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CHAPTER 1

FUNDAMENTALS

1.1 SAFETY

(Ref: S9234-AD-MM0-050)

1.1.1 General safety precautions The following are general safety precautions that are not related to any specific procedures. These are recommended precautions that personnel must understand and apply during many phases of operation and maintenance.

DO NOT SERVICE OR ADJUST ALONE

Personnel shall not enter the gas turbine enclosure for the purpose of servicing or adjusting the equipment except in the presence of someone capable of rendering aid.

RESUSCITATION

Personnel working with or near voltages should be familiar with the modern methods of artificial respiration. Obtain such information from the Bureau of Medicine and Surgery.

ADHESIVES

Do not allow adhesives to contact the skin. Rapid bonding of certain adhesives will cause instant adhesion to body members or objects. Do not attempt to forcefully separate body members if bonded together. Consult the area supervisor or a physician for procedures for separation.

TOXICS

Use all cleaning solvents, fuels, oils, adhesives and epoxy and catalysts in a well-ventilated area. Avoid frequent and prolonged inhalation of fumes. Concentrations of fumes of many cleaners, adhesives and esters are toxic and will cause serious deterioration of the body nervous systems and possible death, if breathed frequently. Avoid frequent or prolonged exposure to the skin. Wash thoroughly with soap and warm water as soon as possible after completing use of such materials. Take special precautions to prevent materials from entering the eyes. If exposed, rinse the eyes in an eye bath fountain immediately and report to a physician.

FLAMMABLES

Keep all cleaning solvents, oils, esters and adhesives away from open flame space heaters, exposed element electric heaters, sparks or flame. Do not smoke when using; or are in the vicinity of flammable materials, or in areas where flammables are stored. Provide adequate ventilation to disperse concentrations of potentially explosive fumes or vapors. Provide approved containers for bulk storage of flammable materials; and for dispensers in the working areas. Keep all containers tightly closed when not in use.

COMPRESSED AIR

Air pressure, used in work areas for cleaning or drying operations, shall be regulated to 29 PSI or less. Use approved safety equipment (goggles/face shield) to prevent injury to the eyes. Do not direct the jet of compressed air at self or other personnel; or so that refuse is blown onto adjacent work stations. If additional air pressure is required to dislodge foreign materials from parts, ensure that approved safety equipment is worn, and move to an isolated area. Be sure that the increased air pressure is not detrimental or damaging to the parts before applying high pressure jets of air.

HEAT AND COLD

Use approved thermally insulated gloves when handling either heated or chilled parts, to prevent burns or freezing of hands. Parts chilled to super-cold (-40 to -65 F.) temperature can cause instant freezing of hands if parts are handled without protective gloves. The outside surfaces of the gas turbine are not insulated. Adequate precautions should be taken to prevent operating personnel from inadvertently coming in contact with the hot surfaces.

HIGH VOLTAGE

Lethal output voltages are generated by the ignition exciter. Do not energize the exciter unless the output connection is properly isolated. If engine mounted, be sure all leads are connected and plug installed before firing the exciter.

MAINTENANCE PROCEDURES

Wear safety glasses or other appropriate eye protection at all times. Do not allow safety-wire or wire clippings to fly from the cutter when removing or installing wire. Do not use fingers as guides when installing parts or to check alignment of holes. Use only correct tools and fixtures, and use as recommended. Avoid short cuts, such as using less than recommended attaching bolts; shorter, or the incorrect quality of bolts. Heed all warnings in the manual text to avoid injury to personnel or damage to equipment.

General Electric LM2500

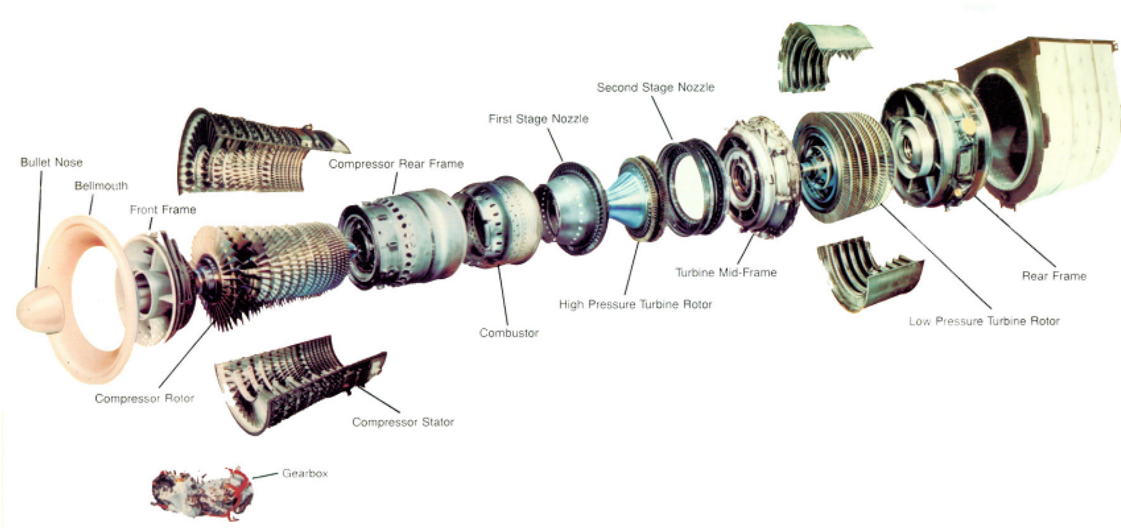


Figure 1-1. Propulsion Engine for FFG 7, DD 963/993, CG 47 and DDG 51 Class Ships

1.2 LM2500 PHYSICAL DESCRIPTION

(Ref: S9234-AD-MMO-010/LM2500)

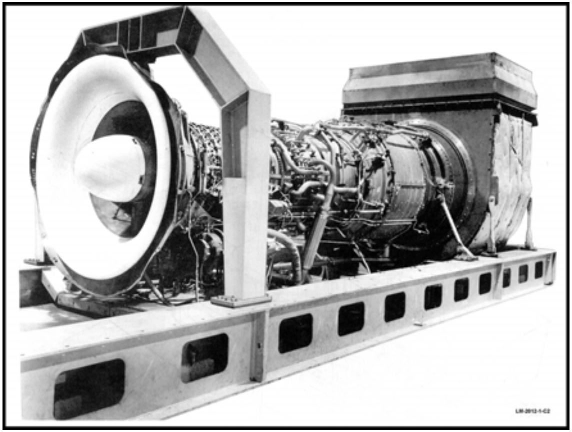


Figure 1-2. Gas Turbine Assembly - Left Side (Typical)

The Gas Turbine Assembly (GTA) consists of a Gas Generator (GG), a Power Turbine (PT), a High-Speed Flexible Coupling Shaft (HSCS), and inlet and exhaust components. The GG is composed of a variable geometry compressor, an annular combustor, a High Pressure Turbine (HPT), an accessory drive system, and controls and accessories. The Power Turbine (PT) is composed of a six-stage Low Pressure Turbine (LPT) rotor, a LPT stator, and a Turbine Rear Frame (TRF). The high-speed flexible coupling shaft is connected to the PT rotor and provides shaft power to the ship's MRG and drive system. The inlet duct and centerbody are the GT inlet components; the exhaust duct, outer core, and inner deflector are the GT exhaust components.

1.2.1 Compressor Section (Ref: S9234-AD-MMO-010/LM2500)

The compressor is a 16 stage, high pressure-ratio, axial flow design. Major components of the compressor are: Compressor Front Frame (CFF), compressor rotor, compressor stator, and Compressor Rear Frame (CRF).

The primary purpose of the compressor section is to compress air for combustion; however, some of the air is extracted for engine cooling and ship use. Air, taken in through the front frame, passes through successive stages of compressor rotor blades and compressor stator vanes and is compressed as it passes from stage to stage. After passing through 16 stages, the air has been compressed in the ratio of 16 to 1. The Inlet Guide Vanes (IGV) and the first 6 stages of stator vanes are variable; their angular position is changed as a function of Compressor Inlet Temperature (CIT) and compressor speed (NGG). This provides stall-free operation of the compressor throughout a wide range of speed and inlet temperatures.

The front of the compressor stator is supported by the front frame casing, and the front of the compressor rotor is supported by the no. 3 roller bearing, which is housed in the front frame hub A sump.

The rear of the compressor stator is supported by the CRF casing, and the rear of the rotor is supported by the no. 4 ball and no. 4 roller bearings, which are housed in the CRF hub B-sump.

1.2.1.1 Front Frame Assembly. The front frame assembly forms a flow path for compressor inlet air. Struts between the hub and outer case provide lubrication supply and scavenge for the A-sump components. The frame also supports the compressor rotor front bearing, inlet duct, centerbody, forward end of the compressor casing, IGV inner support, inlet gearbox, and the A-sump end cover. It provides mounting or attachment provisions for the GG front mounts, handling mounts, CIT Sensor, Inlet Total Pressure (Pt2) Probe, and Transfer Gearbox (TGB) mounts. In the frame are air passages for sump and seal pressurization and ventilation.

A seal oil drain connection is provided at the bottom of the casing. The lower frame strut houses the radial drive shaft which transfers power from the inlet gearbox to the TGB mounted on the bottom of the frame.

1.2.1.2 Compressor Rotor. The compressor rotor is a spool/disk structure with circumferential dovetails. Use of spools makes it possible for several stages of blades to be carried on a single piece of rotor structure. There are seven major structural elements and three main bolted joints. The first-stage disk, the second-stage disk, (with integral front stub shaft), and the Stages 3 through 9 spool are joined by a single bolted joint at Stage 2.

The Stages 3 through 9 spool is bolted with a Stage 10 disk and the Stages 11 through 13 spool, with the joint at Stage 10. The Stages 11 through 13 spool is followed by the rear shaft and an overhung Stages 14 through 16 spool, with a single bolted joint at Stage 13. Interfering rabbets are used in all flange joints for good positioning of parts and for rotor stability.

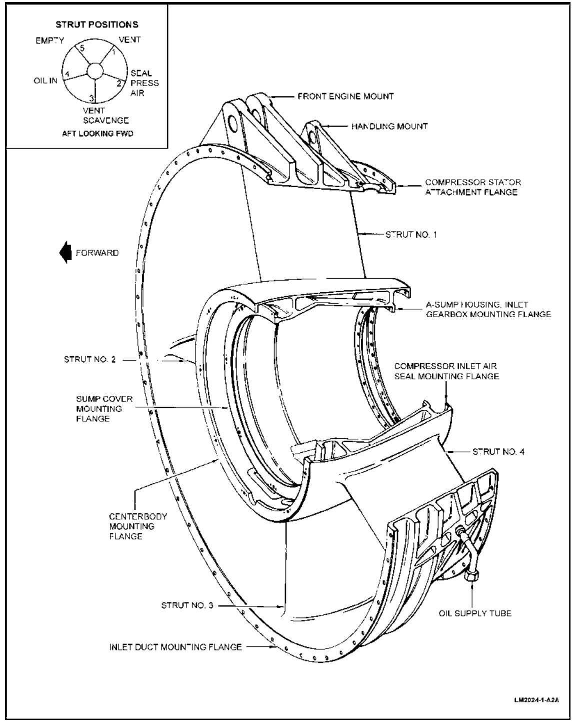


Figure 1-3. Front Frame Assembly

An air duct, supported by the front and rear shafts, routes Stage 8 air aft through the center of the rotor for pressurization of the B-sump seals. Rotor spool/disk materials are titanium for Stages 1 through 10 and Inconel 718 for the remainder. Close vane-to-rotor spool and blade-to-stator casing clearances are obtained with metal spray rub coating. Thin squealer tips on the blades and vanes contact the sprayed material; abrasive action on the tips prevents excessive rub while obtaining minimum clearance.

The first and second stage disks have a series of single blade axial dovetails, while each of Stages 3 through 16 have one circumferential dovetail groove in which blades are retained. Blades in Stages 1 through 14 are titanium; blades in Stages 15 and 16 are A286. The first stage blades have mid-span platforms to reduce blade tip vibration.

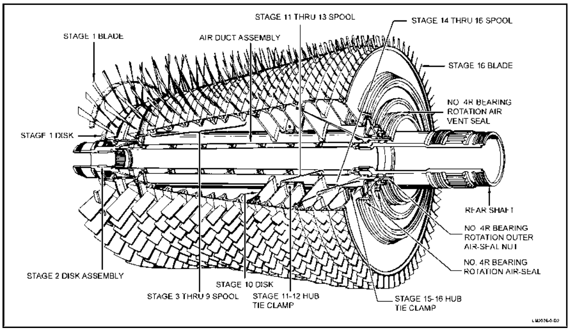


Figure 1-4. Compressor Rotor

1.2.1.3 <u>Compressor Stator.</u> The compressor stator has one stage of IGV and 16 stages of stator vanes. The IGVs and Stages 1 through 6 are Variable Stator Vanes (VSVs).

Material of the IGVs and vanes of Stages 1 and 2 is titanium, while Stages 3 through 16 are A286. Stage 8 vanes are A286 (airfoil) and stainless steel (base). The stator casing consists of four sections bolted together. The two front casing halves are made of titanium, and the two rear casing halves are made of Inconel 718.

Three bleed manifolds are welded to the stator casings. Bleed air extracted from inside the annulus area at the tips of the eighth stage vanes is used for sump pressurization and cooling. Bleed air extracted at the ninth-stage vane is used for PT cooling, PT forward seal pressurization, and PT balance piston cavity pressurization.

Bleed air extracted at the thirteenth stage vanes is used for cooling the second stage HPT nozzle.

The IGVs and stages 1 and 2 are shrouded. These shrouds, which are aluminum extrusions split into forward and aft halves, are held together with bolts. The first and second stage vane shrouds mate with rotor seal teeth. The IGVs and VSVs are actuated by a pair of master levers. The aft ends of the master levers are attached to pivot posts at about the tenth stage, one on each side of the casing. Each of the master lever forward ends is positioned by a hydraulic actuator. Adjustable linkages connect directly from the master levers to the actuating rings. Lever arms connect the actuating rings to the variable vanes.

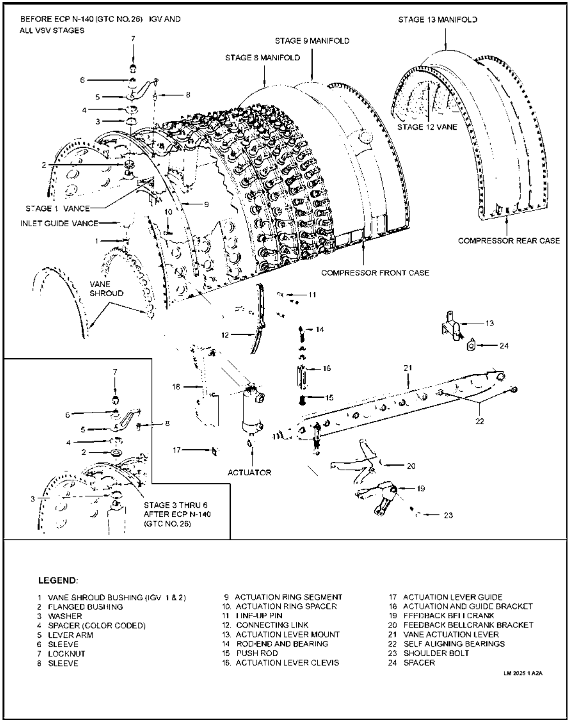


Figure 1-5. Compressor Stator

1.2.1.4 <u>Compressor Rear Frame.</u> The CRF assembly is made of Inconel 718 and consists of the outer case, the struts, the hub, and the B-sump housing. Its outer case supports the combustor, the fuel manifold, 30 fuel nozzles, two spark igniters, and the first-stage turbine nozzle support.

Bearing axial and radial loads and a portion of the first-stage nozzle load are taken in the hub and transmitted through 10 radial struts to the case. The hub is a casting which provides about half of the radial lengths of the 10 struts. The outer strut ends are castings which are welded to the hub to complete the struts. The hub and strut assembly is welded to the case, a sheetmetal and machined ring weldment that is the combustor outer case as well as the structural load path between the compressor casing and the Turbine Midframe (TMF).

To provide the ship with Compressor Discharge Pressure (CDP) air, an internal manifold within the frame extracts air from the combustion area and routes it through struts 3, 4, 8, and 9. Six borescope ports located in the case just forward of the midflange permit inspection of the combustor, fuel nozzles, and the first-stage turbine nozzle. Two borescope ports are provided in the aft portion of the case for inspection of the turbine blades and nozzles.

