE		DWG. NO. 277A2415			
SCALE -		WEIGHT -		SHEET 1					

DT-1N

1. NOTES FOR PIPING SYMBOLS

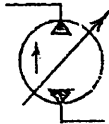
1.1 LINE WIDTH OR SYMBOL SIZE DOES NOT ALTER THE MEANING OF THE SYMBOL.

1.2 LETTER SYMBOLS FOR PIPING ARE NOT NECESSARILY ABBREVIATIONS.

1.3 SYMBOLS MAY BE ROTATED OR REVERSED WITHOUT ALTERING THEIR MEANING EXCEPT IN THE CASES OF LINES TO RESERVOIR, & ACCUMULATOR.

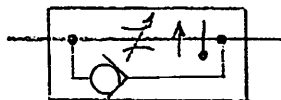
1.4 GRAPHIC SYMBOLS ARE ILLUSTRATED WITHOUT ACTUATORS OR CONTROLS. SELECTION OF ACTUATORS AND CONTROLS SHALL BE MADE FROM THE GRAPHICS IN PARAGRAPH 4 OF THIS DRAWING.

ie:



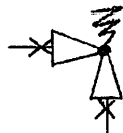
HYDRAULIC PUMP, BIDIRECTIONAL-VARIABLE DISPLACEMENT, PRESSURE COMPENSATED.

ie:



FLOW CONTROL VALVE, ADJUSTABLE, TEMPERATURE AND PRESSURE COMPENSATED.

ie:

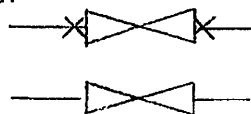


RIGHT ANGLE GLOBE VALVE, WELDED FLANGE SPRING OPERATED.

1.5 MANY OF THE GRAPHIC & LETTER SYMBOLS SHOWN HAVE BEEN EXTRACTED FROM AMERICAN NATIONAL STANDARDS INSTITUTE GRAPHICS SYMBOLS PUBLICATIONS. FLUID POWER SYMBOLS FROM ANSI Y32.10, PROCESS FLOW SYMBOLS FROM ANSI Y32.11 AND FABRICATION SYMBOLS FROM Z32.2.3. FOR ADDITIONAL SYMBOL OR COMBINATION REQUIREMENTS SEE THESE PUBLICATIONS BEFORE DEVISING A NEW SYMBOL.
EACH SYMBOL IS DRAWN TO SHOW NORMAL, AT REST OR NEUTRAL CONDITION OF COMPONENT UNLESS MULTIPLE DIAGRAMS ARE FURNISHED SHOWING VARIOUS PHASES OF CIRCUIT OPERATION.

1.6 SHOW A NOTCH FOR EACH DETENT IN THE ACTUAL COMPONENT BEING SYMBOLIZED. A SHORT LINE INDICATES WHICH DETENT IS IN USE.

1.7 FLANGED JOINTS HAVE BEEN ILLUSTRATED ON FABRICATION SYMBOLS. WHEN WELDED, OR SCREWED FLANGES ARE REQUIRED ILLUSTRATE WITH THE PROPER SYMBOL, ie:



1.8 AN ARROW PARALLEL TO THE SHORT SIDE OF A SYMBOL, WITHIN THE SYMBOL, INDICATES THE COMPONENT IS PRESSURE COMPENSATED.

GE Power Generation	GENERAL ELECTRIC COMPANY GAS TURBINE Greenville, SC		SIZE A	CAGE CODE	DWG. NO. 277A2415
	DRAWN		DISTR TO		
ISSUED		76-11-11		SCALE NONE	SHEET 2

1.9 DEFINITIONS: FLUID POWER - FLUID POWER ARE THOSE SYSTEMS THAT TRANSMIT AND CONTROL POWER THROUGH USE OF A PRESSURIZED FLUID (LIQUID OR GAS) WITHIN AN ENCLOSED CIRCUIT.

PROCESS FLOW - PROCESS FLOW ARE THOSE SYSTEMS THAT TRANSMIT FLUID (LIQUID OR GAS) TO THE ATMOSPHERE.

1.10 SYSTEM DEFINITION:

0416	DIAGRAM, SCHEM PP-LUBE OIL	PROCESS FLOW
0417	CLG & SLG AIR	FLUID POWER
0418	CONTROL OIL	FLUID POWER
0419	CONTROL AIR	FLUID POWER
0420	COOLING WATER	PROCESS FLOW
0421	STARTING MEANS	FLUID POWER
0422	FUEL GAS	FLUID POWER
0423	DISTILLATE FO	FLUID POWER
0424	LIQ FUEL	FLUID POWER
0425	ATOMIZING AIR	FLUID POWER
0426	FIRE PROTECT	PROCESS FLOW
0427	LIQ FUEL FWD	PROCESS FLOW
0428	STATION AIR	FLUID POWER
0430	ST TURB ST SYS	FLUID POWER
0431	ST INJECTION	FLUID POWER
0432	INLET AIR HTG	FLUID POWER
0434	HYDR SUPPLY	FLUID POWER
0439	HYDR FAN DR	FLUID POWER
0440	LOAD COMPRESSOR	PROCESS FLOW
0441	TURB & CPRSR CLN	PROCESS FLOW
0442	TURB & CPRSR CLN	PROCESS FLOW
0443	CPRSR CLN	PROCESS FLOW
0460	HYDR BRAKE SYS	FLUID POWER
0461	WATER FWD UNIT	PROCESS FLOW
0462	WATER INJ SYS	PROCESS FLOW
0464	HYDROGEN SERVICE	PROCESS FLOW
C027	FW & CONDENSER	PROCESS FLOW
C049	PLANT ST SYS	PROCESS FLOW
C059	STEAM & WATER	PROCESS FLOW
C060	CONT AIR	FLUID POWER
C068	COMB AIR	PROCESS FLOW



GE Power Generation

GENERAL ELECTRIC COMPANY
GAS TURBINE
Greenville, SC

SIZE

A

CAGE CODE

DWG. NO.

277A2415

DRAWN

ISSUED

SCALE NONE

SHEET

3

DISTR TO

2. LETTER SYMBOLS

AA -	ATOMIZING AIR	S -	FLOW SIGHT
AB -	AIR BLEED	SA -	AIR SIGNAL, TURBINE START
ABD -	AIR BOX DRAIN	SE -	STEAM EXHAUST
AC -	CONTROL AIR	SR -	SOLONOID HEAD RELEASE
AD -	COMPRESSOR DISCHARGE AIR	SS -	STEAM SUPPLY
AE -	EXTRACTION AIR	SF -	SEAL FLUID
AI -	COMPRESOR INLET AIR	T -	THERMOMETER
AMB -	AMBIENT PRESSURE	TC -	TRIP COIL
AP -	PURGE AIR	TOL -	TORQUE CONVERTOR OIL
APL -	PACKING LEAK OFF AIR	VA -	AIR BLEED VALVE
AR -	REGULATED AIR (AFTR PRESSURE REDUCING VALVE)	VB -	RELIEF VALVE
AS -	AIR SUPPLY	VL -	VALVE STEM LEAKOFF
AT -	ATMOSPHERE AIR	VPR -	PRESS. REDUCING VALVE
AV -	AIR VENT	WD -	WATER DRAIN
AVC -	VARIABLE CONTROL AIR	WF -	FRESH WATER FEED
DOF -	DIESEL FUEL OIL	WR -	RETURN WATER
DOL -	DIESEL LUBE OIL	WS -	SALT WATER FEED
DPG -	DEFERENTIAL PRES. GAUGE	WT -	WATER VENT
EE -	ENGINE EXHAUST	WWL -	WARM WATER LOOP
ES -	ELECTRICAL SIGNAL	W -	WATER
FB -	FILTER BYPASS		
FD -	FIRE DETECTOR		
FI -	FILTER ISOLATION		
GF -	GAS FUEL		
GPL -	GAS VALVE STEM PACKING LEAK OFF		
GFV -	GAS FUEL VENT		
HP -	HIGH PRESSURE		
L -	LATCH CO2 OPERATED		
LP -	LOW PRESSURE		
M -	MOTOR		
NO -	NORMALLY OPEN		
NC -	NORMALLY CLOSED		
OA -	AIR SIGNAL, OIL FUEL OPERATION		
OBD -	OVERBOARD DRAIN		
OD -	OIL DRAIN		
OF -	FUEL OIL		
OFD -	OIL FUEL DRAIN		
OFV -	OIL FUEL VENT		
OH -	HYDRAULIC SYSTEM OIL		
OHT -	HYDRAULIC TRIP OIL		
OL -	LUBE OIL		
OLB -	BRG. LIFT OIL		
OLT -	TRIP OIL		
OLV -	LUBE OIL VENT		
ON -	CONTROL OIL HIGH PRES.		
OR -	REGULATED OIL		
OS -	SEAL OIL		
OT -	TRIP CIRCUIT OIL		
OV -	VARIABLE CONTROL OIL		
P -	PNEUMATIC HEAD RELEASE		
PC -	G. T. PACKAGE CONNECTION		
PD -	PULSATION DAMPER		
PS -	PILOT SUPPLY PRESSURE		
RC -	RUN COIL		



GE Power Generation

GENERAL ELECTRIC COMPANY
GAS TURBINE
Greenville, SC

SIZE

A

CAGE CODE

DWG. NO.