The B-sump housing is fabricated from an Inconel 718 casting that forms the sump cavity and supports the sump seals, an Inconel 718 sheet support cone, and a machined circumferential flange. Sump service tubing attachment points are made with standard fittings, which allows the housing to be removed from the frame without breaking permanent connections. To provide for differential thermal growth between sump service tubing and the surrounding structure, the tubes are attached only at the sump and have slip joints where they pass through the outer strut ends.

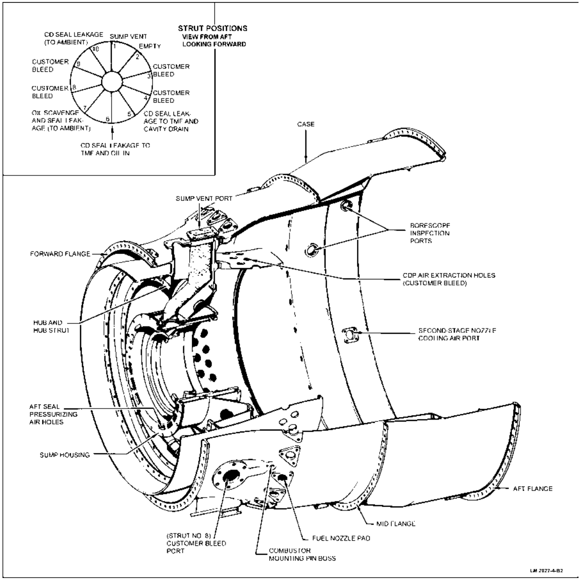


Figure 1-6. Compressor Rear Frame

1.2.2 <u>Combustion Section</u> (Ref: S9234-AD-MMO-010/LM2500)

The combustor is annular and consists of four major components riveted together: cowl (diffuser) assembly, dome, inner liner, and outer liner. The cowl assembly, in conjunction with the CRF, serves as a diffuser and distributor for the CDP air. It furnishes uniform air flow to the combustor throughout a large operating range, thereby providing uniform combustion and even-temperature distribution at the turbine. The cowl assembly consists of machined ring inner and outer cowl inlets welded to the inner and outer cowl walls. Strength and stability of the cowl ring section are provided with a truss structure consisting of 40 box sections welded to the cowl walls. The box sections also serve as aerodynamic diffuser elements. To provide a short overall combustor system length, the cowl assembly leading edge fits within and around the CRF struts.

The combustor is mounted in the CRF on ten equally spaced mounting pins in the forward (low temperature) section of the cowl assembly. These pins provide positive axial and radial location and assure centering of the cowl assembly in the diffuser passage. The mounting hardware is enclosed within the CRF struts so that it will not affect air flow.

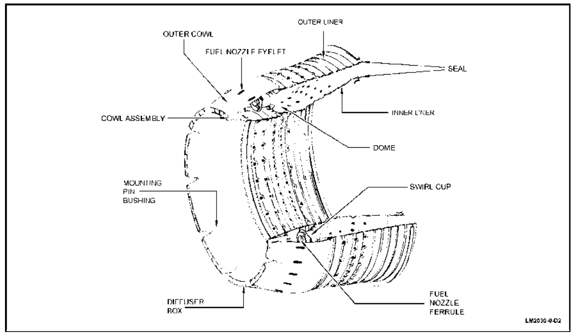


Figure 1-7. Combustor

Thirty vortex-inducing axial swirl cups in the dome (one at each fuel nozzle tip) provide flame stabilization and mixing of the fuel and air. The interior surface of the dome is protected from the high temperature of combustion by a cooling-air film. Accumulation of carbon on the fuel nozzle tips is prevented by venturi-shaped spools attached to the swirler. The combustor liners are a series of overlapping rings joined by resistance-welded and brazed joints. They are protected from the high combustion heat by circumferential film-cooling. Primary combustion and cooling air enters through closely spaced holes in each ring. These holes help to center the flame and admit the balance of the combustion air. Dilution holes are employed on the outer and inner liners for additional mixing to lower the gas temperature at the turbine inlet. Combustor/turbine nozzle air seals at the aft end of the liners prevent excessive air leakage while providing for thermal growth.

1.2.3 <u>HP Turbine Section</u> (Ref: S9234-AD-MMO-010/LM2500)

The HPT section consists of the HPT rotor, first and second stage turbine nozzle assemblies, and TMF. The turbine rotor extracts energy from the gas stream to drive the compressor rotor with which it is mechanically coupled. The turbine nozzles direct the hot gas from the combustor onto the rotor blades at the optimum angle and velocity.

The front end of the turbine rotor is supported at the compressor rotor rear shaft by the no. 4 bearings. The rear of the rotor is supported by the number 5 bearing in the TMF. The turbine nozzles are contained in and supported by the CRF. The TMF, besides supporting the aft end of the turbine rotor, also supports the front end of the PT, which is aerodynamically coupled to the GG. It contains the transition duct through which the gas flows from the HPT section into the PT.

1.2.3.1 <u>High Pressure Turbine Rotor.</u> The HPT rotor consists of a conical forward shaft, two disks with blades and retainers, a conical rotor spacer, a thermal shield, and a rear shaft.

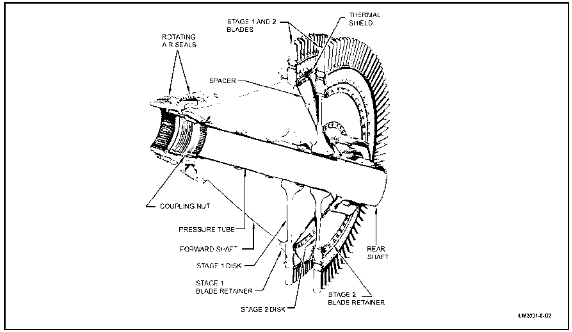


Figure 1-8. High Pressure Turbine Rotor

The forward turbine shaft transmits energy to the compressor rotor. Two seals are on the forward end of the shaft. The front seal helps prevent CDP air from entering the B sump. The other seal maintains CDP in the plenum formed by the rotor and the combustor. This plenum is a balance chamber that provides a corrective force that minimizes the thrust load on the no. 4 ball bearing. The inner diameter of the rabbet on the rear flange positively locates the first-stage blade retainer. The retainer has an integral face seal that helps to maintain balance chamber pressure by preventing excessive air leakage between the rotor and the first-stage turbine nozzle. The outer diameter of the rabbet positively locates the first-stage disk for stability of the rotor assembly.

Turbine blades in both stages are long-shanked and internally air-cooled. Use of long-shank blades provides thermal isolation of dovetails, cooling air flow paths, high damping action for low vibration, and low disk rim temperature. The blades are brazed together in pairs on paired blade configuration. On single shank turbine configurations the blades are one-piece castings.

Channel-shaped tip caps are inserted into the blade tips and are held by crimping the blade tips and by brazing. The turbine blades are coated to improve erosion and oxidation resistance.

Bosses around the rim boltholes on both sides of each disk rim provide resistance to low cycle fatigue. The bottom tangs and the bottoms of the slots are enclosed in the cooled region of the rotor.

1.2.3.2 High Pressure Turbine Rotor Cooling The HPT rotor is cooled by a continuous flow of CDP air that passes through holes in the first stage nozzle support and forward turbine shaft. This air-cools the inside of the rotor and both disks before passing through the blade dovetails and out the blade cooling holes.

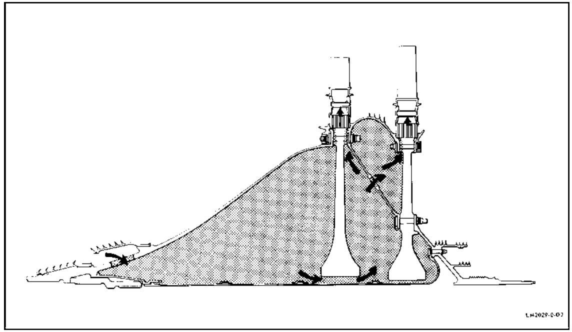


Figure 1-9. High Pressure Turbine Rotor Cooling

1.2.3.3 High Pressure Turbine Blade Cooling. Both stages of the HPT blades are cooled by CDP which flows through the dovetail and through blade shanks into the blades. Stage 1 blades are cooled by internal convection and external film cooling. The convection cooling of the center area is accomplished through a labyrinth within the blade. The leading edge circuit provides internal convection cooling by airflow through the labyrinth then out through the leading edge, tip, and gill holes. Convection cooling of the trailing edge is provided by air flowing through the trailing edge exit holes. Stage 2 blades are cooled by convection, with all of the cooling air discharged at the blade tips.

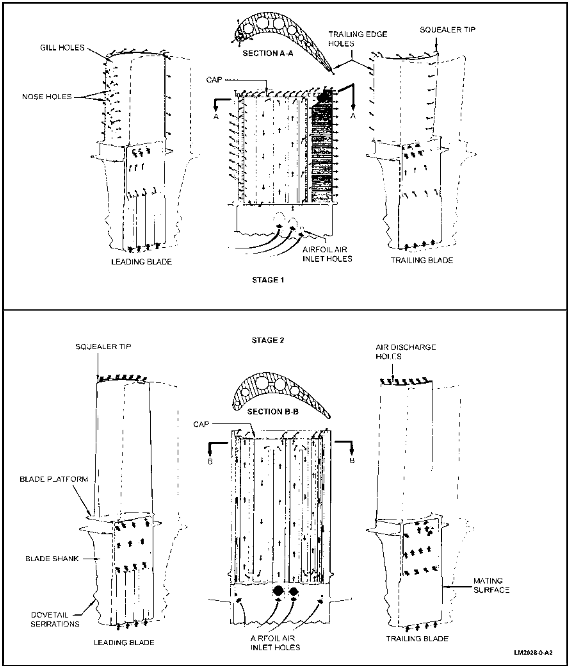


Figure 1-10. High Pressure Turbine Rotor Blade Cooling (Paired Blade)

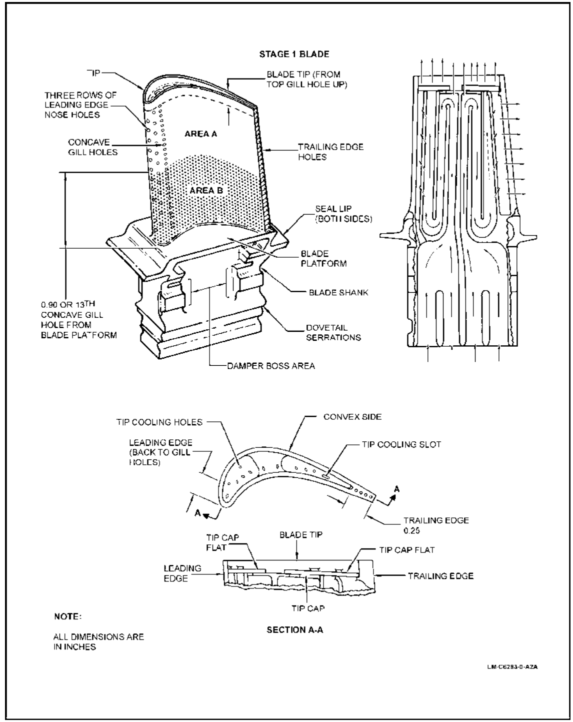


Figure 1-11. High Pressure Turbine Rotor Stage 1 Blade (Single Shank)

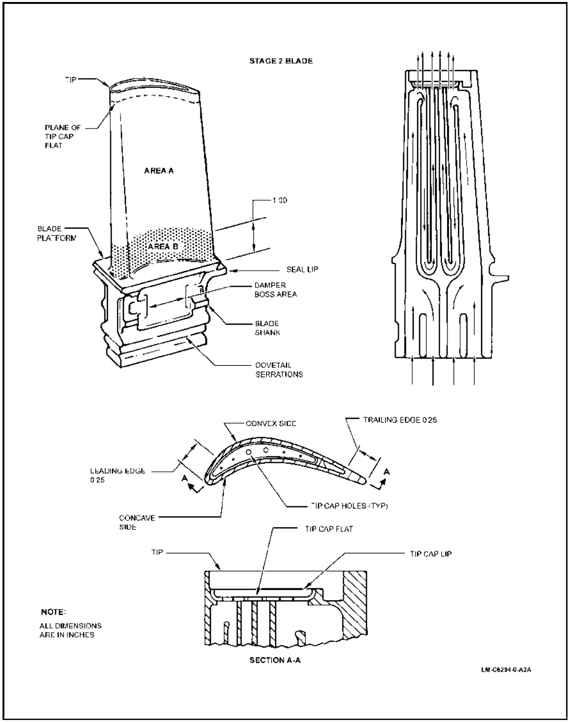


Figure 1-12. High Pressure Turbine Rotor Stage 2 Blade (Single Shank)

1.2.3.4 Stage 1 Turbine Nozzle Assembly. The major parts of the Stage 1 turbine nozzle assembly are the nozzle support, nozzles, inner seal, outer seal, and baffles.

The nozzles are coated to improve erosion and oxidation resistance. They are bolted to the Stage 1 nozzle support and receive axial support from the Stage 2 nozzle support. There are 32 nozzle segments in the assembly, each segment consisting of two vanes. The vanes are cast and then welded into pairs (segments) to decrease the number of gas leakage paths. These welds are partial-penetration welds to allow easy separation of the segments for repair and replacement of individual vanes.

The Stage 1 nozzle support, in addition to supporting the Stage 1 nozzle segments, forms the inner flow path wall from the CRF to the nozzle segments and is bolted to the aft end of the pressure balance seal support.

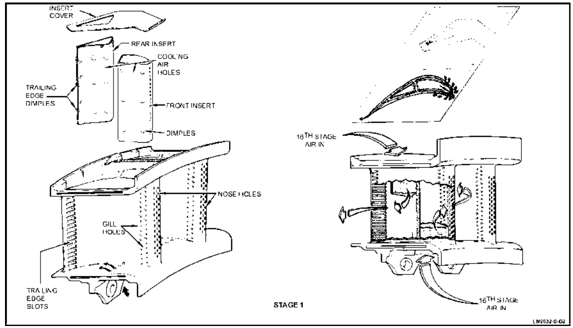


Figure 1-13. Stage 1 High Pressure Turbine Nozzle Cooling

1.2.3.5 Stage 1 Turbine Nozzle Assembly Cooling. The first stage nozzle assembly is air-cooled by convection and film-cooling by CDP air that flows through each vane. Internally, the vane is divided into two cavities. Air flowing into the forward cavity is discharged through holes in the leading edge and through gill holes on each side, close to the leading edge, to form a thin film of cool air over the length of the vane. Air flowing into the aft cavity is discharged through trailing edge slots.

1.2.3.6 Stage 2 Turbine Nozzle Assembly. The major parts of the second stage nozzle assembly are the nozzles, nozzle support, first and second stage turbine shrouds, and interstage seal.

The nozzle support is a conical section with a flange that is bolted between the flanges of the CRF and the TMF. The support mounts the nozzles, cooling air feeder tubes, and the first and second-stage turbine shrouds.

The nozzles are cast and then coated. The vanes (two per nozzle) direct the gas stream onto the second stage turbine blades. The inner ends of the nozzles form a mounting circle for the interstage seal attachment.

The turbine shrouds form a portion of the outer aerodynamic flow path through the turbine. They are located radially in line with the turbine blades and form a pressure seal to prevent excessive gas leakage over the blade tips. The sealing (rubbing) surface is nickel-aluminide compound. The first stage consists of 24 segments; the second stage, 11 segments.

The interstage seal is composed of six segments bolted to the nozzles. It minimizes the gas leakage between the second stage nozzle and the turbine rotor. The sealing surface has four steps for maximum effectiveness of each sealing tooth. The seal backing material and the honeycomb sealing surface are Hastelloy X. The seals are pregrooved to preclude seal rub under emergency shutdown conditions.

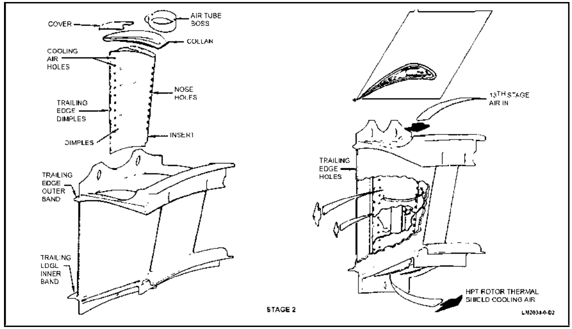


Figure 1-14. Stage 2 HP Turbine Nozzle Cooling

1.2.3.7 Stage 2 Turbine Nozzle Assembly Cooling. The second stage nozzle assembly is air-cooled by convection. The nozzle vane center area and leading edge are cooled by internal air (stage 13) that enters through the cooling air tubes. Some of the air is discharged through holes in the trailing edge, while the remainder flows out through the bottom of the vanes and is used for cooling the interstage seals and the turbine blade shanks.

1.2.3.8 Turbine MidFrame. The TMF supports the aft end of the HPT rotor and the forward end of the PT rotor. It is bolted between the rear flange of the CRF and the front flange of the PT stator. The frame provides a smooth diffuser flow passage for HPT discharge air into the PT. Piping for bearing lubrication and seal pressurization is located within the frame struts.

The frame contains ports for the HPT exhaust thermocouples and pressure probes. These ports also provide access for borescope inspection of the PT inlet area. The PT first stage nozzle assembly is part of the frame.

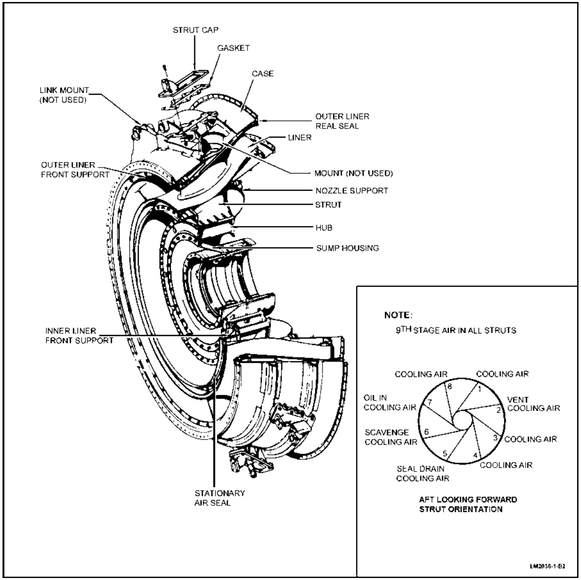


Figure 1-15. Turbine Mid-Frame

The frame hub is an open, drum-shaped, one-piece casting with flanges to support the sump housing, stationary seals, inner liner support, and PT first stage nozzle support. It has eight gusseted pads spaced around the circumference for attaching the struts.

The bearing support cone and the sump housing are bolted to the forward flange of the hub. The sump housing is of double-wall construction so that the inner or wetted wall can be cooled with air to prevent coking. The sump vent tubes also are double-walled to provide the same function.

The liner assembly consists of an inner and an outer liner held together with airfoil-shaped strut fairings butt-welded to both liners. This assembly guides the gas flow and shields the main structure from high temperature. The liner assembly is supported at the forward end by inner and outer liner supports. Seals at both ends of the inner and outer liners are provided to prevent excessive leakage of cooling air from behind the liner assembly.

The PT first-stage turbine nozzle consists of 14 segments of six vanes each. The inner end is retained by the nozzle support, and the outer end is secured between the frame aft flange and the PT stator front flange.

1.2.4 Accessory Drive Section (Ref: S9234-AD-MMO-010/LM2500)

The accessory drive section consists of an inlet gearbox in the hub of the front frame, a radial drive shaft inside the 6 o'clock strut of the front frame, and a Transfer Gear Box (TGB) bolted underneath the front frame. The fuel pump and Main Fuel Control (MFC), the pneumatic starter, and the lube and scavenge pump are mounted on the aft side of the TGB. An air-oil separator on the front is a part of the gearbox.

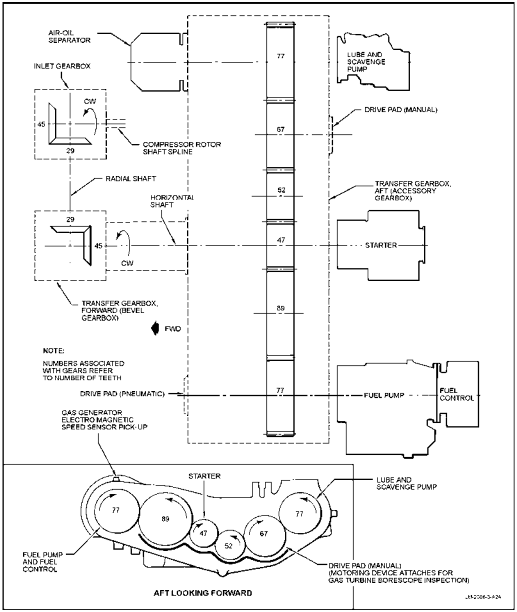


Figure 1-16. Accessory Drive Section

Power to drive the accessories is extracted from the compressor rotor through a large-diameter hollow shaft that is spline-connected to the rotor front shaft. A set of bevel gears in the inlet gearbox transfers this power to the radial drive shaft, which transmits the power to another set of bevel gears in the forward section of the TGB. A short horizontal drive shaft transmits the power to the accessory drive adapters in the TGB.

1.2.4.1 Inlet Gearbox. The inlet gearbox assembly consists of a cast aluminum casing, a shaft, a pair of bevel gears, bearings, and oil jets. The casing, which is bolted inside the front frame hub, mounts two duplex ball bearings and a roller bearing. It has internal oil passages and jets to provide lubrication for the gears and bearings. The shaft, which rotates on a horizontal axis, is splined at the aft end to mate with the second-stage disk of the compressor rotor.

The forward end of the shaft mounts the upper bevel gear and is supported by a duplex ball bearing. The lower bevel gear, which rotates on a vertical axis, is supported at its upper end by a roller bearing and at its lower end by a duplex ball bearing. The lower end is also splined to mate with the radial drive shaft.

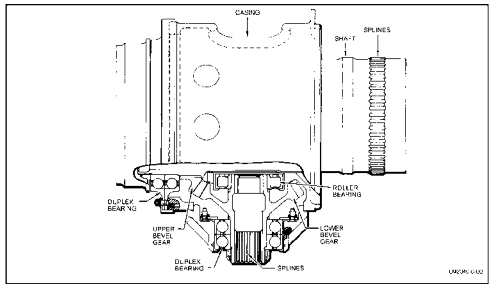


Figure 1-17. Inlet Gearbox

1.2.4.2 Radial Drive Shaft. The radial drive shaft, a hollow shaft externally splined on each end, mates with the bevel gears in the inlet and TGBs. Its function is to transmit power from the inlet gearbox to the forward section (bevel gearbox) of the TGB. The shaft contains a shear section to prevent damage to the accessory drive system.

1.2.4.3 Transfer Gearbox. The TGB assembly consists of a two-piece aluminum casing, an air-oil separator, gears, bearings, seals, oil nozzles, and accessory adapters. The forward section (bevel gearbox) contains a set of right-angle bevel gears and a horizontal drive shaft that transmits the power to the gear train in the rear section (accessory gearbox). Each bevel gear is supported by a duplex ball bearing and a roller bearing. An access cover in the bottom of the casing facilitates installation of the radial drive shaft.

The "plug-in" gear concept is used on all accessory adapters and idler gears in the aft section. This permits an entire gear, bearing, seal, and adapter assembly to be removed and replaced without disassembling the gearbox. Each spur gear is supported by a casing-mounted roller bearing on one end and an adapter-mounted ball bearing on the other end. The accessory drive spur gears are internally splined. Internal tubes and oil nozzles provide lubrication of the gears and bearings. Gearbox carbon face seals are retained from the outside of the gearbox and can be replaced without disassembly of the gearbox.

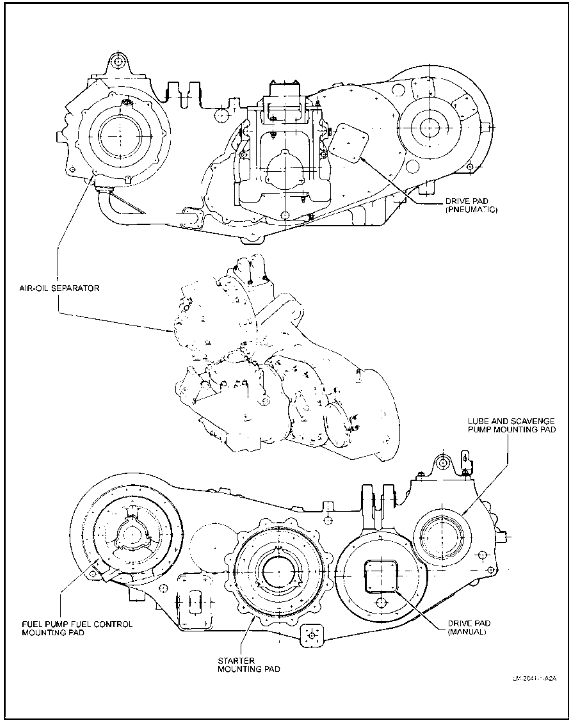


Figure 1-18. Transfer Gearbox

1.2.4.4 Air-Oil Separator. The air-oil separator consists of a fabricated sheet metal impeller with a cast aluminum housing. It is mounted on the front of the accessory section of the TGB and is considered a part of the gearbox. To prevent excessive oil loss from venting oil vapor overboard, all sumps are vented to the air-oil separator. The sump air is vented to the exhaust duct after passing through the separator. Oil is collected on the inside of the impeller as the oil-laden sump air passes through the separator.

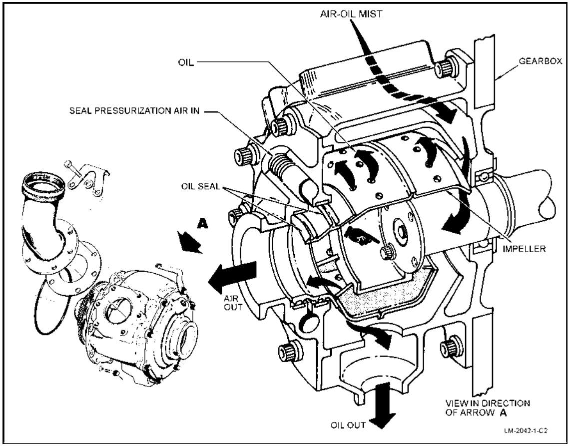


Figure 1-19. Air-Oil Separator

Small holes in the segments of the impeller allow the collected oil to be discharged to the separator outer housing. Vanes on the housing wall are used to collect and direct the oil to the gearbox. GTs with six element lube oil pumps (GTC no. 83) have oil scavenged back to the lube oil pump. To prevent oil and oil vapors from escaping past the end of the impeller, the separator has two labyrinth seals, with the cavity between the two seals pressurized with Stage 8 ejector air

1.2.4.5 Gearbox Mounted Accessories. Mounted on the Aft side of the TGB are four major accessories: the pneumatic Starter, the Lube and Scavenge Pump, the fuel pump and the MFC. The MFC is mounted on the aft side of the fuel pump.

1.2.5 Power Turbine Section (Ref: S9234-AD-MMO-010/LM2500)

1.2.5.1 Power Turbine Rotor. The PT rotor consists of six disks, each having integral spacers. Each disk spacer is attached to the adjacent disk by close-fitting bolts. The front shaft is secured between Stages 2 and 3 spacers, and the rear shaft between Stages 5 and 6 spacers. Blades of all six stages contain interlocking tip shrouds for low vibration levels and are retained in the disks by dovetails. Replaceable rotating seals, secured between the disk spacers, mate with stationary seals to prevent excessive gas leakage between stages.

1.2.5.2 Power Turbine Stator. The PT stator consists of two casing halves, Stages 2 through 6 turbine nozzles, and six stages of blade shrouds. The first-stage nozzle is part of the TMF assembly. Stages 2 and 3 nozzles have welded segments of six vanes each. Stages 4, 5, and 6 nozzles have segments of two vanes each.

Honeycomb shrouds, mounted in casing channels, mate with the shrouded blade tips to provide close clearance seals and also to act as a casing heat shield. The stationary interstage seals are attached to the inner ends of the nozzle vanes to maintain low air leakage between stages. Insulation is installed between nozzles/shrouds and casing to protect the casing from the high temperature of the gas stream.

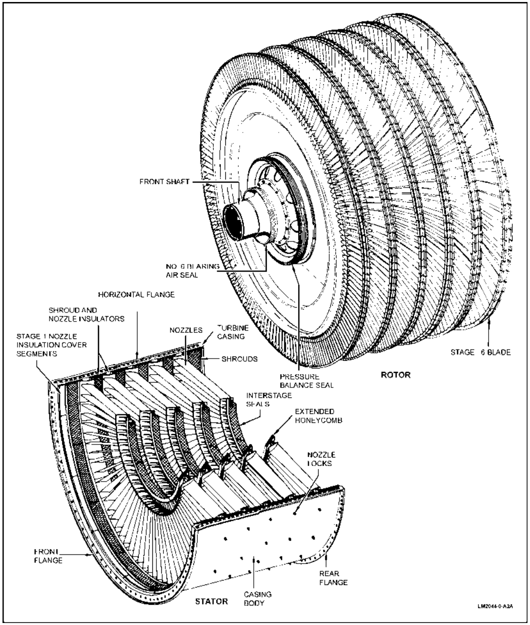


Figure 1-20. Power Turbine Rotor and Stator

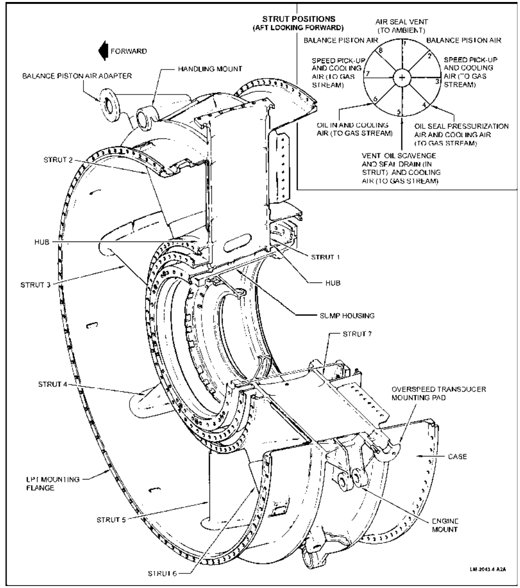


Figure 1-21. Turbine Rear Frame

1.2.5.3 Turbine Rear Frame. The TRF consists of an outer casing, eight equally spaced radial struts, and a single-piece cast steel hub. It forms the PT exhaust flow path and supports the aft end of the PT and the forward end of the HSFCS. The TRF hub supports the inner deflector of the exhaust system.

It also contains a bearing housing for the no. 7 ball and no. 7 roller bearings. The bearing housing is a one-piece casting of 17-4 PH stainless steel material. The hub and the bearing housings have flanges to which air-oil seals are attached to form the D-sump. The frame casing supports the outer cone of the exhaust system and provides attaching points for the GT rear supports. The struts contain service lines for lubrication, scavenge, and vent. The NPT pickups also pass through the struts.

1.2.6 <u>HSFC Shaft</u> (Ref: S9234-AD-MMO-010/LM2500)

The HSCS consists of a forward adapter which mates with the PT, two flexible couplings, a distance piece, and an aft adapter which mates with the ship's MRG and drive system. The forward and aft adapters are connected to the distance piece by the flexible couplings. The flexible couplings allow for axial and radial deflections between the GT and the ship's MRG during operation. Inside the aft adapter and the rear flexible coupling is an axial damper system consisting of a cylinder and a piston assembly. The damper system prevents excessive cycling of the flexible couplings. Anti-deflection rings restrict radial deflection of the couplings during shock loads.

1.2.7 <u>Bearings</u> (Ref: S9234-AD-MMO-010/LM2500)

The GTA bearings support two separate rotating systems: the GG and the PT. Seven bearings are used: no. 3, 4R, 4B, 5, 6, 7B, and 7R, (no. 1 and 2 bearings are not used in this application.) All bearing outer races, except no. 4B and 7R, are flanged. The no. 4B bearing is retained by a spanner nut across its outer face. The no. 7R bearing is retained by a tabbed ring which engages slots in the outer race. Bearings no. 3 and 5, under some conditions, can be lightly loaded. To prevent skidding of the rollers under these conditions, the outer race is very slightly elliptical to keep the rollers turning.