277A2415

DRAWN

ISSUED

76-11-11

SCALE NONE

SHEET

4

DISTR TO

SIZE DWG NO. REV
A 277A2415 5 G

SUBJECT		FLUID POWER	PROCESS FLOW	FABRICATION
3.	LINE CONVENTIONS			
3.1	MAIN CONDUCTOR (PIPE/TUBE)	_____	_____	_____
3.2	PILOT LINE (CONTROL)	_____	_____	_____
3.3	DRAIN LINE	_____	_____	_____
3.4	OUTLINE	_____	_____	_____
3.5	PURCHASER FURNISHED	_____	_____	_____
3.6	HEAT TRACED		=====	
3.7	AIR LINE		# # #	
3.8	CROSSING	+	+	
3.9	CONNECTING	+	+	
3.9.1	FLEXIBLE CONNECTION		+	
3.10	G.T. PACKAGE CONNECTION	— (PC)	— (PC)	
3.11	WELDED JOINT			×
3.12	SCREWED JOINT			+
3.13	FLANGED JOINT			#
3.14	OUTLET-FAR SIDE			○
3.15	OUTLET-NEAR SIDE			●
3.16	DIRECTION		→	→
3.17	PNEUMATIC (SOURCE)	→		
3.18	HYDRAULIC (SOURCE)	→		



GE Power Generation

GENERAL ELECTRIC COMPANY
GAS TURBINE
Greenville, SC

SIZE

A

CAGE CODE

DWG. NO.

277A2415

DRAWN

ISSUED

76-11-11

SCALE NONE

SHEET 5

DISTR TO

SUBJECT		FLUID POWER	PROCESS FLOW	FABRICATION
4.	ACTUATORS AND CONTROLS			
4.1	SPRING			
4.2	MANUAL			
4.3	PUSH BUTTON			
4.4	LEVER			
4.5	THERMAL			
4.6	MECHANICAL			
4.7	DETENT (SEE NOTE 1.6)			
4.8	SOLENOID			
4.9	WEIGHTED			
4.10	PRESSURE COMPENSATED (SEE NOTE 1.8)			
4.11	MOTOR OPERATED			
4.12	GAS CHARGED			
4.13	DIAPHRAGM			
4.14	FLOAT OPERATED			
4.15	ADJUSTED OR VARIED			
4.16	ROTATING SHAFT			
4.17	LINKAGE, MECHANICAL			
4.18	GEARED			
 GE Power Generation GENERAL ELECTRIC COMPANY GAS TURBINE Greenville, SC		SIZE A	CAGE CODE	DWG. NO. 277A2415
DRAWN		SCALE NONE		SHEET 6
ISSUED 76-11-11		DISTR TO		

SUBJECT		FLUID POWER	PROCESS FLOW	FABRICATION
4.19	CENTRIFUGAL			
4.20	DISC (RUPTURE)			
4.21	FAN			

GENERAL ELECTRIC COMPANY
GAS TURBINE
Greenville, SC

GE Power Generation

SIZE

A

CAGE CODE

DWG. NO.

277A2415

DRAWN

ISSUED

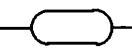
76-11-11

SCALE NONE

SHEET

7

DISTR TO

SUBJECT		FLUID POWER	PROCESS FLOW	FABRICATION
5.	STORAGE			
5.1	RESERVOIR VENTED ABOVE FLUID LEVEL			
5.2	RESERVOIR VENTED BELOW FLUID LEVEL			
5.3	RESERVOIR PRESSURIZED ABOVE FLUID LEVEL			
5.4	RESERVOIR PRESSURIZED BELOW FLUID LEVEL			
5.5	ACCUMULATOR			
5.6	RECEIVER			



GE Power Generation

GENERAL ELECTRIC COMPANY
GAS TURBINE
Greenville, SC

SIZE
A

CAGE CODE

DWG. NO.
277A2415

SCALE **NONE**

SHEET **8**

DRAWN

ISSUED

DISTR TO

SUBJECT		FLUID POWER	PROCESS FLOW	FABRICATION
6	CONDUCTOR			
6 1	DISCONNECT, CONNECTED			
6 2	DISCONNECT, DISCONNECTED			
6.3	DISCONNECT, CONNECTED WITH CHECKS			
6 4	DISCONNECT, DISCONNECTED WITH CHECKS			
6 5	LINE, FLEXIBLE			
6.6	LINE RESTRICTION, FIXED			
6.7	PLUGGED PORT/TAP			
6.7.1	PLUG TAP W/WELL			
6.8	PNEUMATIC OUTLET TO ATMOSPHERE (ORIFICE) UNCONNECTABLE			
6.9	PNEUMATIC OUTLET TO ATMOSPHERE (ORIFICE) CONNECTABLE			
6 10	DIAPHRAGM SEAL			
6.11	FUNNEL, DRAIN			
6 12	HOPPER			
6.13	SIPHON, PIGTAIL			
6.14	TRAP			
6.15	VENT			
6.16	FLOW DIVIDER			



GE Power Generation

GENERAL ELECTRIC COMPANY
GAS TURBINE
Greenville, SC

SIZE

A

CAGE CODE

DWG. NO.

277A2415

DRAWN

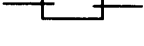
ISSUED

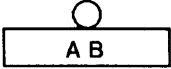
SCALE NONE

SHEET

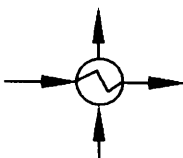
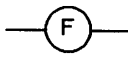
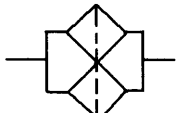
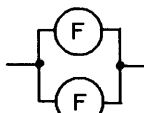
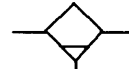
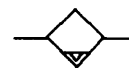
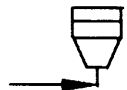
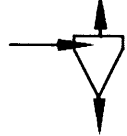
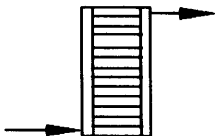
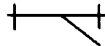
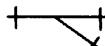
9

DISTR TO

SIZE DWG NO 277A2415 10 REV G		SUBJECT	FLUID POWER	PROCESS FLOW	FABRICATION
		6.17 FLANGE, 150 LB-300 LB			
		6.18 FLANGE, 400 LB AND UP-MALE			
		6.19 FLANGE, 400 LB AND UP-FEMALE			
		6.20 FLANGE, BLIND			
		6.21 ORIFICE FLANGE			
		6.22 BUSHING			
		6.23 CAP			
		6.24 CROSS			
		6.25 ELBOW, 45°			
		6.26 ELBOW, 90°			
		6.27 ELBOW, STREET			
		6.28 JOINT, COUPLING			
		6.29 JOINT, EXPANSION			
		6.30 LATERAL			
		6.31 PLUG, PIPE			
		6.32 REDUCER, CONCENTRIC			
		6.33 REDUCER, ECCENTRIC			
		6.34 SLEEVE			
		6.35 TEE			
		6.36 UNION			
		6.37 CLUTCH			
 GE Power Generation GENERAL ELECTRIC COMPANY GAS TURBINE Greenville, SC SIZE A CAGE CODE DWG. NO. 277A2415					
DRAWN		ISSUED 76-11-11		SCALE NONE	SHEET 10

SIZE A	DWG NO 277A2415	SH 11	REV G	SUBJECT	FLUID POWER	PROCSS FLOW	FABRICATION		
				6.38 LATCH					
				6.39 INITIAL DISCHARGE					
				6.40 EXTENDED DISCHARGE					
				6.41 ALARM BELL					
 GE Power Generation				GENERAL ELECTRIC COMPANY GAS TURBINE Greenville, SC		SIZE A	CAGE CODE	DWG. NO. 277A2415	DISTR TO
DRAWN		SCALE NONE		SHEET 11					
ISSUED									

SIZE DWG NO. REV
A 277A2415 SH. 12 G

SUBJECT	FLUID POWER	PROCESS FLOW
7. CONDITIONER		
7.1 HEAT EXCHANGER		
7.2 COOLER		
7.3 FILTER		
7.4 FILTER, DUPLEX		
7.5 SEPARATOR & MANUAL DRAIN		
7.6 SEPARATOR & AUTOMATIC DRAIN		
7.7 SEPARATOR, CENTRIFUGE		
7.8 SEPARATOR, CYCLONE		
7.9 SEPARATOR, ELECTROSTATIC PRECIPITATOR		
7.10 STRAINER, Y		
7.11 STRAINER/SCREEN		SAME AS 6.30 
7.12 STRAINER, WITCH'S HAT		



GE Power Generation

GENERAL ELECTRIC COMPANY
GAS TURBINE
Greenville, SC

SIZE

A

CAGE CODE

DWG. NO.