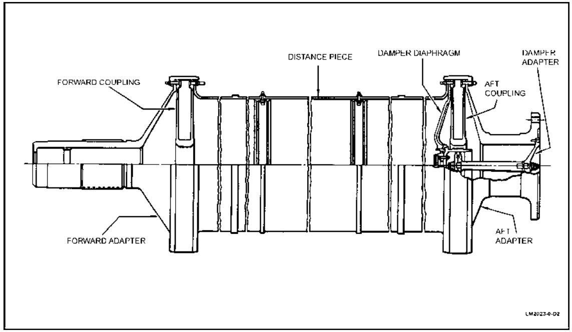


Figure 1-22. High Speed Flexible Coupling Shaft

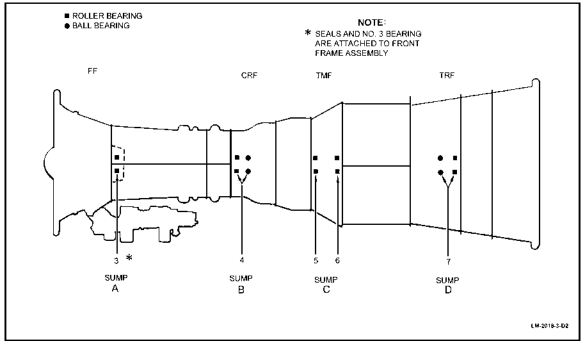


Figure 1-23. Gas Turbine Bearings

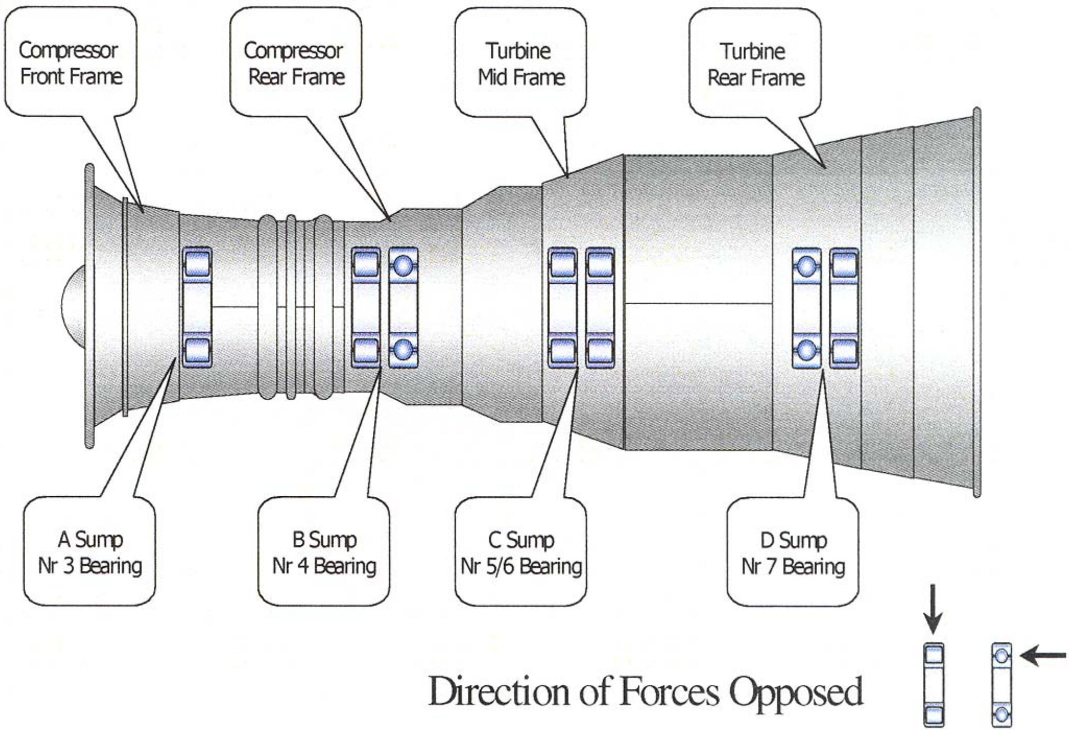


Figure 1-24. LM2500 Engine Bearing Layout

1.2.7.1 <u>Gas Generator Bearings.</u> Support for the GG rotors consists of a four-bearing system: the no. 3 and 4R bearings are roller bearings mounted on the forward and aft compressor shafts respectively, Bearing no. 4B is a ball bearing mounted adjacent to and aft of the no. 4R bearing and is used to carry the thrust load of the GG rotors. The no. 5 bearing is a roller bearing supporting the rear shaft of the GG turbine rotor.

1.2.7.2 <u>Power Turbine Bearings.</u> PT rotor support consists of three bearings: the no. 6, 7B, and 7R bearings. The no. 6 and 7R bearings are roller bearings mounted on the forward and aft rotor shafts respectively. The no. 7B bearing is a ball bearing mounted on the rear shaft, just forward of the no. 7R bearing. It carries the thrust load of the PT rotor.

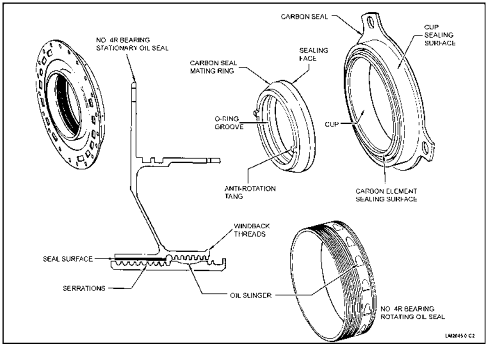


Figure 1-25. Typical Oil Seals

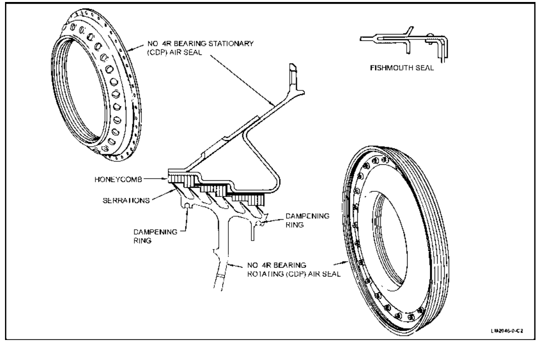


Figure 1-26. Typical Air Seals

1.2.8 <u>Seals</u> (Ref: S9234-AD-MM0-010/LM2500)

1.2.8.1 <u>Oil Seals.</u> The oil seals are of two types: labyrinth/windback used in the sump areas, and carbon seals used in the TGB. The labyrinth/windback seal combines a rotating seal having oil slingers and a serrated surface with a stationary seal having windback threads and a smooth rub surface. The oil slingers throw oil into the windback threads that direct the oil back to the sump area. The serrations cut grooves into the smooth surface of the stationary seal to maintain close tolerances throughout a large temperature range. This seal allows a small amount of seal pressurization air to leak into the sump, thereby preventing oil leakage. The carbon seal consists of a stationary spring-loaded carbon sealing ring and a rotating highly polished steel-mating ring. It prevents oil in the gearbox from leaking past the drive shafts of the starter, fuel pump, and auxiliary drive pad.

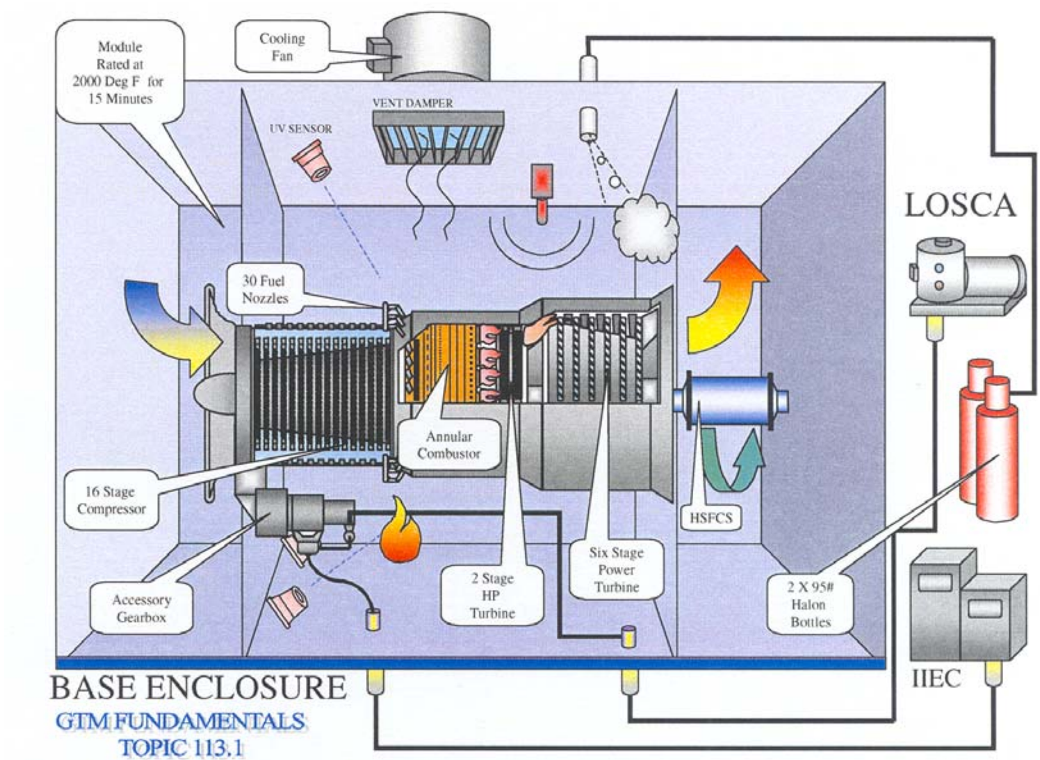


Figure 1-27.   Base Enclosure

1.2.8.2 Air Seals. The GT air seals are of two types: labyrinth/honeycomb used in the sump and turbine areas, and fishmouth used in the combustor and TMF. The labyrinth/honeycomb seal combines a rotating seal having a serrated surface with a stationary seal having a honeycomb surface. The serrations cut into the honeycomb to maintain close tolerances over a large temperature range. The fishmouth seals are circular, sheet metal, stationary, interlocking-type seals used to prevent excessive leakage of hot combustion gas from the primary airflow.

1.2.9 Gas Turbine Modules (Ref: S9234-AD-MMO-010/LM2500)

The main propulsion GTs are housed in modular enclosures. The enclosures provide for GT mounting, GT cooling, airborne noise reduction, and fire extinguishing capability. Attenuation of structure-borne noise, and vibration and shock protection for the GTM are accomplished with a resilient mounting system (32 Module Mounts) between the modules and the propulsion bedplates.

1.2.10 Intake and Exhaust Systems (Ref: S9234-AD-MMO-010/LM2500)

The main propulsion intake systems supply a high volume of air from the atmosphere to the GTM with minimum pressure drop. The intake ducts also provide moisture separation, silencing, anti-icing protection, and GT cooling air. Blow-in doors protect the GT from air starvation in the event of inlet blockage.

The intake systems also allow for main propulsion GT removal. The main propulsion exhaust system routes the GTM exhaust gases to the atmosphere. They are designed to prevent re-ingestion of exhaust gases into the intakes and minimize heating of topside equipment. Exhaust duct sidewall baffles reduce the exhaust noise level.

1.3 FUNCTIONAL DESCRIPTION

1.3.1 Fuel System (Ref: S9234-AD-MMO-010/LM2500)

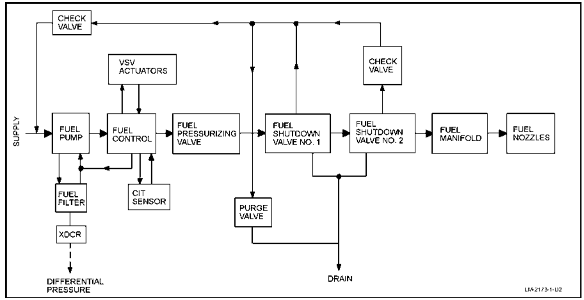


Figure 1-28. LM2500 Fuel Oil System

The fuel system regulates and distributes fuel to the combustion section of the Gas Generator (GG) to control Gas Generator Speed (NGG). The Power Turbine Speed (NPT) is not directly controlled, but is established by the gas stream energy level produced by the GG. An electronic overspeed switch that is located in the electronic enclosure provides overspeed protection.

Fuel from the ship's supply flows through the base inlet connector to the fuel pump boost element. From the boost element, it passes through the pump high-pressure element, through a pump-mounted filter, to the fuel control. A filter bypass valve will allow fuel to bypass the filter if it becomes clogged.

To assure an adequate supply of fuel for Gas Turbine (GT) operation, the fuel pump has a higher fuel flow capacity than the GT uses. The fuel is divided within the fuel control into metered flow and bypass flow. A bypass valve accomplishes this division as it maintains a preset pressure drop across the metering valve. Bypass fuel is ported to the high-pressure element inlet screen of the fuel pump. If an abnormal condition occurs that causes pump outlet pressure to become too high, a relief valve in the pump bypasses fuel back to the high-pressure element inlet screen.

A pressurizing valve, mounted on the fuel control outlet port, maintains backpressure to ensure adequate fuel pressure for fuel control servo operation. Two electrically operated fuel shutdown valves connected in series provide a positive fuel shutoff. When the fuel shutdown valves are open, metered fuel for GT operation flows from the fuel control, through the pressurizing valve, shutdown valves, fuel manifold, and fuel nozzles. When the fuel shutdown valves are closed, metered fuel is bypassed to the fuel pump inlet, and the fuel drain ports in the valves open to allow fuel remaining in the manifold, nozzles, and lines to drain. Thirty fuel nozzles, which project through the compressor rear frame into the combustor, produce an effective spray pattern from start to full power.

The fuel and speed governing system controls the variable vanes to maintain satisfactory compressor performance over a wide range of operating conditions. At high inlet air temperature and low compressor speeds, the larger forward stages of the compressor are capable of pumping more air than the smaller aft stages. Because of this characteristic, the aft stages could become overloaded, causing the airflow to stop and possibly reverse. This is known as compressor stall and is prevented by having the Inlet Guide Vanes (IGVs) and first six stages of Variable Stator Vanes (VSVs). The fuel and speed governing system controls the VSVs, scheduling them towards the closed position when compressor speed drops or inlet temperature rises, thereby matching the output of the forward stages to that of the rear stages.

The VSVs are positioned by two hydraulic actuators, operated by fuel pressure from the fuel control, position the VSVs. In the fuel control is a VSV scheduling cam, which is positioned by NGG and Compressor Inlet Temperature (CIT) signals, a variable vane feedback mechanism (which receives a VSV position signal front external linkage), and a VSV pilot valve (which is positioned as a result of the comparison of the scheduling cam position and the feedback signal). Changes in NGG rotate the scheduling cam, while changes in CIT translate the cam. Movement of the cam repositions the pilot valve. The pilot valve ports high-pressure fuel (fuel pump discharge pressure) to either the rod-end (closing) or head-end (opening) of the VSV actuators and vents the other end to bypass pressure.

The VSV actuating linkage mechanically transmits the actuator movement to the VSVs and IGVs. A flexible cable attached to the linkage transmits a feedback signal to the fuel control. The feedback mechanism in the control repositions the pilot valve to terminate the actuator signal when the VSVs reach the scheduled position.

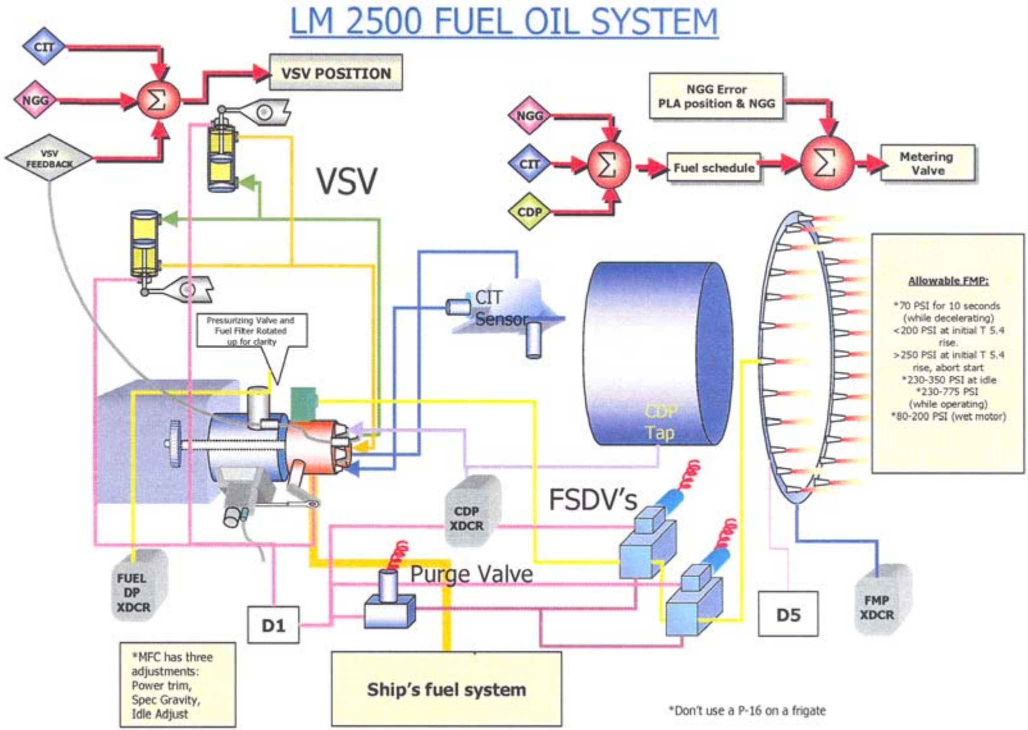


Figure 1-29. LM2500 Fuel Oil System

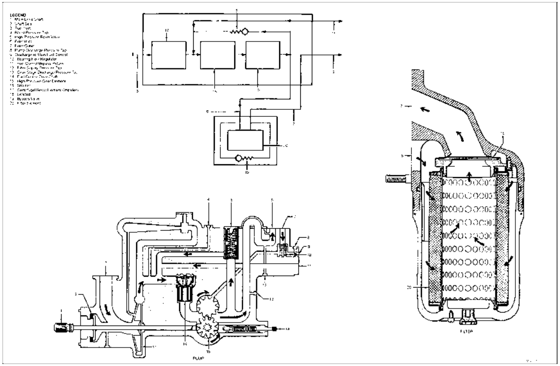


Figure 1-30. Fuel Pump and Filter

1.3.1.1 Fuel Pump And Filter. The fuel pump contains two pumping elements, a centrifugal boost element and a high pressure gear element. It provides mounting pads and flange ports for the fuel filter and the Main Fuel Control (MFC). This feature reduces the amount of external piping required. The pump also provides a drive shaft for the MFC, eliminating the need for a separate Transfer Gearbox (TGB) drive pad.

a. Fuel from the ship's supply enters the pump through the fuel inlet port, is boosted in pressure by the centrifugal boost element and discharges into a circumferential scroll. The flow passes through a screen that has an integral bypass, and then into the high pressure positive displacement gear element. The combination of pumping elements is designed to provide improved fuel pump characteristics so that normal operation can be sustained without external boost pumps. The pump incorporates a high pressure relief valve which cracks at not less than 1350 PSIA and reseats at not less than 1325 PSIA, thereby protecting the pump and downstream components against excessive system pressures.

b. The fuel filter is a high pressure filter mounted on the fuel pump and flangeported to eliminate external piping. The head houses a bypass relief valve, and the bowl houses the filter element. The filter element, which is rated at 46 microns nominal and 74 microns maximum, prevents larger contaminants from being carried into the MFC.

c. High pressure fuel flows from the fuel pump through the flange port and enters the filter bowl. The fuel then flows from the outside of the filter element to the center, up into the head, out the flange return port, and back into the fuel pump where it is routed to the MFC. If the filter becomes clogged, the bypass relief valve will open at 35 PSID, allowing fuel to bypass the filter element. The relief valve resets at 27 PSID.

1.3.1.2 Fuel Control and Pressurizing Valve.

a. The MFC is basically a speed governor which senses NGG speed and power lever position and adjusts the fuel flow as necessary to maintain the desired speed set by the power lever. The control is a hydromechanical device that operates by use of fuel-operated servo valves. It performs the following functions:

(1) Controls speed by metering fuel to the fuel nozzles during acceleration, deceleration, and steady-state operation. Excess fuel supplied by

the fuel pump to the control is returned to the pump downstream of its low pressure element. The control also uses the fuel from the pump as a hydraulic medium.

(2) Alters the fuel schedule automatically to maintain the speed setting and establishes fuel limits for acceleration and deceleration. The GT parameters vary, so the fuel limits vary to provide optimum acceleration and deceleration schedules. In order for the control to determine the schedules, certain parameters - Compressor Discharge Pressure (CDP), Compressor Inlet Temperature (CIT), and Gas Generator Speed (NGG) must be sensed. The control, using hydromechanical mechanisms, senses the parameters and computes a limit. The computed limit is compared with actual fuel flow and controls the metering valve should the Governor attempt to exceed the limit.

(3) Schedules Variable Stator Vane (VSV) position and directs high pressure (pump discharge) fuel to the VSV actuators to position the vanes as the schedule changes. The signal which determines the position of the VSV actuators is the result of the control sensing NGG and CIT and computing the optimum schedule.

b. The control may be divided into a number of working sections, each of which serves a specific function. The operation of these sections is described in the following paragraphs.

1.3.1.3 Fuel Supply. Fuel is supplied to the control at fuel pump discharge pressure. The pump supplies more fuel than is required for any engine operating condition. Required fuel flow is determined by a metering valve orifice area, with excess fuel being directed through a bypass valve to the fuel pump. Regulated pressure in the case of the control is used as a reference pressure in the servomechanisms.

a. One of the three parameters which determine the fuel flow limits is NGG. The fuel control contains a three dimensional (3-D) cam which is rotated in proportion to NGG.

b. The second of the three parameters is CIT. The three dimensional cam is moved axially in relation to CIT.

c. The third parameter is CDP. Changes in CDP rotate the CDP cam that is mechanically linked to the 3-D cam by levers that combine the output of both cams in adding linkage.

d. For each NGG and CIT combination there is a unique position of the 3-D cam. The combination of the 3-D cam position and the CDP cam output in the adding linkage defines the allowable acceleration fuel flow limit. A third input, which represents metered fuel input to the Gas Generator (GG) is combined to the adding linkage to determine acceleration and deceleration limits.

e. Power demand is applied through the Power Lever Angle (PLA) Actuator to a speed governor. The speed governor senses GG speed. The governor automatically controls flow of fuel to the GG to maintain a constant GG speed. This is accomplished by means of a flyweight and pilot valve.

f. To ensure that the GG never exceeds a predetermined safe operating speed, fuel flow is reduced by means of a force applied to a constant differential pressure valve.

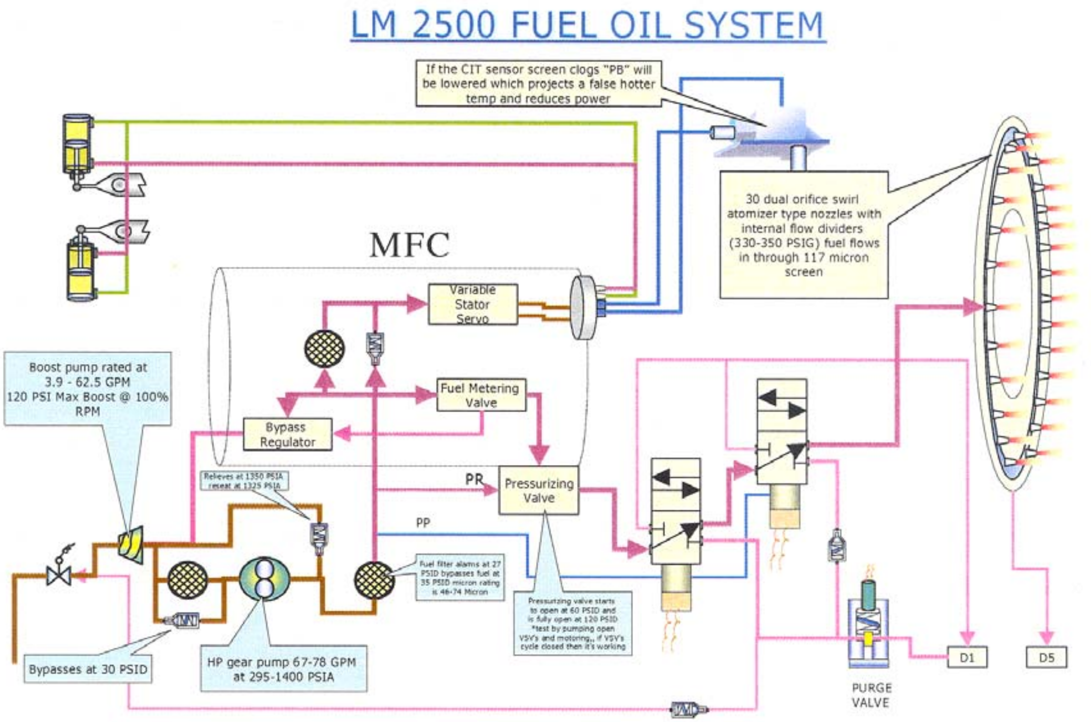


Figure 1-31.   LM2500 Fuel Oil System

1.3.1.4 Variable Stator Vane Positioning. The variable vane valve integrates signals from the 3-D cam (GG speed and CIT parameters) and stator vane feedback. The valve then directs a resulting high pressure hydraulic signal to one of two sides of the pistons in the two variable vane actuators mounted on the GG compressor. The actuators mechanically position the VSVs. The stator vane feedback signal, which is developed at the no. 1 actuator bellcrank and transmitted to the control by flexible cable, represents actual stator vane position. The bottom half of the 3-D cam contains the mechanical schedule for fuel flow. The top half is designed to control variable vane position. Cam output is mechanically transmitted to the variable vane valve. When the valve is moved, fuel pressure is ported to either the rod-end or head end of the variable vane actuators. Actuator movement, sensed by the variable vane feedback cable, renulls the variable vane valve.

a. The pressurizing valve pressurizes the fuel system to provide adequate fuel control servo supply and variable vane actuation pressures during GG operation at low fuel flow levels. It is a fuel-pressure- operated valve.

b. The fuel pressurizing valve is held closed by spring pressure and fuel pressure from the fuel control. As fuel pressure at the valve inlet reaches opening pressure, the valve piston is driven open; fuel goes into the valve sleeve, then passes through ports in the sleeve to the valve outlet port. At GG shutdown, when inlet fuel pressure drops below approximately 60 PSIG above reference pressure, spring force returns the piston to its seat to shutoff the normal flow path.

1.3.1.5 Fuel Shutoff Valves. Two identical, pilot-valve-actuated, electrically controlled fuel shutoff valves are used on the GG. When energized, they port the metered fuel to the GG fuel manifold. When deenergized, they port the fuel to bypass (at the fuel pump inlet).

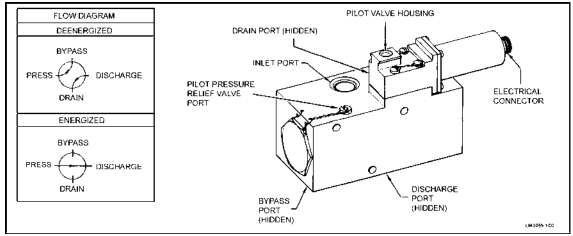


Figure 1-32. Fuel Shutoff Valve

a. The fuel shutoff valves are in series in the fuel line and in parallel electrically. Thus both valves must be energized to permit fuel flow to the manifold, but de-energizing of either valve will shutoff fuel flow to the manifold. In operation, pilot pressure is supplied to the valves by the fuel pump. When the valves are energized, internal pilot valves will port this pressure to actuate the main shutoff valves. When deenergized, the pilot valves will cause the shutoff valves to port the inlet pressure to the fuel pump inlet and the manifold to drain.

b. Each shutoff valve has a pilot pressure bleed relief valve to prevent backflow through the valve during GT motoring. Later configurations may have blocking tabs (IGTC 63) or plugs (GTC 57) installed in place of pilot pressure relief valves to prevent fuel leakage into manifold. A check valve having a 2

PSID cracking pressure is located in the bypass port of the no. 2 shutoff valve to prevent fuel backflow into the no. 2 valve bypass line.

1.3.1.6 Fuel Nozzle. The fuel nozzle is a dual orifice, swirl atomizer with an internal flow divider. Fuel enters the nozzle through an individual fuel tube encased in a leak barrier (shroud) tube. The 30 fuel nozzles produce the desired spray pattern throughout the range of fuel flows.

Fuel entering the nozzle flows through a 117-micron screen and then the flow divider. When the nozzle is pressurized, primary fuel flows into a drilled passage and tube assembly in the nozzle shank, through the primary fuel spin chamber, and into the combustor. When nozzle fuel pressure rises to 330-350 psi, the flow divider opens to introduce secondary flow. Secondary fuel flows from the nozzle fuel chamber, through the flow divider, down the nozzle shank, into the secondary fuel spin chamber, and combines with the primary flow as it enters the combustor. A small quantity of air is scooped out of the main airstream by the shroud on the nozzle tip. This cools the nozzle tip and retards the accumulation of carbon deposits on its face.

1.3.1.7 Variable Stator Vane Actuators. Two VSV actuators, mounted tangentially on the compressor stator front flange at the 3 and 9 o'clock positions, mechanically position actuator levers which control VSV angles. The VSV actuators are single-ended, uncushioned hydraulic cylinders that are driven in either direction by high pressure fuel. Piston stroke is controlled by internal stops. A cross-piston, bi-directional bleed flow is provided. The actuator is sealed against fuel leakage by two rod-end seals. A port between the two rod-end seals drains any leakage past the first seal. A wiper is provided to ensure the piston rod is dirt-free as it moves through the seals.

The end of the rod is threaded and fitted with an adjustable extension containing a spherical bearing.

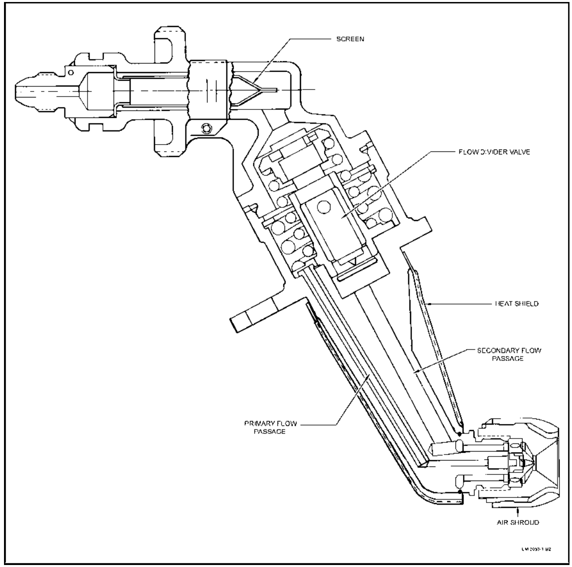


Figure 1-33. Fuel Nozzle

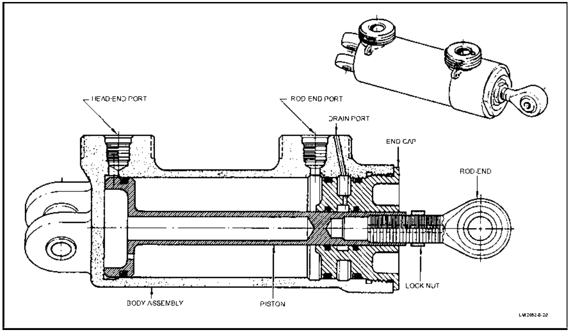


Figure 1-34.   Variable Stator Vane Actuators

The fuel control schedules high-pressure fuel to either of the ports (rod-end or head end) with resulting piston movement in the desired direction. The fuel control also will reduce pressure in the opposite direction of desired movement. Seal leakage fuel is drained out through the drain port. Each actuator is connected to a master lever mounted on a pivot post located at the 3 o'clock and 9 o'clock position at the outside of the compressor case at approximately, the 10th stage. Adjustable interstage linkages connect directly from the master levers to the actuation ring connectors. All actuation driving mechanisms are spherical-bearing-mounted or slot loaded bearing mounted to eliminate misalignment. The actuation ring (halfrings) connectors, which are linked at the horizontal splitline of the compressor stator, rotate circumferentially about the horizontal axis of the compressor. Movement of the half-rings is transmitted to the individual vanes through vane actuation levers.

1.3.1.8 Purge Valve. The purge valve is an electrically operated, normally closed, on-off valve used to drain low-temperature fuel from the system prior to GT start. It is spring-loaded to the closed position; a solenoid opens the valve when energized. Approximately three gallons of fuel are drained from the system during purging.