277A2415

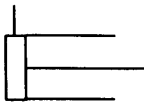
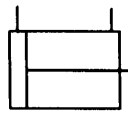
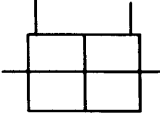
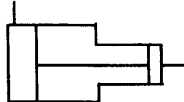
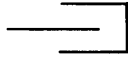
DRAWN

ISSUED

SCALE NONE

SHEET 12

DISTR TO

SIZE		DWG. NO.	REV	SUBJECT		FLUID POWER	PROCESS FLOW
A		277A2415	13	8. LINEAR DEVICE			
				8.1 CYLINDER, SINGLE ACTING			
				8.2 CYLINDER, DOUBLE ACTING SINGLE ENDED			
				8.3 CYLINDER, DOUBLE ACTING DOUBLE ENDED			
				8.4 PRESSURE INTENSIFIER			
				8.5 LINEAR VARIABLE DIFFERENTIAL TRANSFORMER			

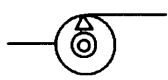
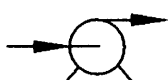
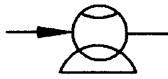
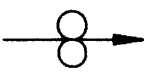
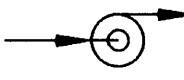
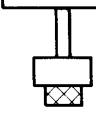
 GE Power Generation	GENERAL ELECTRIC COMPANY GAS TURBINE Greenville, SC		SIZE A	CAGE CODE	DWG. NO. 277A2415
	DRAWN		SCALE NONE		
ISSUED			SHEET 13		

DISTR TO

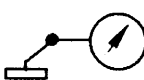
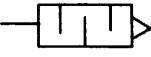
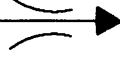
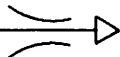
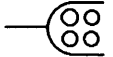
SH. 14 REV. G
SIZE DWG. NO. 277A2415
A

SUBJECT		FLUID POWER	PROCESS FLOW
9	ROTARY DEVICE		
9.1	MOTOR, PNEUMATIC, UNIDIRECTIONAL		
9.2	MOTOR, PNEUMATIC, BI-DIRECTIONAL		
9.3	MOTOR, HYDRAULIC, UNIDIRECTIONAL		
9.4	MOTOR, HYDRAULIC, BIDIRECTIONAL		
9.5	PUMP PNEUMATIC, FIXED DISPLACEMENT, COMPRESSOR		
9.6	PUMP, PNEUMATIC, FIXED DISPLACEMENT, VACUUM		
9.7	PUMP, HYDRAULIC, FIXED DISPLACEMENT UNIDIRECTIONAL		
9.8	PUMP, HYDRAULIC, FIXED DISPLACEMENT BIDIRECTIONAL		
9.9	PUMP-MOTOR, HYDRAULIC, VARIABLE OPERATING IN ONE DIRECTION AS A PUMP OPERATING IN THE OTHER DIRECTION AS A MOTOR.		
9.10	PUMP-MOTOR, HYDRAULIC, VARIABLE OPERATING ONE DIRECTION OF FLOW AS EITHER A PUMP OR AS A MOTOR.		
9.11	MOTOR, ELECTRIC		
9.12	OSCILLATOR, HYDRAULIC		
9.13	OSCILLATOR, PNEUMATIC		
9.14	HEAT ENGINE		

 GE Power Generation GENERAL ELECTRIC COMPANY GAS TURBINE Greenville, SC	SIZE A	CAGE CODE	DWG. NO. 277A2415
	SCALE NONE		
DRAWN	SHEET 14		
ISSUED	DISTR TO		

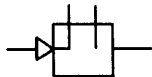
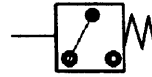
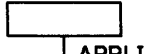
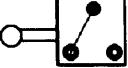
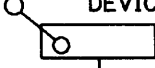
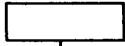
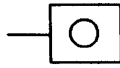
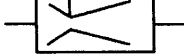
SIZE DWG. NO. REV A 277A2415 15 G		SUBJECT	FLUID POWER	PROCESS FLOW
		9 15 COMPRESSOR		
		9 16 PUMP, CENTRIFUGAL		
		9.17 PUMP, METERING		
		9 18 PUMP, POSITIVE DISPLACEMENT		
		9.19 PUMP, TURBINE		
		9 20 PUMP (WITH SHAFT)		
		9.21 PUMP, VERTICAL		
 GE Power Generation GENERAL ELECTRIC COMPANY GAS TURBINE Greenville, SC		SIZE A	CAGE CODE	DWG. NO. 277A2415
DRAWN		SCALE NONE		SHEET 15

DISTR TO

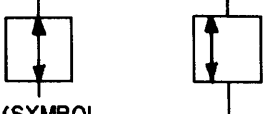
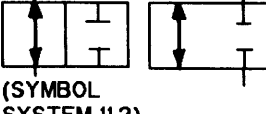
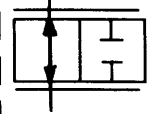
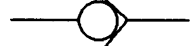
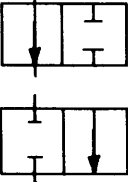
SIZE DWG NO. 277A2415 SH. 16 REV. G		SUBJECT	FLUID POWER	PROCESS FLOW
		10 INSTRUMENTS & ACCESSORIES		
		10 1 BELL, ALARM		
		10.2 GAGE, PRESSURE INDICATING		
		10.3 GAGE, PRESSURE INDICATING PANEL MOUNTED		
		10 4 GAGE, PRESSURE INDICATING WITH SNUBBER		
		10 5 GAGE, TEMPERATURE INDICATING		
		10 6 GAGE, LIQUID LEVEL		
		10.7 GAGE GLASS		
		10 8 METER, FLOW RATE		
		10.9 METER, TOTALIZING		
		10 10 MUFFLER		
		10.11 NOZZLE, HYDRAULIC		
		10 12 NOZZLE, PNEUMATIC		
		10.13 NOZZLE, SPRAY, EXTENDED DISCHARGE		
		10.14 NOZZLE, SPRAY, INITIAL DISCHARGE		
		10 15 NOZZLE, FUEL		
		10 16 ORIFICE PLATE/FLANGE		
 GE Power Generation GENERAL ELECTRIC COMPANY GAS TURBINE Greenville, SC		SIZE A	CAGE CODE	DWG. NO. 277A2415
DRAWN		SCALE NONE	SHEET 16	

DISTR TO

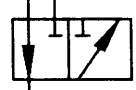
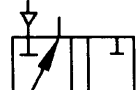
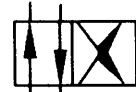
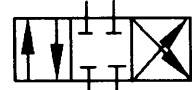
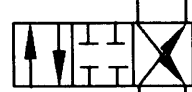
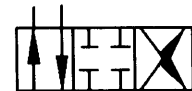
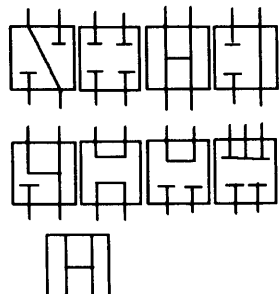
SIZE A DWG NO. 277A2415 SH. REV 17 G

SUBJECT	FLUID POWER	PROCESS FLOW
10.17 PITOT TUBE		
10.18 SIGHT FLOW INDICATOR		
10.19 SWITCH, PRESSURE		
10.20 SWITCH, LIMIT		
10.21 TRANSDUCER		
10.22 THERMOCOUPLE (ENTER APPLICABLE DEVICE CODE IN BOX)		
10.23 THERMOWELL		
10.24 VENTURI		
10.25 NOZZLE, WATER		
10.26 THERMOCOUPLE		
10.27 THERMOMETER		

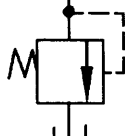
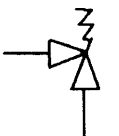
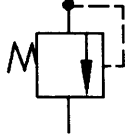
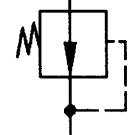
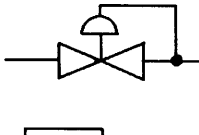
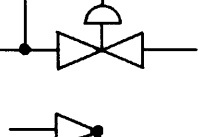
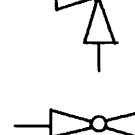
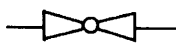
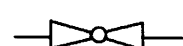
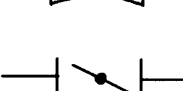
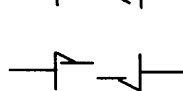
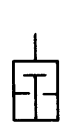
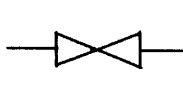
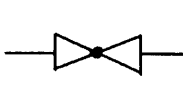
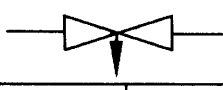
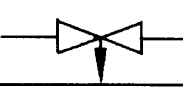
 GE Power Generation	GENERAL ELECTRIC COMPANY GAS TURBINE Greenville, SC		SIZE A	CAGE CODE	DWG. NO. 277A2415
	DRAWN		SCALE NONE		
ISSUED		SHEET 17		DISTR TO	

SUBJECT	FLUID POWER	PROCESS FLOW
11 VALVE		
11.1 A BASIC CONTROL VALVE SYMBOL IS COMPOSED OF ONE OR MORE ENVELOPES WITH LINES INSIDE THE ENVELOPE TO REPRESENT FLOW PATHS AND FLOW CONDITIONS BETWEEN PORTS. THREE SYMBOL SYSTEMS ARE USED TO REPRESENT VALVE TYPES SINGLE ENVELOPE, BOTH FINITE AND INFINITE POSITION, AND MULTIPLE ENVELOPE, INFINITE POSITION.	(FLOW PATHS (PORTS INTERNALLY OPEN) INTERNALLY BLOCKED)  (SYMBOL SYSTEM 11.1)	
11.2 IN INFINITE POSITION SINGLE ENVELOPE VALVES, THE ENVELOPE IS IMAGINED TO MOVE TO ILLUSTRATE HOW PRESSURE OR FLOW CONDITIONS ARE CONTROLLED AS THE VALVE IS ACTUATED.	(FLOW PATHS (PORTS INTERNALLY OPEN) INTERNALLY BLOCKED)  (SYMBOL SYSTEM 11.2)	
11.3 MULTIPLE ENVELOPES SYMBOLIZE VALVES PROVIDING MORE THAN ONE FINITE FLOW PATH OPTION FOR THE LIQUID. THE MULTIPLE ENVELOPE MOVES TO REPRESENT HOW FLOW PATHS CHANGE WHEN THE VALVING ELEMENT WITHIN THE COMPONENT IS SHIFTED TO ITS FINITE POSITIONS. MULTIPLE ENVELOPE VALVES CAPABLE OF INFINITE POSITIONING BETWEEN CERTAIN LIMITS ARE SYMBOLIZED ABOVE WITH THE ADDITION OF HORIZONTAL BARS WHICH ARE DRAWN PARALLEL TO THE ENVELOPE. THE HORIZONTAL BARS ARE THE CLUES TO THE INFINITE POSITIONING FUNCTION POSSESSED BY THE VALVE REPRESENTED	(FLOW PATHS INTERNALLY OPEN)  (SYMBOL SYSTEM 11.3)	
11.4 ON OFF-TWO WAY, 2 PORTED	 (SIMPLIFIED SYMBOL)	
11.5 CHECK-TWO WAY, 2 PORTED		
11.6 TWO WAY, 2 POSITION (NORMALLY OPEN CONDITION) (NORMALLY CLOSED CONDITION)		
 GE Power Generation	GENERAL ELECTRIC COMPANY GAS TURBINE Greenville, SC	SIZE A CAGE CODE DWG. NO. 277A2415
DRAWN	SCALE NONE	SHEET 18
ISSUED		

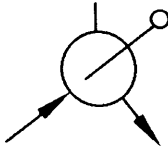
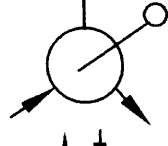
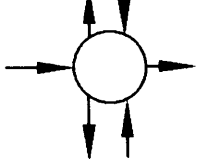
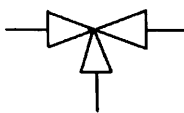
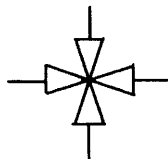
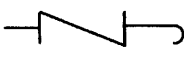
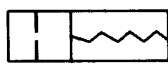
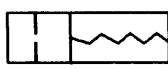
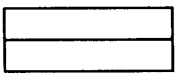
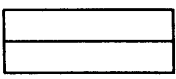
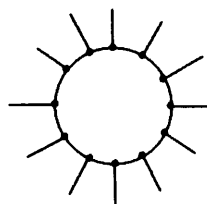
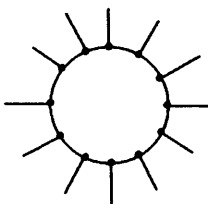
SIZE DWG NO. 277A2415
 SHEET 19
 REV G

SUBJECT	FLUID POWER	PROCESS FLOW
11.7 TWO WAY, INFINITE POSITION (NORMALLY OPEN CONDITION)		
(NORMALLY CLOSED CONDITION)		
11.8 THREE WAY, TWO POSITION (NORMALLY OPEN CONDITION)		
(NORMALLY CLOSED CONDITION)		
11.9 FOUR WAY, TWO POSITION (NORMAL)		
(ACTUATED)		
11.10 FOUR WAY, THREE POSITION (NORMAL)		
(ACTUATED LEFT)		
(ACTUATED RIGHT)		
TYPICAL FLOW PATHS FOR CENTER CONDITIONS		
IN TRANSIT CONDITION		

 GE Power Generation	GENERAL ELECTRIC COMPANY GAS TURBINE Greenville, SC	SIZE A	CAGE CODE	DWG. NO. 277A2415
	DRAWN	SCALE NONE	SHEET 19	DISTR TO
ISSUED				

SIZE DWG NO. REV		277A2415 20 G	
SUBJECT		FLUID POWER	PROCESS FLOW
11.11	PRESSURE RELIEF (NORMAL)		
11.12	SEQUENCE	(SIMPLIFIED SYMBOL) 	
11.13	PRESSURE REDUCING		
11.14	BACK PRESSURE REGULATING		
11.15	ANGLE (GLOBE ILLUSTRATED)		
11.16	BALL		
11.17	BUTTERFLY		
11.18	CHECK, ORIFICED		
11.19	COCK/PLUG		
11.20	FOOT OPERATED		
11.21	GATE		
11.22	GLOBE		
11.23	NEEDLE		
 GENERAL ELECTRIC COMPANY GAS TURBINE Greenville, SC		SIZE A	CAGE CODE DWG. NO. 277A2415
DRAWN		SHEET 20	
ISSUED		SCALE NONE	

DISTR TO

SIZE A DWG NO 277A2415 SH. 21 REV G	SUBJECT	FLUID POWER	PROCESS FLOW
	11 24 SELECTOR		
	11 25 TRANSFER, 6 PORT		
	11 26 THREE WAY		
	11.27 FOUR WAY		
	11 28 PURGE OR VENT		
	11 29 CLOSED CENTER 4 WAY, INFINITE POSITION SERVO AT NULL		
	11.30 3 WAY, SERVO AT NULL		
	11.31 SPRING CHECK VALVE		
	11.32 CHEMICAL ISOLATER		
	12 DISTRIBUTOR		
	12.1 MANIFOLD		
 GE Power Generation GENERAL ELECTRIC COMPANY GAS TURBINE Greenville, SC	SIZE A	CAGE CODE	DWG. NO. 277A2415
DRAWN			
ISSUED		SCALE NONE	SHEET 21

DISTR TO





GLOSSARY OF TERMINOLOGY

(Mark IV, Mark V Gas Turbine Control System)

An understanding of the Mark IV and V gas turbine control system requires a knowledge of the terminology used in the electrical control system and for the mechanics of the gas turbine. This glossary is divided into part (A) Mark IV and V Electrical Control Terminology, and part (B) Gas Turbine Terminology.

A. MARK IV AND MARK V ELECTRICAL CONTROL TERMINOLOGY

Address The identification code that distinguishes one memory location or input/output port from another.

Address Bus A bus used to transmit the identification code that distinguishes one memory location or I/O port from another.

Algorithm Refer to CONTROL ALGORITHM

Analog A continuous signal or a representation of a quantity that can have any value.

Application Application-oriented computer programs, such as the Sequencer Code and Control Algorithms.

Software which are customized to the needs of each installation.

Array Systematic arrangement of numbers or data in tabulated form.

ASCII Abbreviation for American Standard Code for Information Interchange. Each character is assigned a number between 32 and 127.

ASM-86 A low-level programming language designed for the Intel 8086 microprocessor. ASM-86 is used in the Mark IV computer operating system

to perform operations which require a fast execution time.

Assembler A computer program that converts assembly language programs into a form (machine language) that the computer can understand. The assembler translates mnemonic instruction codes into binary numbers, replaces names with their binary equivalents, and assigns locations in memory to data and instructions.

Assembly Language A programming language in which the programmer can use mnemonic instruction codes, labels, and names to refer directly to their binary equivalents. The assembler is a low-level language, since each assembly language instruction translates directly into a specific machine language instruction.

Asynchronous Operation of a switching network by a free-running signal. Completion of one instruction triggers the next instruction.

Back-plane The internal wiring of a module between pins of the cards located in the module. Some modules have a "flow-soldered" back-plane, which is a printed circuit card that the other cards plug into.

Baud A measure of the rate of data flow transfer. The number of signal elements (bits) transmitted per second. (2400 Baud transfers 2400 Bits = 300 Bytes/sec.)

Binary A system of numbers using 2 as a base. (In contrast to the decimal system, which uses 10 as a base).

Bit A single binary digit which can be in either of two states (0/ or 1).

Bootstrap Technique for loading first instructions of a program into memory and then using these instructions to bring in the rest of the program.



BRAM Battery-backed Random Access Memory is used to retain field editable software during power outages for a given length of time.

Bus A group of parallel lines that connect two or more devices.

Byte A data element consisting of 8 bits.