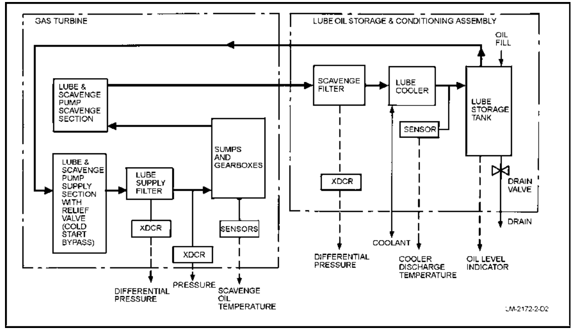


Figure 1-35.   LM2500 Lubrication System

1.3.2 Lube Oil System (Ref: S9234-AD-MMO-010/LM2500)

The lubrication system provides the GT bearings, gears, and splines with adequate cool oil to prevent excessive friction and heat. Lubrication oil is stored in an oil tank, which is a component of the Lube Oil Storage and Conditioning Assembly (LOSCA).

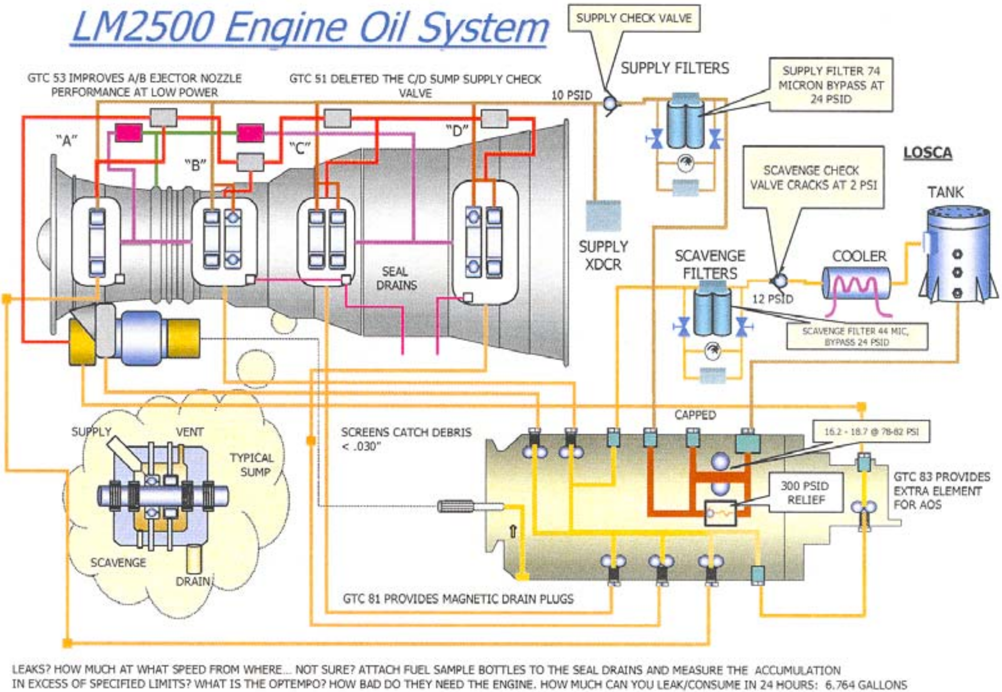


Figure 1-36. LM2500 Engine Oil System

The oil is gravity-fed to the GT mounted lube and scavenge pump. The single supply element of the pump forces the oil through tubes to components and areas requiring lubrication. A duplex filter mounted in the enclosure provides filtration of lube supply oil. Oil nozzles direct the oil onto bearings, gears, and splines. Five or six separate scavenge elements in the lube and scavenge pump remove oil from the A-, B-, C-, and D-sumps, Transfer Gearbox (TGB) and the Air Oil Separator for six element pumps. The scavenged oil is returned to the LOSCA where it is filtered, cooled, and stored. Scavenge oil filtration is provided by a duplex filter mounted on the lube storage tank.

The lubrication system is divided into three subsystems identified as lube supply, lube scavenge, and sump vent.

The lube supply subsystem consists of the Oil tank, Lube and scavenge pump supply section and relief valve (cold start bypass), Lube Supply Duplex Filter, Lube supply check valve, and the C and D sump supply check valve.

Lube oil from the supply tank enters the lube and scavenge pump through an inlet screen, which prevents particles larger than 0.030 inch in size from entering. Output of the supply elements is routed to the lube supply filter. The filter is duplex which allows manual switching from one filter to the other if one of the filters becomes clogged. Each filter incorporates a pressure relief bypass valve to allow full flow to the GT if the filter element becomes clogged. From the filter, the oil flows through a check valve to the inlet gearbox, the TGB, and the GT sumps. Oil going to the C- and D-sumps passes through an additional check valve in the C and D sump supply line.

NOTE

After compliance with GTC no. 51, the additional check valve in the C- and D-sump supply line will not be on the GG.

1.3.2.1 Lube scavenge subsystem. The lube scavenge subsystem consists of the following components: lube and scavenge pump scavenge elements, lube scavenge duplex filter, lube scavenge check valve, heat exchanger (oil cooler).

The five scavenge elements of the lube and scavenge pump scavenge oil from the B-, C-, and D-sumps, and from two areas of the accessory gearbox. Each scavenge element of the pump has an inlet screen which prevents particles larger than 0.030 inch from entering. Oil from the air-oil separator drains into the aft section of the TGB. Oil from the inlet gearbox and the A sump drains through the radial driveshaft sleeve into the forward section of the TGB. Oil from the five scavenge elements exits the pump from a common discharge port. This scavenge discharge is routed to the duplex filter mounted on the LOSCA oil tank. From the filter, the oil passes through a check valve to the LOSCA heat exchanger and then enters the oil tank.

1.3.2.2 Sump Vent Subsystem. The sump vent subsystem consists of one major part, the air-oil separator, and the piping and tubing making up the subsystem.

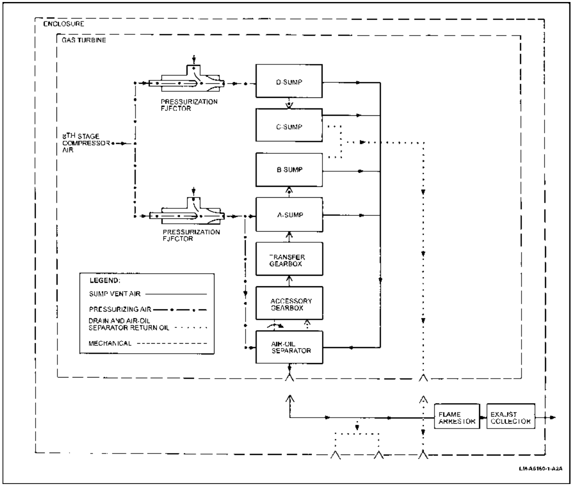
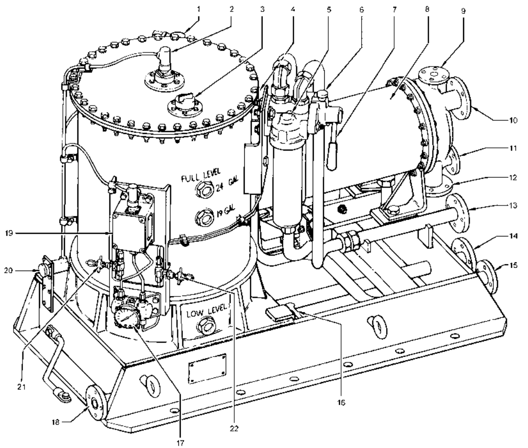


Figure 1-37. Sump Vent System

To prevent oil leakage, main bearing oil seals use pressurization air to cause air to flow across the seals into the sumps. Seal pressurizing air is extracted from the eighth-stage of the compressor and distributed to the oil seals. Ambient air is added to the eight-stage air by means of ejectors to increase the volume and reduce the temperature and pressure. To remove the air, which enters the sumps through the oil seals, and to maintain a pressure drop across the oil seals, the sump air is vented. Each sump area is connected to a sump vent manifold through frame struts. The manifold connects to the air-oil separator, which extracts oil from the air before venting the air into the exhaust duct. Extracted oil is returned to the TGB.

1.3.2.3 Oil Tank (DD-963 and FFG-7). The oil tank is an integral part of the Lube Oil Storage and Conditioning Assembly (LOSCA). The early configuration of cast construction for DD-963, contains six sight glasses (view ports) for visual determination of oil level in the tank. Starting with the second glass from the bottom, they are spaced at 5-gallon intervals. On the later configuration of fabricated construction, three sight glasses are provided for low level, 19-gallon level and full level positions. On DD-963 and CG-47, an oil level switch monitors oil level from within the tank and transmits an electrical signal when the oil level is too high or too low. On FFG-7, DDG-51, an oil level sensor monitors oil level from within the tank and transmits a continuous electrical signal for remote readout of lube oil level. The oil tank is considered full when oil level is visible at the 24-gallon sight glass.

Mounted on the tank are instrumentation valves, a filter differential pressure transducer, a filter differential pressure gage, and an oil temperature sensor. A gravity filler cap is installed on the tank cover fill port. The fill port incorporates a strainer to prevent foreign material from entering the tank. Baffles, located in the bottom of the tank, minimize oil sloshing. Inside the tank at the scavenge inlet is a deaerator which separates air from the scavenge oil. The oil tank may be drained by positioning a lever located in the assembly base.



LEGEND:

1 HEAT EXCHANGER OUTLET TEMP SENSOR	12. HEAT EXCHANGER COOLANT OUT -L5
2 OIL TANK LEVEL SWITCH	13 SCAVENGE OIL FROM GAS TURBINE -L2A
3 GRAVITY FILL CAP	14 LUBE OIL TO GAS TURBINE -L1A
4 HEAT EXCHANGER LUBE VENT (NOT SHOWN)	15 OIL TANK VENT TO DRAIN -D7
5 SCAVENGE OIL FILTER	16. OIL TANK DRAIN VALVE HANDLE
6 FILTER SELECTOR LOCK	17 SCAVENGE FILTER ΔP GAGE
7 FILTER SELECTOR	18. OIL TANK DRAIN -D6
8 HEAT EXCHANGER	19 SCAVENGE FILTER ΔP XCDR
9 HEAT EXCHANGER COOLANT VENT -L8	20 ELECTRICAL CONNECTOR -E15
10 HEAT EXCHANGER COOLANT IN -L4	21. INSTRUMENTATION VALVE
11 HEAT EXCHANGER COOLANT DRAIN -D13	22. INSTRUMENTATION AND OIL SAMPLE VALVE

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Figure 1-38. Lube Oil Storage and Conditioning Assembly

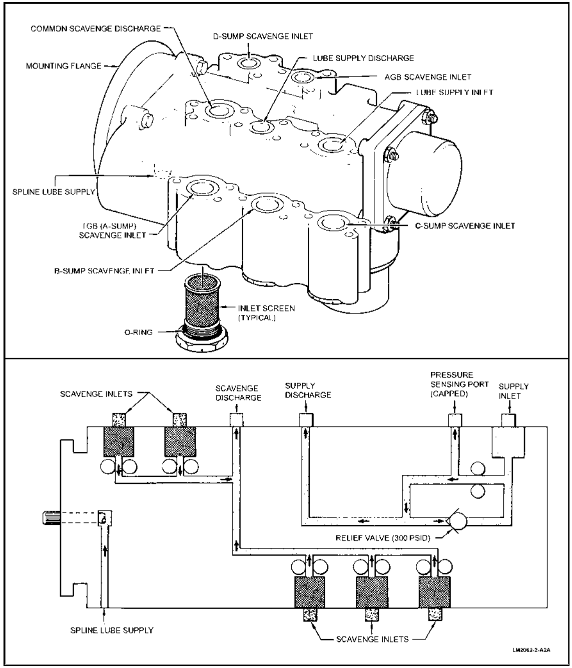

Figure 1-39. 5 Element Lube and Scavenge Pump (Before GTC No. 83)

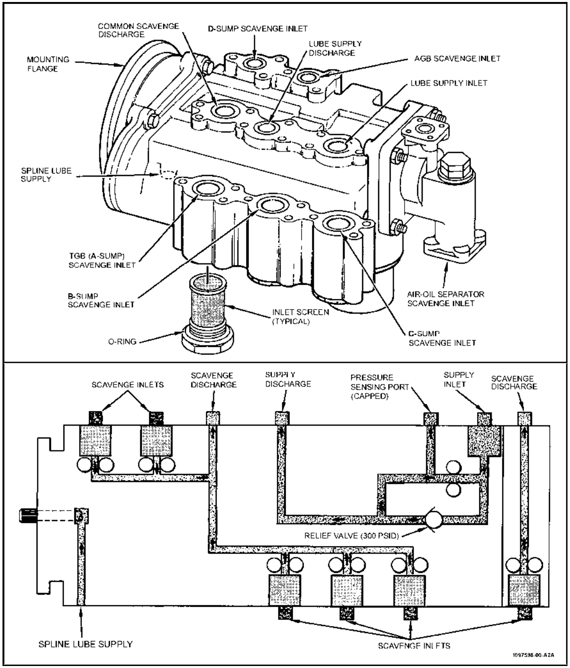

Figure 1-40. Six Element Lube and Scavenge Pump (After GTC No. 83)

1.3.2.4 Lube and Scavenge Pump, Supply Section.

NOTE

There are two types of lube and scavenge pump configurations: Five-element pump (before GTC no. 83) and Six-element pump (after GTC no. 83).

a. The lube and scavenge pump is a positive displacement, vane type pump. The pumps have either five (before GTC no. 83) or six (after GTC no. 83) elements used for lube scavenging and one element for lube supply. Within the pump are inlet screens, one for each element, and a lube supply pressure limiting valve.

b. Oil enters the lube inlet port and passes through a removable, non-bypassing inlet screen which traps particles larger than 0.030 inch. A lube supply pressure limiting valve is provided to limit supply pressure. It is located between the inlet and outlet of the supply element.

NOTE

Lube pump has mag plugs in screens per GTC no. 81

1.3.2.5 Lube Supply Filter. The lube supply filter is of the duplex type, with provisions for manual selection of either element. The duplex filter is located within the enclosure on the base, on the right hand side of the GT aft looking fwd.

a. Oil from the lube and scavenge pump enters the duplex filter inlet port, flows through the selected element (outside to inside), and exits through the filter outlet port. Filter element selection is made by raising the spring-loaded lockpin and moving the lever to the desired position. Release the lockpin, making certain that the pin engages the locking slot in the lever. A drain plug is located at the bottom of each filter bowl so that the oil can be drained from the element prior to its removal for cleaning.

b. A poppet type relief valve is located in the head of the duplex filter which opens at 24 PSID to allow the oil to bypass the filters if they become clogged.

1.3.2.6 Lube Supply Check Valve. The lube supply check valve is located on the downstream side of the lube supply filter. It will open and flow 20 gpm with a maximum differential pressure of 15 PSID. The purpose of the check valve is to prevent the oil in the tank from draining into the sumps and gearbox when the GT is shutdown.

1.3.2.7 C&D Sumps Check Valve. C&D check valve deleted by GTC no. 51.

1.3.2.8 Sumps and Oil Seals. The seven principle bearings supporting the two separate rotating systems are located in four sump enclosures as follows: Bearing no. 3 in the A-sump Bearing no. 4R and 4B in B-sump Bearing no. 5 and 6 in C-sump Bearing no. 7B and 7R in D-sump. Oil from the lube supply system is fed to each of the sumps under controlled pressure and directed by jets on to the bearings. Each of the sumps are encased in protective air jackets, maintained by air seals, which prevents excessive heat from reaching the oil wetted walls of the inner oil seals, thereby preventing coking and thermal deterioration of the oil.

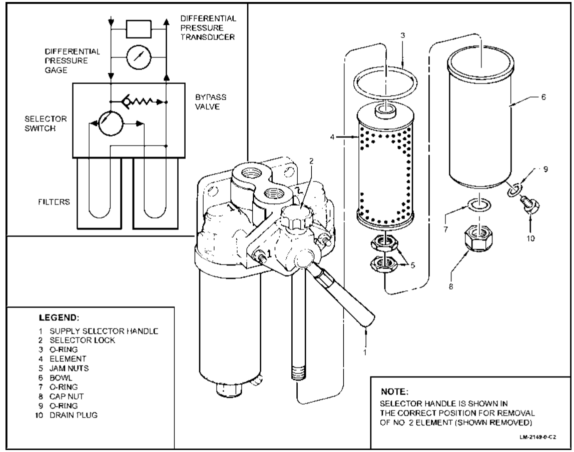

Figure 1-41. Lube Oil Supply and Scavenge Filter

To prevent oil leakage, main bearing oil seals use pressurization air to cause air to flow across the oil seals into the sumps. Seal pressurizing air is extracted from the eighth stage of the compressor and distributed to the oil seals. To remove the air that enters the sumps through the oil seals and to maintain a pressure drop across the oil seals, the sump air is vented. Each sump area is connected to a sump vent manifold through frame struts. The manifold connects to the air-oil separator which extracts oil from the air before venting the air into the exhaust duct. Extracted oil is returned to the TGB.