Checksum A logical sum of data that is included in a record as a guard against recording or transmission errors.

Clock The pulse generator which controls the timing of switching circuits in the microprocessor. Hardware architecture and programming are other factors in determining the rate of data manipulation.

Coding The writing of programs in a language that is comprehensible to a computer system.

Cold Junction The junction between the thermocouple wire and the screw terminals on the thermocouple modules generates an EMF at point of termination called the “cold junction”.

Compiler A program that converts a program in a high-level (i.e. procedure-oriented) language into an assembly or machine language program.

Control Algorithm A PLM-86 Application Software program that performs a specific function, such as speedcontrol or vibration protection.

Control Bus The bus carries commands from and to the CPU for control of the operating system (i.e. read, write, etc.).

Control Constants The subset of “Constants” that are used in the Control Algorithms and the Sequencer Code to define gains, time constants, offsets, etc. Each Control Constant can be called by its Signal Name as shown in the Elementary.

CPU Central Processing Unit, the heart of the computer system, consists of storage elements (registers), arithmetic unit (computation circuits),

control block (instruction-decoding, execution and timing) and I/O.

Cycle The process of powering-down, then powering-up a processor; (i.e. moving the toggle switch on the processor’s power supply to first the DISABLE position, then the ENABLE position). The processor will re-initialize when it is powered back up.

Data Information that is processed by a microprocessor according to its Code. Generally, the microprocessor’s input, output and ‘workspace’ information.

Database The organized collection of Data and Constants that are important to field service personnel.

Data Bus A bus used to transfer coded information to and from the CPU memory storage and peripheral devices.

Differential Input An analog input which has a high impedance to ground on input wires.

Downloading The processor’s operation which copies information from one section of a processor’s Memory into a different section of the same Memory or into another processor’s Memory. If a Controller is ‘cycled’ (powered-down, then powered-up), the <RST> Sequencer Code is downloaded from the Communicator <C> to the Controller.

“Dumb Terminal” Terminal for data input/output to/from Host Computer; (by strict definition: No internal data storage/manipulation)

Editor A program that manipulates text material and allows the user to make corrections, additions, deletions, and other changes.

EPROM Erasable Programmable Read Only Memory can be erased by exposure to ultraviolet light.

EEPROM Electrically Erasable Programmable Read Only Memory is used to store the field edit-



able Application Software so that it will not be lost during a power outage.

Firmware A method of system control program design in which all control instructions are contained in ROM or PROM.

Handshaking A method of controlling data transfers in which the transmitting device generates a data ready signal. This signal directs the receiving device to accept the data. The receiving device then generates a data accepted signal to inform the transmitting device that it may remove the data and proceed.

Hardware Physical equipment forming a computer system (as opposed to the Software).

Hexadecimal A system of numbers using 16 as a base (In contrast to the decimal system which uses 10 as a base.)

High-Level Language A programming language in which the statements represent procedures rather than single machine instructions. PLM-86 is the high-level language used within the Mark IV system. A high-level language requires a compiler that translates each statement into a series of machine language instructions.

IDATA A Database array dedicated to storing integer variable Signal Names, such as speed (TNH) or fuel stroke reference (FSR).

Instruction A group of bits that defines a computer operation and is part of the instruction set.

Instruction Set The set of general-purpose instructions available with a given computer — the set of inputs to which the CPU will produce a known response during the instruction fetch cycle.

Interpreter A program that fetches and executes instructions written in a high-level language. An interpreter executes each instruction as soon as it reads the instruction; it does not produce an object program, as a compiler does.

Interrupt A computer input that temporarily suspends the normal sequence of operations and transfers computer control to an Interrupt Service Routine.

Interrupt Service Routine A program that performs the actions required to respond to an interrupt.

IVAR A Database array dedicated to storing integer data.

LDATA A Database array dedicated to storing logic data Signal Names, such as “complete sequence” (L3) or “flame detected” (L28FD).

LVAR A Database array dedicated to storing logic data.

Linking Loader A loader that will enter a series of program and subroutines into memory and provide the required interconnections.

Low-Level Language A language in which each statement is directly translated into a single machine language instruction.

MDATA A Database array dedicated to storing pre-defined miscellaneous data Signal Names.

MEM A Medium Electronics Module can contain up to 24 circuit cards. The Communicator <C> is a MEM.

Machine Language The programming language that the computer can directly understand with no translation other than numeric conversions. A machine language program can be loaded into memory and executed. The value of every bit in every instruction in the program must be specified.

Membrane Switch One of the pushbuttons which are beneath the overlay on the Operator Interface Module.

Memory The section of a computer which stores information (i.e. code, data and constants) in binary form. Each item in the Memory has a unique address that the CPU can use to access it.



Microcomputer A computer whose CPU is a microprocessor plus memory and input/output circuitry.

Microprocessor A central processing unit generally consisting of an arithmetic and logic unit, control block and register array, and a memory storage system.

Modem A device that adds or removes a carrier frequency to an existing signal which allows data to be transmitted or received on a high frequency channel.

Modular Programming A programming method whereby the entire task is divided into logically separate sections or modules.

MOV A Metal Oxide Varistor. A zener-oxide device that suppresses voltage spikes.

Multiplexing A process of transmitting more than one signal at a time on a single link via time-sharing (i.e. serial) or frequency-sharing (i.e. parallel).

MVAR A Database array dedicated to storing miscellaneous data.

Object Program (Object Code) The program that is the output of a translator program (such as an assembler or compiler). Usually a machine language program ready for execution.

Off-line A function performed with the turbine stopped and/or the control disconnected from the process.

Operating System System software that controls the overall operation of a computer system and performs such tasks as memory allocation, input and output distribution, interrupt processing, and task scheduling.

Optical Isolation A semiconductor device consisting of an LED and a photodiode or phototransistor in close proximity. Current through the LED causes an internal light emission that forces current flow in the phototransistor. Voltage differ-

ences have no effect because the devices are electrically separated.

Page A subdivision of Memory containing 64K (i.e. 65,000 bytes).

Party Line A large number of devices connected to a single line originating in a CPU.

PLM-86 A high-level language designed for systems and application programming of the Intel 8086 microprocessor. Control programs algorithms are written in PL/M-86.

Port The point where the I/O is in contact with the outside world.

Programming The implementation of the control function of a processing system as a sequence of control signals that is organized into words and stored in memory.

PROM Programmable Read Only Memory is used to store software which is not field adjustable and will not be lost during a power outage.

PROM Programmer A piece of equipment that stores Software in a PROM.

Processor A microcomputer (a microprocessor plus Memory and Input/Output circuitry) used in the Mark IV panel. The Communicator <C> and the Controllers <RST>.

Protocol A procedure for data communication.

RAM Random Access Memory can be read and written to during operation and must be backed-up to retain its contents during a power outage.

Real Time In synchronization with the actual occurrence of events.

Real Time Operation A data processing technique which allows the machine to use information as it becomes available, as opposed to batch processing at a time unrelated to the time the information is generated.

Refresh The process of restoring the contents of a dynamic memory before they are lost.



Register A temporary small scale memory used by the CPU for logic, arithmetic or transfer operations.

RS232 An IEEE communication standard used for communication between <C>, <R>, <S>, <T> and the panel mounted printer. It is also available for remote communication.

RS422 An IEEE communication standard used for remote communication.

Rung A series of Sequencer Code commands (i.e. pseudo-contacts) which result in a store statement (i.e. pseudo-coil).

Sampling Rate The frequency that a given program is run. Some control algorithms are run four times every second.

SEM A Small Electronics Module contains up to 12 circuit cards. Controllers <RST> are SEM's.

Sequencer Code The set of instructions that performs the turbine's sequencing functions.

Serial Link An interface between two computer systems that permits one of the systems to transmit data to, and receive data from, the other system.

Single Ended Input An input which has a high impedance to ground on one of the two incoming wires.

Softswitch One of the six pushbuttons, located at the right of the CRT display, which are assigned a function by the display which currently appears on the screen.

Software Computer programs.

Subroutine A sub-program that can be reached from one or more places in a main program.

Stack A data structure used for temporary storage which receives data on the top of the stack and pushes existing data further down in the stack. Data is removed from the top of the stack creating a last-in, first-out arrangement.

Stall A cessation of processor operation (due to malfunction).

String A sequence of character codes stored sequentially in Memory. The Relay Ladder Diagram Rungs consist of one or more strings.

TTL Transistor-Transistor Logic is the most widely used bi-polarity technology for digital integrated circuits.

Utility Program A program that provides basic functions, such as loading and saving programs, initiating program execution, observing and changing the contents of memory locations, or setting breakpoints and tracing.

Voting Voting in the Mark IV means that the control will respond to the majority logic from the three Controllers.

Word Sixteen consecutive bits which the computer can manipulate in a single cycle.

Wire Wrap Wiring within modules is terminated on the card or relay socket pins by wrapping the wire around the pins.



GAS TURBINE TERMINOLOGY

Accessory Compartment A sheet metal house with access doors which may be located on the same base as the turbine or on a separate base. It contains the mechanical accessories needed to support the prime mover operation.

Accessory Coupling A fluid or grease filled flexible coupling which drives the accessory gear from (the forward end of) the prime mover.

Accessory Gear Encompasses a number of gears which drive most of the gas turbine accessories at the proper speeds and which connects the turbine to its starting device. The gear is driven by the starting device, and then by the turbine when the unit reaches self-sufficient speed. Common items driven by this gear are: liquid fuel pump, water pump, main lube pump, main hydraulic pump, main atomizing air compressor.

Accessory Gear Box Refers to the complete accessory gear assembly.

Accumulator A hydro-pneumatic device designed to absorb a hydraulic shock and to deliver a regulated force (in the form of pressure and flow) during transient demands on a system.

Acid Removal Filter The machine part that neutralizes acid in the lube oil supply.

Actuator A self-contained device designed to deliver a controlled or regulated force in order to activate some other device.

Aft End The exhaust end of the gas turbine.

Aftercooler The atomizing air cooler downstream of the main atomizing air compressor.

Air Separator The device which removes large particulate matter from an air supply via an inertial or centrifugal force.

Ambient Air Air surrounding the gas turbine housing which enters the turbine to support combustion.

Annular Space or Annulus The ring like space between the combustion liner and the flow shield.

Anti-Icing System Preheating of the inlet air to prevent ice formation in the inlet system.

Atomizing Air High pressure air which is used to break up liquid fuel into small droplets to improve the combustion.

Aux. Hydraulic Supply Pump The motor driven high pressure pump used to supply servo pressure during start-up or emergency conditions.

Aux. Lube Pump Provides lubricating oil during start-up and shutdown, and serve as a standby to the main pump. An AC motor is usually the drive source.

Axial Flow A (gas turbine) compressor which moves air axially through a series of rotor and stator compressor blades. The rotating elements impart momentum to the air mass, and the stator elements convert that momentum to pressure in conjunction with the converging walls of the compressor casing.

Base Load The load at the rated temperature control setpoint at which the turbine can be operated to maintain the recommended parts life expectancy.

Bearing The stationary machine part which contains the journal bearing liner.

Bearing Feed Header The section of the lube oil piping, downstream of the oil filters, which carries lubrication to the individual turbine bearings.

Bearing Seal A general term identifying a means of preventing oil leakage from a bearing.

Bellmouth The flared bell-shaped cast inlet which provides an even airflow distribution to the compressor through the inlet guide vanes.

Black Start The means of starting a turbine without incoming AC power.

Blade A rotating or stationary airfoil in an axial compressor.



Blow Off Valve A valve which bypasses air from the compressor around the regenerator and the high and low pressure turbines (i.e. two (2) shafts gas turbine) to reduce available energy and prevent overspeed during a sudden loss of load. It is primarily used on two shaft, generator drives.

Brittle The loss of resiliency in the parent metal due to aging, extreme cold or chemical action.

Brake Horsepower The horsepower developed at the load coupling.

Buckets Airfoil elements mounted radially on the rotor wheel to transfer energy from the working medium to the turbine rotor.

Burnishing The process of smoothing a metal surface by means of a mechanical action with no loss of material. This normally occurs on plain bearing surfaces.

Bypass Valve A device which regulates the flow of a fluid in: A) A fuel bypass valve on a liquid fuel system using a positive displacement pump or, B) An air control valve used for compressor pulsation protection.

Centrifugal Separator A device used to remove dust from the gas turbine cooling and sealing air system. Separation is achieved by a centrifugal action.

Chamfer A beveled edge (i.e. by the removal of some of the gear material at an angle from the top land to the bottom land at the ends of the teeth).

Check Valve A device which allows fluid flow in only one (1) direction.

CO₂ Carbon dioxide, used as a fire extinguishing medium.

Combustor or Combustion Chamber The mechanical component of the combustion system in which the combustion takes place (increasing the temperature of the working medium).

Combustion Liner The chamber where chemical energy is released and added to the gas flow path.

Combustion System A system consisting of fuel nozzles, spark plugs, flame detectors, crossfire tubes, combustion liners, transition pieces and a combustion casing or wrapper.

Compression Ratio The ratio of the compressor discharge pressure to the inlet pressure.

Compressor The mechanical component which is used to increase the pressure of the working medium within its structure.

Compressor Discharge Casing Contains the last stages of the compressor stator blades and is used to:

- Join the compressor and turbine stators
- Support the forward end of the combustion wrapper
- Provide an inner support for the first stage turbine nozzles.
- May provide support for a bearing

Control Compt. (Control CAB) The compartment which contains the gas turbine electrical controls and protection equipment.

Cooling and Sealing Air A system which provides air pressure for cooling and sealing various turbine components.

Cooling Water Pump Provides cooling water flow for the system. A gear box or electric motor drives the pump.

Cooling Water Radiator The on or off base water/air or water/water heat exchanger.

Coupling A component which connects a driven component to the drive source. Examples: Accessory Gear Coupling, Load Coupling, Pump Coupling, Starting Motor Coupling, etc.

Coupling Comp. A housing for the load coupling.



Cranking The turning of the turbine rotor during start-up or shutdown.

Crossfire Tubes The piping which interconnects the combustion chambers on multiple combustion chamber turbines. These tubes also allow flame propagation from the two (2) spark plug ignited combustors to the other chambers.

Cycle Thermal The ratio of the net work output to the total heat input = [Work of Turbine - Work of Compressor]/Heat Input.

Diaphragm The stationary element containing a set of nozzles used to expand the working medium and direct it against the rotating blades.

Diffuser The section designed to increase the area of the flowpath to convert flow velocity to static fluid pressure.

Distance Piece A hollow cylindrical shaft used to couple the axial-flow compressor to the first stage turbine wheel.

Eductor A device used for evacuating an enclosed space usually by means of air purge.

Electrostatic A device used for removing oil particles from an air/oilmixture using the charged particle Precipitator method.

Emergency Stop An immediate de-activation of the fuel system due to an emergency electrical or mechanical device or done manually.

Emergency Lube Oil Pump The back-up lube oil pump to the main pump. It uses the 125 Vdc battery to power the motor.

Evaporator Cooling Liquid (usually water) is added to an air supply, and the resultant evaporation cools the air mass and increases its mass per unit volume.

Exhaust Diffuser The component which slows the exhaust gas exit from the last turbine stage to recover energy, and reduce losses.

Exhaust Frame The machine part which usually support the aft journal bearing. The air discharged from the exhaust diffuser is directed to the turning vanes. Air-cooled, internal struts maintain position of the bearing.

Exhaust Hood The component which surrounds the aft bearing area and is bolted to the turbine case aft flange. It assists in guiding air flow in to the turning vanes.

Exhaust Plenum An enclosed cavity which receives discharged exhaust gases after the gases exit from the load turbine wheel.

Exhaust Ports Machine bosses on the compressor casing which extracts air for cooling and sealing.

Exhaust Pressure Drop Exhaust duct losses.

Exhaust Stack The exhaust assembly which can include silencing sections.

Exit Guide Vanes Guide vanes at the exhaust end of the load turbine which direct the gas flow to the exhaust.

Expansion Joints Devices that allow thermal expansion.

Extraction Valves Devices used to assist in preventing compressor surge by allowing air to be extracted during off-design periods from an intermediate compressor stage.

Filters Components normally used to remove solid particulate matter in a given size range from an air/fluid supply and from lube oil.

Fin Fan (Cooling Fan) A mechanically or electric motor driven air fan used to cool the water running through the radiators.

Firing Temp The temperature of the air mass at the inlet of the first stage turbine nozzle.

Flame Detectors Sensors (usually ultraviolet) used to detect flame.

Flow Divider A device which distributes fuel flow equally to the fuel nozzles.



Fluid A general term used to describe a liquid or gas.

Fuel Forwarding Skid The off-base pumping unit used to transfer, condition and control the flow of liquid fuel to the turbine.

Fuel, Gas Either natural gas with a high heat content or manufactured gas.

Fuel, Light Distillate (Also known as No. 2 fuel.) A volatile distillate fuel having good combustion properties, clean burning and readily atomized. Preheating is usually not necessary.

Fuel Nozzle The device that injects fuel into the combustion chamber.

Fuel Oil Stop Valve A spring-closed, hydraulically opened device used as a positive shutoff of liquid fuel.

Fuel Pump, Main The shaft driven, high pressure, liquid fuel pump.

Fuel, Residual Low volatility petroleum products remaining at the end of a refinery distillation processes. All residual fuels require heating for pumping, filtering and proper air atomization at the fuel nozzle.

Fuel Treatment The process of treating residual fuel to eliminate or inhibit contaminants.

GAC Abbreviation for the Generator Auxiliary Compartment containing high voltage switch gear and excitation.

Gib Block A steel block welded to the turbine base which has adjusting bolts for axial and transverse locating of the turbine. Provision is made for a gib key in the gib block.

Gib Key The key for the gib block (i.e. described above). It is machined as an integral part of the lower half of the exhaust frame.

Heat Consumption The heat consumed at rated output (i.e. BTU/hr.).