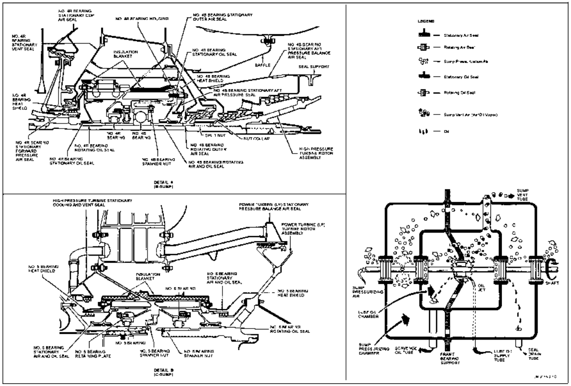

Figure 1-42. Typical Sumps

1.3.2.9 Gearbox and Seals. The TGB contains carbon oil seals that depend on a tight fit (rub) of the stationary member against the rotating member to prevent oil from crossing the seal. The stationary member is a carbon ring that is spring-loaded against a highly polished steel rotating mating ring.

a. Oil is directed into the gearbox bearings by lube nozzles and is scavenged from the gearbox through a port located on the bottom aft face of the gearbox. Oil draining from the A-sump (compressor front frame) flows into and is scavenged from the TGB.

b. The gearbox is vented through the radial drive shaft and drive shaft housing into the A-sump cavity and out through the compressor front frame strut.

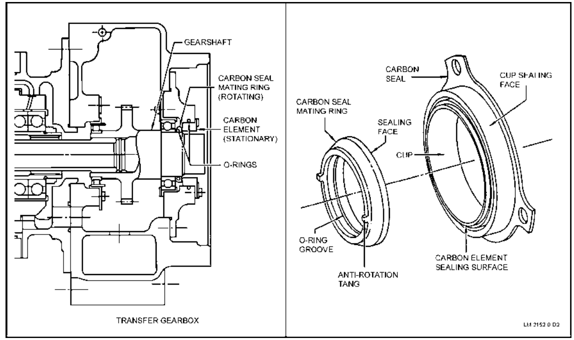

Figure 1-43. Gearbox Oil Seals

1.3.2.10 Lube and Scavenge Pump, Scavenge Section.

NOTE

There are two types of lube and scavenge pump configurations: Five element pump (before GTC No. 83) and Six element pump (after GTC No. 83).

a. Scavenge oil enters the pump through scavenge oil ports, passes through an inlet screen in each port, and enters the scavenge element. The lube and scavenge pump scavenge discharge is routed to the duplex filter mounted on the LOSCA oil tank.

b. On five-element pumps, the elements of the lube and scavenge pump scavenge oil from A-, B-, C-, and D-sumps, and AGB. The output of the five scavenge elements are connected inside the pump and discharge through a common scavenge discharge port. There are five Resistance Temperature Detector (RTDs) located in the scavenge oil system lines, in the immediate vicinity of the pump. They sense oil temperature for A-, B-, C-, and D-sumps and AGB and provide a signal to the off-engine electronic controls.

c. On six element pumps, the elements of the lube and scavenge pump scavenge oil from A-, B-, C-, and D-sumps, AGB, and air-oil separator. The output of A-, B-, C-, and D-sumps, and AGB scavenge elements are connected inside the pump and discharge through a common scavenge discharge port. The output of the air-oil separator scavenge element is routed via an external tube to the scavenge discharge port tube. There are five RTDs located in the scavenge oil system lines, in the immediate vicinity of the pump. They sense oil temperature for A-, B-, C-, and D-sumps and AGB and provide a signal to the off-engine electronic controls.

1.3.2.11 Duplex Scavenge Filter. The scavenge oil filter is the duplex type with provisions for manual selection of either element while the GT is shutdown or operating. The scavenge filter is located on and is part of the LOSCA.

a. Oil from the GT enters the filter inlet port, flows through the selected element (outside to inside), and exits through the filter outlet port. A drain plug is located at the bottom of each filter bowl so that the oil may be drained from the element prior to its removal for cleaning. Filter selection is made by placing the selector lever in front of the element not to be used. The spring-loaded lockpin must be raised from its locking slot before the lever can be moved. The lockpin must be engaged in the locking slot after the lever is positioned to keep the lever from being accidentally moved.

b. A poppet type relief valve is located in the head of the duplex filter which opens at 24 PSID to allow oil flow if filters should become clogged. The relief valve closes at 20 PSID.

1.3.2.12 Scavenge Check Valve. The scavenge check valve is located between the scavenge filter and the heat exchanger. It will open and flow 20 gpm with a maximum differential pressure of 15 PSID. The purpose of this check valve is to prevent the oil in the scavenge lines from draining back into the sumps and gearbox when the GT is shutdown.

1.3.2.13 Heat Exchanger. The heat exchanger (oil cooler) is a shell-tube assembly with the coolant (ship's MRG lube oil) passing through the inside of the tubes and the GT lube oil flowing around the outside of the tubes. Flange-type ports are used for coolant connections; threaded ports are used for oil inlet, discharge, and venting. Direct access to the inside of the coolant tubes for cleaning is accomplished by removing the end domes.

Coolant flows into the heat exchanger, passes through one set of tubes enroute to the back of the exchanger, returns through another set of tubes, and exits the heat exchanger. Coolant may circulate continuously, even when the GT is shutdown. GT lube oil enters the heat exchanger through the oil inlet, flows around the coolant tubes, and exits through the oil outlet port. Vent ports (not used) are provided for both oil and coolant cavities. A drain port is provided for draining the coolant.

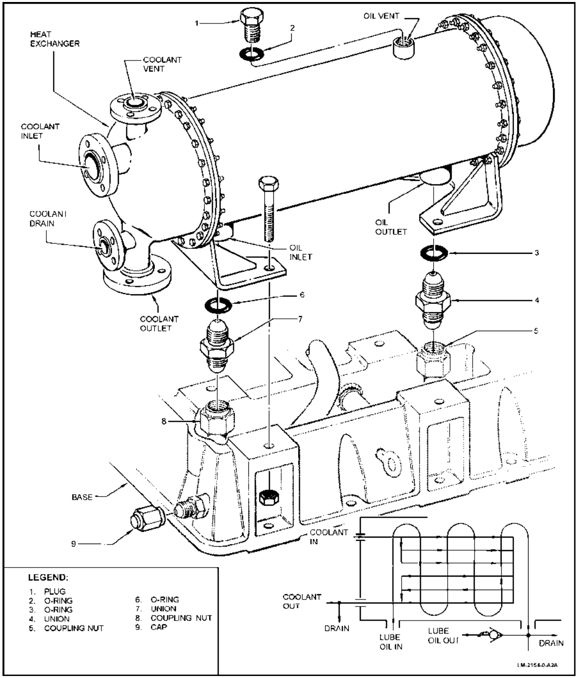

Figure 1-44. Heat Exchanger

1.3.2.14 Air-Oil Separator. Each of the sumps are encased in protective air jackets, maintained by air seals, which prevents excessive heat from reaching the oil wetted walls of the inner oil seals, thereby preventing coking and thermal deterioration of the oil.

a. To prevent oil leakage, main bearing oil seals use pressurization air to cause air to flow across the oil seals into the sumps. Seal pressurizing air is extracted from the eighth-stage of the compressor and distributed to the oil seals. To remove the air that enters the sumps through the oil seals and to maintain a pressure drop across the oil seals, the sump air is vented. Each sump area is connected to a sump vent manifold through frame struts. The manifold connects to the air-oil separator that extracts oil from the air before venting the air into the exhaust duct. Extracted oil is returned to the TGB.

b. The air-oil separator consists of a fabricated sheet metal impeller with a cast aluminum housing. To prevent excessive oil loss from venting oil vapor overboard, all sumps are vented to the air-oil separator. The sump air is vented to the exhaust duct after passing through the separator and flame arrestor. Oil is collected on the inside of the impeller as the oil-laden sump air passes through the separator. Small holes in the segments of the impeller allow the collected oil to be discharged to the separator outer housing. Vanes on the housing wall are used to collect and direct the oil to the separator outlet where it is returned to the gearbox or scavenged back to the lube oil pump (six element) directly per GTC no. 83. To prevent oil and oil vapors from escaping past the end of the impeller, the separator has two labyrinth seals, with the cavity between the two seals pressurized with eighth stage ejector air.

1.3.3 Starting System (Ref: S9234-AD-MMO-010/LM2500)

The starter system consists of a pneumatic turbine starter and a starter valve. The starter is mounted on the aft face of the TGB, and the valve is line mounted behind the starter. The starter drives the GG through the gearbox to a speed at which the GG can sustain itself. In addition, the starter is used periodically to motor the GG for waterwashing.

a. The starter valve, upon receiving an electrical signal, opens to permit air to flow to the starter. The starter then produces the necessary torque to drive the GG to a speed that will permit lightoff and sustained operation. When the starter reaches a predetermined speed, the starter governor trips the starter cutout switch, and the electrical signal to the starter valve is discontinued. The valve closes and shuts off airflow to the starter. As the GG continues to accelerate, the starter-overrunning clutch automatically disengages.

b. During start, the ignition system produces the high-energy sparks that ignite the fuel-air mixture in the combustor. It consists of two ignition exciters, two ignition leads, and two spark igniters.

1.3.3.1 Air Regulating Valve. The starter valve is a normally closed pneumatic regulator and shutoff valve. It consists of a bleed-on regulator, a solenoid switcher, a pneumatic switcher, a check valve, an actuator, and a butterfly valve.

The valve contains both electrical and mechanical position indicators and is both pneumatic and spring-loaded in the closed position.

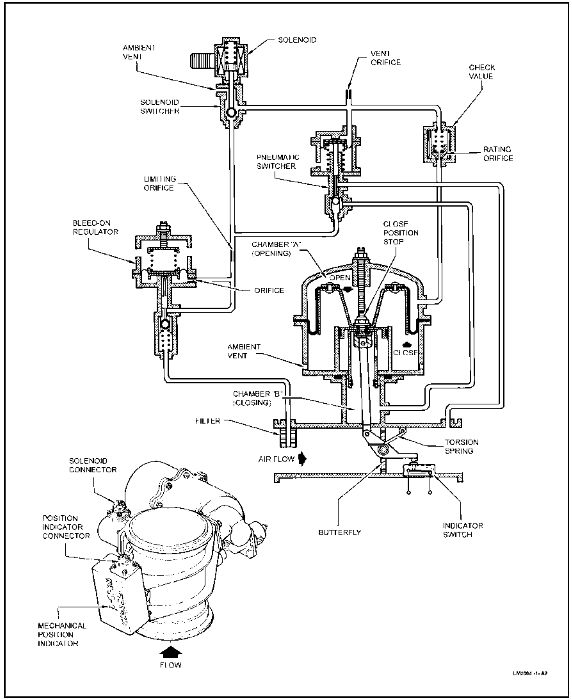

Figure 1-45. Air Regulating Valve

a. When the solenoid is energized, the ambient vent of the solenoid switcher closes, and regulated pressure is ported to the piston of the pneumatic switcher. The pressure passes through the check valve to the opening chamber of the actuator. The piston in the pneumatic switcher allows pressure in the closing chamber of the actuator to bleed to the outside of the valve. Pressure in the opening chamber increases as pressure in the closing chamber decreases, causing the butterfly valve to open.

b. When inlet pressure is lower than the desired outlet pressure, forces acting on the actuator are such that the butterfly is held in the full open position. When outlet pressure increases to the desired level, the actuator forces balance, and the butterfly moves to an intermediate position. Any slight change in outlet pressure causes a corresponding modulation of the butterfly position to maintain desired outlet pressure.

c. When the solenoid switcher is deenergized, it shuts off regulated pressure to the pneumatic switcher and check valve, simultaneously venting the opening chamber to ambient and de-energizing the pneumatic switcher. The pneumatic switcher ports regulated pressure to the closing chamber of the actuator and shuts off the outlet bleed of the closing chamber. The check valve opens to permit full flow of opening chamber air to ambient to effect fast closing of the butterfly valve.

1.3.3.2 Pneumatic Starter. The pneumatic starter consists of an inlet assembly, turbine assembly, reduction gearing, cutout switch, overrunning clutch, and a splined output shaft. The turbine is a single-stage, axial-flow type. The reduction gearing is a compound planetary system with a rotating ring gear. The overrunning clutch is a pawl and ratchet type that provides positive engagement during starting and overrunning when driven by the GG. The cutout switch is normally closed and is actuated by a centrifugal governor that trips the switch. The output shaft has a shear section to prevent over-torque damage.

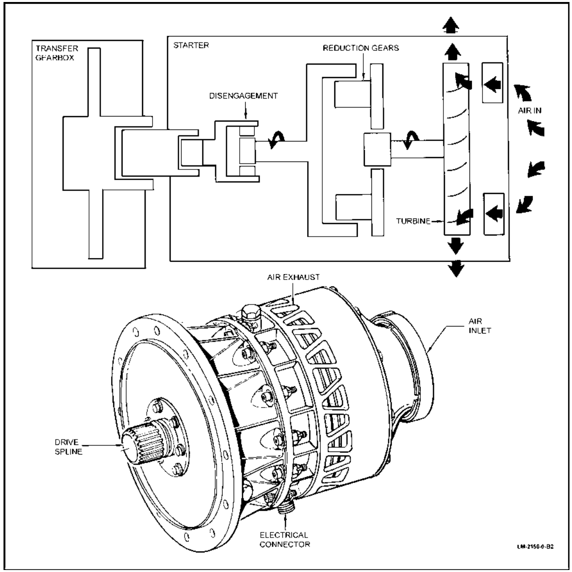

Figure 1-46. Pneumatic Starter

a. To ensure containment of the turbine wheel in case of thrust bearing failure, the starter incorporates a containment ring and a brass rub ring that has 12 tungsten carbide inserts. In event of a turbine thrust bearing failure during operation, the rub ring will prevent the starter air pressure from moving the turbine wheel out from under the present containment ring. The tungsten carbide inserts will machine the wheel at its thinnest section, causing wheel rim separation to occur while the turbine wheel is still under the containment ring, thus assuring containment. The brass ring will also act as a heat sink and will minimize turbine wheel temperature rise.

b. Compressed air supplied to the inlet stator housing is directed to the turbine wheel through the stator nozzle. A gearset transforms the high-speed and low torque of the turbine wheel to low speed and high torque of the output shaft. Exhaust air is released through the perforated exhaust screen at approximately ambient pressure. The drive shaft assembly provides disengagement from the output shaft after NGG exceeds the driveshaft speed and allows the output shaft to rotate with the GG while the driveshaft and gears coast to a stop.

1.3.3.3 Ignition Exciter. The ignition exciters are the capacitor discharge type. They are located on the right side of the front frame at the 2 o'clock position and are attached to special mounts, which absorb shock and vibration. The exciters operate on 115 V, 60 Hz input. The power is transformed, rectified, and discharged in the form of capacitor discharge energy pulses through the coaxial-shielded leads to the spark igniters.

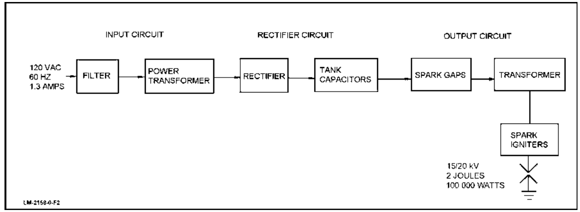

Figure 1-47. Ignition System Block Diagram

a. When the starting switch is closed, shipboard 60 Hertz (Hz) power is applied to the exciter circuits. The exciter consists of input, rectifier, discharge and output circuits. The input circuit includes a filter, which prevents feedback of Radio frequency interference (RFI) (generated within the exciter) and prevents introduction of Electrical Magnetic Interference (EMI) (generated externally); and a power transformer that provides step-up voltage for the rectifier circuit. The full wave rectifier circuit includes diodes that rectify the high voltage AC and capacitors that are arranged in a voltage doubler configuration. Tank capacitors store up the DC voltage developed in the rectifier circuit until the potential developed reaches the breakdown point of spark gaps in the discharge circuit. The discharge circuit contains the spark gaps, high frequency (HF) capacitor, resistors and HF transformer. When the spark gaps breakdown, a current (caused by a partial discharge of the tank capacitors) through the HF transformer and in conjunction with the HF capacitor causes a series resonant condition to exist and HF oscillations occur in the output circuit. These HF oscillations cause ionization of a recessed spark gap of the igniter plug. A low resistance path now exists for total discharge of the tank capacitor producing a high-energy spark used to ignite the fuel within the combustor. The spark rate is determined by the total rectifier circuit resistance, which controls the Resistive Capacitive (RC) time constant in the charging circuit.