Heat Exchanger/Cooler The heat transfer equipment used to extract excessive heat from one working fluid and transmit it to another non-working fluid for eventual dissipation to the atmosphere.

Heat Rate The ratio of input energy to output energy (i.e. BTU/BHP-HR).

Heat Recovery System The means of recovering heat which would otherwise be lost during the process.

Heating Value The heat content of a given fuel (i.e. BTU/lb.).

High Pressure Turbine The first stage turbine (that drives the compressor on 2-shaft gas turbines).

Hot Gas Path A path of flow of the hot gases consisting of the combustion chambers, transition pieces, turbine nozzles and buckets, and the exhaust section.

Hydraulic Ratchet A form of turning gear which turns the rotor slightly at periodic intervals.

Inductor Alternator A permanent magnet type of AC generator connected to the compressor shaft.

Inlet Guide Vane The guide vanes at the inlet to the compressor which direct and control the air flow to the first stage of the axial flow compressor.

Inlet Plenum An enclosed cavity that directs the inlet air to the gas turbine.

Inlet Pressure Drop The inlet duct pressure drop (in inches of water).

Inlet Temperature The inlet air temperature to the gas turbine compressor.

Journal Bearing The part that supports the weight of the rotating shaft during normal operation.

Labyrinth Packing A seal designed with multiple rows of (aluminum alloy) teeth located at the extremities of the bearing assemblies. Sealing air is circulated between the shaft and the seal to prevent oil from passing the seal and spreading along the shaft.



Lagging The thermal and/or acoustic covering or enclosure.

Lifting Trunnion Extensions which are integrally cast as part of the casing and used to hold slings for lifting purposes.

Lighting Transformer A device usually associated with backfeeding the generator output of 13.8KV and reducing it to 480/V 3-phase.

Load Shaft The low pressure turbine shaft.

Load Turbine Nozzle The variable angle nozzle between the high pressure and low pressure turbine wheels on 2-shaft turbines which is to apportion energy distribution between the turbines.

Low Pressure Turbine The load turbine.

Lube Oil Header The main lube oil piping which feeds the turbine bearings, gears, coupling, etc.

LVDT Abbreviation for Linear Variable Differential Transformer.

Mist Eliminator A device which removes small oil droplets from the oil tank vent system prior to the discharge of the vapor in to the atmosphere.

Model Defines the gas turbine frame size.

Nozzle/Diaphragm Assembly A combination of the nozzle and the air control device between the turbine stages at the inner side wall.

Nozzle Segment A small number of nozzle partitions made as an assembly: multiple assemblies will constitute a complete nozzle assembly.

Off-Base A part which is not mounted on the accessory, turbine or generator base.

On-Base A part which is mounted on the accessory, turbine or generator base.

Outer Combustion Casing A cover that provides a pressure vessel and an air flow path.

Overspeed Bolt A spring loaded sliding rod, which is located in the accessory gear box mounted on the shaft connected to the turbine rotor, and mechanically senses a rotor overspeed condition and generates a trip independent of the electrical overspeed protection system.

Pad Support pads located on all base mounted assemblies.

Partition The airfoil shaped stator portion of the nozzle assembly.

Peak Load The load reached at the peak exhaust temperature control setpoint (above the base load setpoint) which produces more power but reduces the life expectancy of the turbine parts.

Peak Reserve A short term rating (seldom used) for getting maximum power, recognizing that this drastically reduces the life of the hot section turbine parts.

Platform The portion of a turbine bucket between the airfoil shape and the shank.

Plenum An enclosure which contains a volume of air (i.e. inlet) or exhaust gas (i.e. exhaust).

Power Plant A comprehensive term for the components which are contained in an integrated power system.

Pre-cooler The air cooler upstream of the main atomizing air compressor.

Pre-selected Load An adjustable, pre-designated load point between spinning reserve and base load.

Pressure Ratio The ratio of the compressor discharge pressure to the inlet pressure.

Pulsation Protection A mechanical network designed to prevent surge/pulsation during off-speed conditions of the compressor.

Pump, Centrifugal A non-positive displacement pump designed to use a rotor impeller in an enclosure as a means of transferring a fluid from one place to another.



Pump, Gear A positive displacement pump that consists of a drive gear and driven gear mounted in a housing. The working medium travels from the intake port around the outside of the gear to the outlet port.

Regenerative Cycle The working cycle which recovers a portion of the exhaust heat to reduce the cycle heat input required to reach cycle operating temperatures. The working medium passes through compressor, regenerator, combustor, turbine and regenerator.

Regenerator A heat exchanger used to transfer heat from the exhaust gas to the working fluid before it enters the combustor.

Rotor The rotating part of an assembly which is usually surrounded by a stator or stationary casing.

RTD Abbreviation for a Resistance Temperature Detector.

SFC Specific fuel consumption (i.e. lbs/BHP-HR) defined for a given fuel heating value.

Shaft Horsepower The power developed at the input or output shaft.

Shank The portion of a bucket between the platform and the dovetail.

Shroud A segmented part located adjacent to the blade tips which is used to limit the working fluid leakage.

Silencer A section of the inlet or exhaust of a gas turbine designed to reduce the sound level of air passing through it.

Simple Cycle A cycle where the working fluid passes directly through the compressor, combustor and turbine (without heating/cooling).

Single Shaft Turbine A gas turbine whose rotating components, (compressor and turbine) are arranged on one shaft.

Soleplates Individually grouted-in foundation plates used for mounting and supporting the pads of the gas turbine bases.

Spinning Reserve The minimum load control point based on generator output.

Stage The combination of one row of stator blades or nozzles with one row of rotor blades or buckets.

Starting Clutch The (overrunning, hydraulically positioned jaw) clutch which connects the torque converter or turning gear output to the accessory gear box and disengages when the turbine reaches self-sustaining speed.

Starting Device The machine part used to produce adequate torque for the starting system. Some types of starting devices are:

1. Diesel Engine
2. Electric Motor
3. Steam Turbine
4. Natural Gas Expansion Turbine
5. Turbine Impingement
6. Air motor

Stator The stationary part of an assembly usually surrounding a rotating component or rotor.

Stub Shaft A hollow cylindrical section integral with the first stage compressor wheel.

Thermocouple A pair of dissimilar metals joined in series to form a closed circuit, which will generate a thermo-electric current when heated.

Thrust Bearing An active or inactive machine part which absorbs the axial thrust of the rotating shaft.

Tie Bolt A large bolt used to assemble the compressor rotor wheels.

Torque Converter A hydraulic device coupled to the turbine starting means which transfers and



amplifies torque causing turbine compressor shaft rotation during start up.

Transition Piece A thin walled duct used to conduct the combustion gases from the circular combustion chambers to the annular turbine nozzle passage.

Turbine Stage A set of stationary nozzles and one row of moving buckets mounted on a wheel. The working medium expands through the stationary nozzle to a lower pressure causing kinetic energy to be transferred to the moving buckets.

Turbine Wheels Discs on the gas turbine shaft which are used to mount buckets on the wheel periphery.

Turning Gear The machine part which is used to break the turbine away while starting and rotate the shaft during cooldown and inspection.

Two-shaft Turbine A turbine arrangement where the high pressure and low pressure turbine stages are only coupled aerodynamically and run at different speeds.

Valve, Pressure Regulating A valve designed for continuous automatic control of pressure.

Valve, Relief A valve that automatically maintains a maximum, predetermined pressure by discharging or bypassing the fluid in a system.

Valve, Servo A hydraulically powered valve with provisions for direct control (i.e. positioning) in direct relation with a primary control of a comparatively low level of force. Used for proportional control.

Valve, Solenoid A valve specifically designed to control the flow of fluid by means of the magnetic action of an electric coil on a movable core or plunger, which actuates the valve stem or pilot needle. Used for on-off control.

Valve, Temp. Regulating A self-acting valve designed for controlling the flow of fluids via a thermostatic element located in the fluid.

Vane An airfoil used to direct the flow of air or gas.

Water Removal Filter A device which removes suspended water from the lube oil.

Wheelspace Temperature The temperature of the air in close proximity to the surface of the turbine wheel below the platform surface of the turbine buckets.



GE Power Systems Training

*General Electric Company
One River Road
Schenectady, NY 12345*

BASIC CONTROL DEVICE FUNCTION NUMBERS

AMERICAN NATIONAL STANDARDS INSTITUTE

1	MASTER ELEMENT	50	INSTANTANEOUS OVERCURRENT or RATE-of-RISE RELAY
2	SEQUENCE TIMER	51	AC TIME OVERCURRENT RELAY
3	CHECKING RELAY	52	AC CIRCUIT BREAKER or CONTACTOR
4	MASTER RELAY	55	POWER FACTOR RELAY
5	STOPPING DEVICE	57	SHORT CIRCUITING or GROUNDING DEVICE
6	STARTING CIRCUIT BREAKER	59	OVERVOLTAGE RELAY
8	CONTROL POWER DISCONNECTING DEVICE	60	VOLTAGE or CURRENT BALANCE RELAY
10	UNIT SEQUENCE SWITCH	62	STOPPING or OPENING TIMER RELAY
12	OVERSPEED DEVICE	63	LIQUID or GAS PRESSURE or VACUUM
13	SYNCHRONOUS SPEED DEVICE	64	GROUND PROTECTIVE RELAY
14	SPEED RELAY	65	GOVERNOR
15	SPEED or FREQUENCY MATCHING DEVICE	66	NOTCHING or JOGGING DEVICE
18	ACCELERATING or DECELERATING DEVICE	67	AC DIRECTIONAL OVERCURRENT RELAY
20	SOLENOID VALVE	68	BLOCKING RELAY
21	DISTANCE RELAY	69	PERMISSIVE CONTROL DEVICE
23	TEMPERATURE CONTROL DEVICE	70	ELECTRICALLY OPERATED RHEOSTAT
25	SYNCHRONISM CHECK DEVICE	71	LIQUID or GAS LEVEL RELAY
26	TEMPERATURE SENSING DEVICE	72	DC CIRCUIT BREAKER or CONTACTOR
27	UNDERVOLTAGE	75	POSITION CHANGING MECHANISM
28	FLAME DETECTOR	77	PULSE TRANSMITTER
30	ANNUNCIATOR RELAY	80	LIQUID or GAS FLOW RELAY
32	DIRECTIONAL POWER RELAY	81	FREQUENCY RELAY
33	POSITION SWITCH	82	DC RECLOSING RELAY
34	MASTER SEQUENCE DEVICE	83	AUTOMATIC SELECTIVE CONTROL or TRANSFER RELAY
37	UNDERCURRENT or UNDERPOWER RELAY	84	OPERATING MECHANISM
38	BEARING PROTECTIVE DEVICE	85	CARRIER or PILOT-WIRE RECEIVER RELAY
39	MECHANICAL CONDITION MONITOR	86	LOCK-OUT RELAY
40	FIELD RELAY	87	DIFFERENTIAL PROTECTIVE RELAY
41	FIELD CIRCUIT BREAKER	88	AUXILIARY MOTOR or MOTOR GENERATOR
43	MANUAL TRANSFER or SELECTOR DEVICE	89	LINE SWITCH
45	ATMOSPHERIC CONDITION MONITOR	90	REGULATING DEVICE
46	REVERSE-PHASE or PHASE-BALANCE CURRENT RELAY	91	VOLTAGE DIRECTIONAL RELAY
47	PHASE-SEQUENCE VOLTAGE RELAY	93	FIELD-CHANGING CONTACTOR
48	INCOMPLETE SEQUENCE RELAY	94	TRIPPING or TRIP-FREE RELAY
49	MACHINE or TRANSFORMER THERMAL RELAY	96	TRANSDUCER



GE Power Systems Training

*General Electric Company
One River Road
Schenectady, NY 12345*



GEK 95149C
Revised, June 2001

GE Power Systems Generator

International Conversion Tables

Category	To convert from	To	Multiply by +
ACCELERATION	Ft/sec ²	meter/sec ²	3.048 E-01
	In/sec ²	meter/sec ²	2.540 E-02
AREA	Ft ²	meter ²	9.290 E-02
	In ²	meter ²	6.452 E-04
TORQUE	dyne-cm	newton meter	1.000 E-07
	kilogram-force-meter	newton meter	9.807 E+00
	lb-force-inch	newton meter	1.130 E-01
	lbf-foot	newton meter	1.356 E+00
	ozf-foot	newton meter	7.062 E-03
TORQUE/LENGTH	lbf-ft/in	newton m/m	5.338 E+01
	lbf-in/in	newton m/m	4.448 E+00
ELECTRICITY and MAGNETISM	amp hr	coulomb	3.600 E+03
	faraday (chem)	coulomb	9.650 E+04
	gauss	tesla	1.000 E-04
	gilbert	amp-turn	7.958 E-01
	maxwell	weber	1.000 E-08
	oersted	amp/meter	7.958 E+01
	unit pole	weber	1.257 E-07
ENERGY (Includes Work)	Btu*	joule	1.054 E+03
	ft-lb-force	joule	1.356 E+00
	kilowatt hr	joule	3.600 E+06
	watt-sec	joule	1.000 E+00
	ft-poundal	joule	4.214 E-02
FORCE	kg-force	newton	9.807 E+00
	oz-force	newton	2.780 E-01
	lb-force	newton	4.448 E+00
	poundal	newton	1.383 E-01
FORCE/LENGTH	lb-force/in	newton/meter	1.751 E+02
	lb-force/ft	newton/meter	1.459 E+01
HEAT	Btu* in/sec ft ² deg F	watt/meter K	5.189 E+02
	Btu* in/hr ft ² deg F	watt/meter K	1.441 E-01
	Btu* /ft ²	joule/meter ²	1.135 E+04
	Btu* /hr ft ² deg F	joule/kg K	5.674 E+00
	Btu*/lbm deg F	joule/kg K	4.184 E+03
	Btu*/sec ft ² deg F	watt/meter ² K	2.043 E+04
	cal/cm ²	joule/meter ²	4.184 E+04
	cal/cm ² sec	watt/meter ²	4.184 E+04
	cal/cm sec deg C	watt/meter K	4.184 E+02
	cal*/g	joule/kg	4.184 E+03
	cal*/g deg C	joule/kg K	4.184 E+03
LENGTH	foot	meter	3.048 E-01
	inch	meter	2.540 E-02
	foot	millimeter (mm)	3.048 E+02
	inch	millimeter (mm)	25.40 E+00

+E Indicates the power of 10 by which the number must be multiplied, i.e., 4.047E+03 = 4.047 x 10³.
*Thermochemical

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes the matter should be referred to the GE Company.

Category	To convert from	To	Multiply by +
MASS	oz mass (av)	kilogram	2.835 E-02
	lb-mass (av)	kilogram	4.536 E-01
	ton (2000 lbm)	kilogram	9.072 E+02
MASS/VOLUME (Includes Density)	lbm/ft ³	kilogram/meter ³	1.602 E+01
	lbm/in ³	kilogram/meter ³	2.768 E+04
	oz-mass (av)/in ³	kilogram/meter ³	1.730 E+03
	lb-mass (av)/gal	kilogram/meter ³	1.198 E+02
	g/cm ³	kilogram/meter ³	1.000 E+03
POWER	Btu*/sec	watt	1.054 E+03
	Btu*/min	watt	1.757 E+01
	Btu*/hr	watt	2.929 E-01
	Cal*/sec	watt	4.184 E+00
	Cal*/min	watt	6.973 E-02
	ft-lb force/hr	watt	3.766 E-04
	ft-lb force/min	watt	2.260 E-02
	ft-lb force/sec	watt	1.356 E+00
PRESSURE (Force/Area)	hp (elec)	watt	7.460 E+02
	atm (760 Torr)	pascal	1.013 E+05
	bar	pascal	1.000 E+05
	dyne/cm ²	pascal	1.000 E-01
	gram (force)/cm ²	pascal	9.807 E+01
	in of Hg (60 F)	pascal	3.377 E+03
	in of water (60 F)	pascal	2.488 E+02
	lb-force/ft ²	pascal	4.788 E+01
	lbf/ft ²	kg/m ²	4.882 E+00
	lbf/in ² (psi)	pascal	6.895 E+03
TEMPERATURE	lbf/in ²	kg/cm ²	7.037 E-02
	Torr (mm Hg, 0 C)	pascal	1.333 E+02
	degree Celsius (°C)	degree Kelvin (K)	T _K = t _C + 273.15
VELOCITY (Includes Speed)	degree Fahrenheit (°F)	degree Celsius	t _C = (t _F - 32)/1.8
	degree Celsius	degree Fahrenheit	t _F = (t _C · 1.8) + 32
VELOCITY (Includes Speed)	ft/hr	meter/sec	8.467 E-05
	ft/min	meter/sec	5.080 E-03
	ft/sec	meter/sec	3.048 E-01
	in/sec	meter/sec	2.540 E-02
VISCOSITY	ft ² /sec	meter ² /sec	9.290 E-02
	lbm/ft sec	pascal-sec	1.488 E+00
	lbf sec/ft ²	pascal-sec	4.788 E+01
VOLUME (Includes Capacity)	ft ³	meter ³	2.832 E-02
	gallon (US)	meter ³	3.785 E-03
	inch ³	meter ³	1.639 E-05
	liter	meter ³	1.000 E-03
	oz (US fluid)	meter ³	2.957 E-05
VOLUME/TIME (Includes Flow)	ft ³ /min	meter ³ /sec	4.719 E-04
	ft ³ /sec	meter ³ /sec	2.832 E-02
	in ³ /min	meter ³ /sec	2.731 E-07
	gal/min	meter ³ /sec	6.309 E-05

+E Indicates the power of 10 by which the number must be multiplied, i.e., 4.047E+03 = 4.047 x 10³.

*Thermochemical



GE Power Systems

General Electric Company
One River Road, Schenectady, NY 12345
518 • 385 • 2211 TX: 145354