1.3.3.4 Spark Igniters. The spark igniters are surface gap type. They have internal passages for air-cooling and air vents to prevent the accumulation of carbon in interior passages. The igniter has a seating flange with attached copper gaskets for sealing purposes. There are grooves cut in the outer surface of the tip and axial holes for cooling the outer and inner electrodes with CDP air.

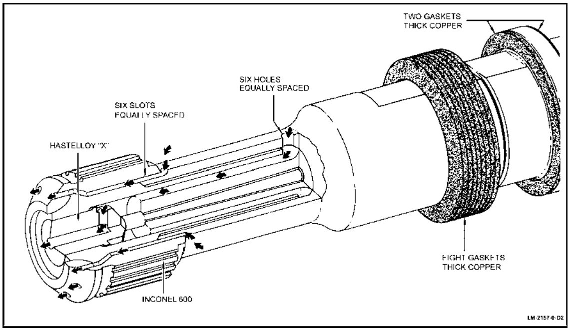

Figure 1-48. Spark Igniter

a. The surface gap will ionize at 8,500 volts when dry and 15,000 volts if wet. There is a discharge of two joules of energy across the gap. This energy level is lethal, and output from the spark exciter, leads, or igniter should never be contacted by personnel.

1.3.3.5 Ignition Leads. The ignition leads are low-loss connections between the ignition exciters and the spark igniters. They are coaxial, having metallic shielding that incorporates copper inner braid, sealed flexible conduit, and nickel outer braid.

1.3.4 Ice Detection (Ref: S9234-AD-MMO-010/LM2500)

The ice detector system consists of an ice detector sensor and a signal conditioner. The sensor measures temperature and humidity, and transmits proportional electrical signals to the signal conditioner. The signal conditioner performs the logic, amplification, etc., to provide a signal when icing conditions exist (temperature below 41 F and humidity above 70 percent).

1.3.4.1 Ice Detector Sensor. The ice detector, together with a signal conditioner, form part of a system to give warning of the onset of icing conditions. The detector is designed for marine use.

a. The detector consists of a sensor assembly mounted in a body secured to a mounting plate assembly. The body and mounting plate are machined from stainless steel. A filter cover assembly protects the sensing element, while allowing the passage of atmospheric air over two sensors. The sensor assembly, retained in the body by a circlip and collar, consists of a temperature sensor and a humidity sensor. Electrical connection to the sensing element is made through a fixed plug secured to the mounting plate.

b. Changes in temperature of the air flowing over the sensor assembly vary the electrical resistance of the thermistor temperature sensor. As temperature decreases, the resistance of the thermistor increases; at 41 F, resistance is approximately 2.4K ohms. The change in resistance modifies a DC signal in the ice detector signal conditioner.

c. Changes in the moisture content of the air flowing over the sensor assembly vary the electrical resistance of the humidity sensor. The humidity sensor is a salt treated wafer. As it absorbs moisture from the surrounding air, its resistance decreases as the humidity increases; at 70 percent relative humidity, resistance is approximately 435K ohms. The change in resistance affects the feedback to an amplifier in the ice detector signal conditioner.

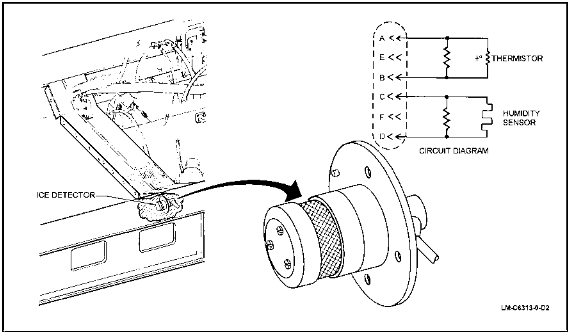

Figure 1-49. Ice Detector

1.3.4.2 Ice Detector Signal Conditioner. The signal conditioner, together with an ice detector, form part of a system to give warning of the onset of icing conditions. The signal conditioner is intended for marine use.

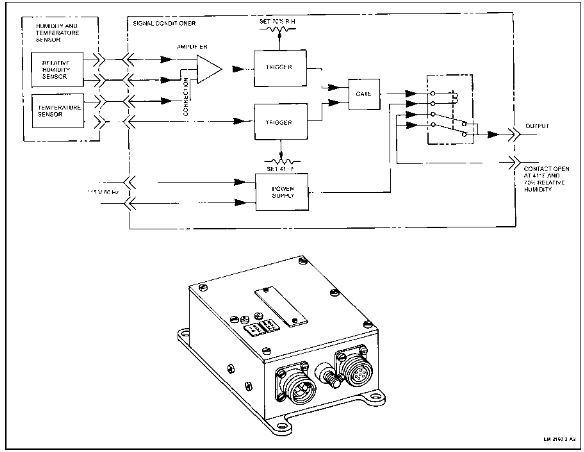

Figure 1-50. Ice Detector Signal Conditioner

a. The signal conditioner consists of two printed circuit-board assemblies, a transformer and a relay and capacitor all mounted within a welded aluminum alloy box. The printed circuit-board assemblies and transformer are mounted on spacers secured to the bottom and one side of the box, while the capacitor and relay are secured to the side of the box opposite the transformer. The box is closed by a cover bearing identification labels and two screws that close access holes to two potentiometers positioned on the upper circuit-board assembly.

b. Electrical connection to the signal conditioner is provided by a seven-pin socket (connection to the ice detector) and a seven-pin plug (AC input and warning output). A bonding stud is mounted between the two connectors. The signal conditioner is mounted by four lugs formed on the bottom of the box.

c. The amplifier is fed with a stabilized DC supply and an input from a square-wave generator. The relative humidity sensors connected in the feedback loop of the amplifier, while the temperature dependent resistor (temperature sensor) provides both a correction signal to the amplifier and an input signal to the temperature trigger circuit. The temperature sensor is operated at a very low DC voltage to reduce errors in temperature measurement due to self heating.

d. The output from the amplifier is fed to the relative humidity trigger circuit. Both the temperature and relative humidity trigger circuits are set to operate at pre-determined levels of 41 F and 70 percent relative humidity. When the temperature and humidity are sensed, outputs from the two trigger circuits are fed to a gate operating in the "and" mode. Thus when the relative humidity is greater than the preset value at an ambient temperature of less than the pre-set value, the gate will produce an output. The output from the gate circuit energizes a relay causing a contact opening. The contact opening operates a ship warning device.

1.3.5 Vibration Detection (Ref: S9234-AD-MMO-010/LM2500)

Two vibration detection systems are used. The DDG-51 class ships, and engines that have had GTC no. 77 and AYC no. 31 incorporated, use accelerometers to monitor GT vibration. All remaining engines use velocity transducer to monitor GT vibration. The system that uses accelerometers consists of two accelerometers, a power supply, and a signal conditioner. The accelerometers, when subjected to vibration, produce an electrical charge that is transmitted to the signal conditioner. The signal conditioner processes this charge into a corresponding filtered velocity signal. This velocity signal is supplied to the ship's monitoring system.

1.3.5.1 Accelerometer. The accelerometers, together with the signal conditioner and power supply, form part of the engine vibration monitoring system. Mounting brackets secure the accelerometers to the engine at the CRF and TRF. The DDG-51 class ships delete the power supply with ECP N-304 incorporation. The CG-47 class ships with Smart Ship alteration use accelerometers and a RSI vibration monitor that replaces the power supply and signal conditioner. The accelerometers are constructed of a piezoelectric material contained in a stainless steel housing. The piezoelectric material emits an electric charge when subjected to mechanical vibration. This electric charge is transmitted to the signal conditioner or RSI vibration monitor.

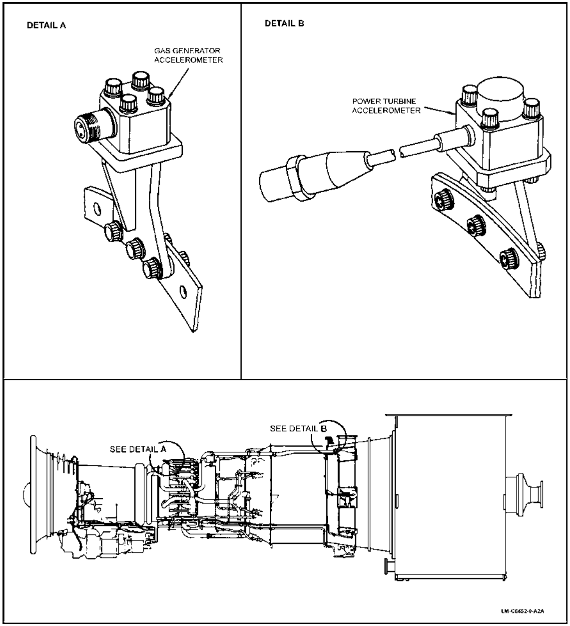

Figure 1-51. Accelerometer Locations

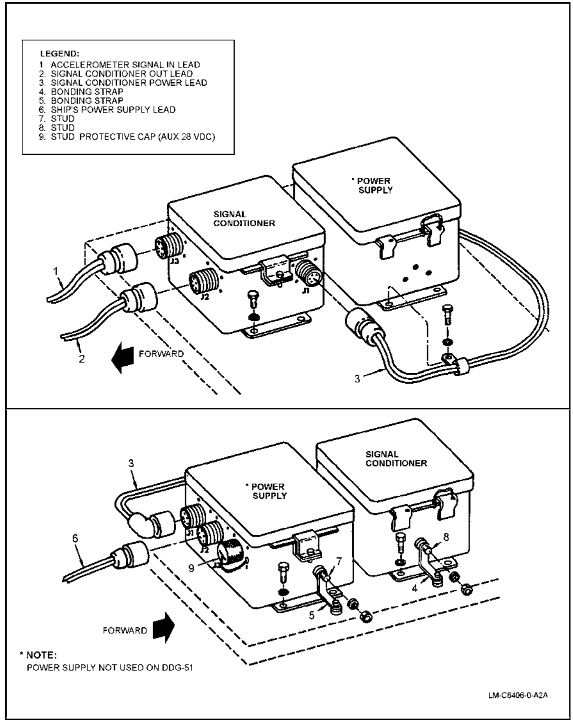

Figure 1-52. Accelerometer Signal Conditioner and Power Supply

1.3.5.2 Accelerometer Signal Conditioner. The accelerometer signal conditioner is contained in a metal box attached to the underside of the BEA. Mounted with the signal conditioner is the accelerometer system power supply.

a. The signal conditioner requires 28 VDC input at J1 connector pins A (+) and B (-), and pins D (+) and E (-). This 28 VDC is delivered by the systems power supply to both the GG and Power Turbine (PT) systems. The 28VDC is modified to produce +15 VDC and -15 VDC supplies for use by the signal conditioning cards.

b. Two identical conditioning cards are located in the signal conditioner, one card for the GG accelerometer and the other card for the PT accelerometer. The signal conditioner J2 connector supplies the output signal to the ship's monitoring system.

1.3.5.3 Remote Signal Interface. The RSI vibration monitor is a metal box attached to the underside of the BEA.

a. The RSI vibration monitor requires a 115 VAC input at J5 connector. This 115 is converted to VDC by the internal power supply and is delivered to the internal modules.

b. Signal conditioning cards are located in the RSI vibration monitor for the GG and PT accelerometer inputs at J1 connector and speed inputs at J3 connector. The RSI vibration monitor J2 and J4 connectors supply the output signal to the ship's monitoring system.

1.3.6 Fire Detection and Extinguishing (Ref: S9234-AD-MMO-010/LM2500).

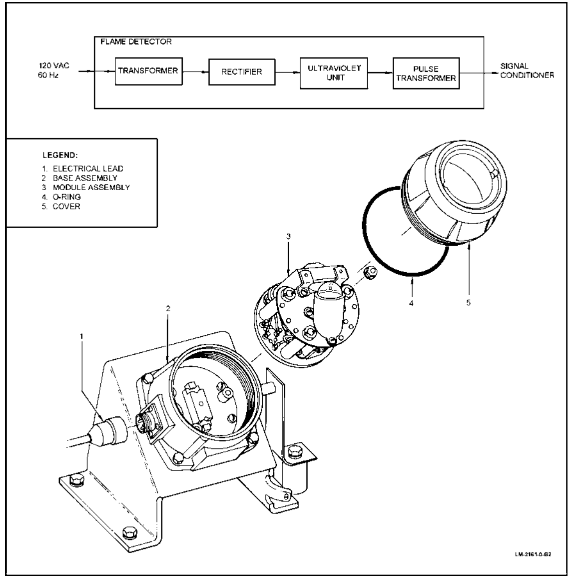

Figure 1-53. Ultraviolet Flame Detector

1.3.6.1 Flame Detector. The flame detector is an electronic tube that responds to ultraviolet (uv) radiation in ordinary flames. It is insensitive to infrared and ordinary visible light sources. The tube has two symmetrical electrodes within the gas-filled envelope. It operates on pulsating DC. Alternating Current (AC) enters the detector and is stepped up by a transformer. This AC is then rectified to pulsating DC that is fed to the uv sensor. When uv light containing wave lengths in the range of 1,900-2,100 Angstrom units ionize the gas in the tube, the current is allowed to flow through the tube. The current then goes to a pulse transformer that couples it to the signal conditioner.

1.3.6.2 Flame Detector Signal Conditioner. The flame detector signal conditioner is contained in a metal box that is attached to the underside of the BEA.

a. Three identical detector cards (one for each uv sensor) are located in the signal conditioner at connectors J4, J5, and J6. The detector card amplifies, rectifies, and filters the current pulse from the uv sensor to provide an output voltage level proportional to the ultraviolet light level at the uv sensor.

b. The three detector outputs are "Diode OR-ed" and applied to the comparator card input. The comparator card, located in the signal conditioner at connector J3, is a power amplifier and provides sufficient power to energize the alarm control relay R2 when the input signal exceeds a threshold level set by potentiometer R9.

c. The energized alarm control relay contacts complete the alarm control circuitry external to the GT modules, resulting in an alarm indication.

d. The interlock relay R1 energizes when all three uv sensors are properly connected, all circuit cards are properly installed in the signal conditioner, and all harness connectors are properly installed.

e. The power supply card, located in the signal conditioner at connector J2, converts the AC outputs of a power transformer to DC voltage levels required for the signal conditioner.

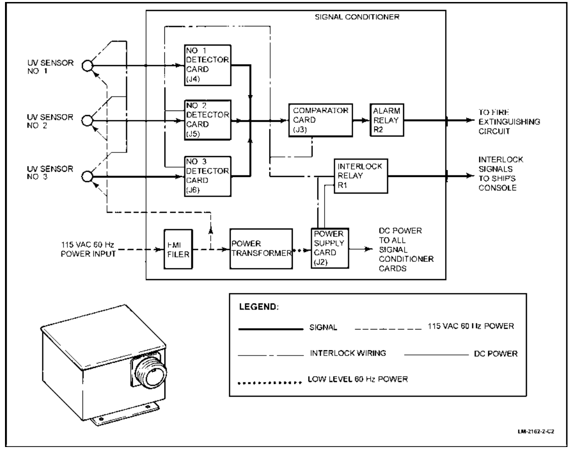

Figure 1-54. Flame Detector Signal Conditioner

1.3.7 Fire Detection, Alarm and Extinguishing DD963 and CG-47 (Ref: S9234-AD-MMO-010/LM2500)

The fire detection system consists of three flame detectors, a flame detector signal conditioner, and two temperature switches. The alarm system consists of a manual FIRE ALARM pushbutton in addition to the electrical signal generated by closure of either temperature switch or the flame detector signal conditioner. The extinguishing system consists of two Carbon Dioxide (CO2) discharge nozzles, an extinguish release inhibit switch and a CO2 release switch.

a. The UV-type flame detectors sense the presence of fire in the enclosure and generate an electrical signal that is transmitted to the signal conditioner. The conditioner provides a signal to the ship's fire extinguishing system. The temperature switches are mounted on the interior ceiling of the enclosure. Temperature above a preset value causes switch contacts to close, thus providing a signal to the ship's fire extinguishing system.

b. The CO2 release switch is mounted to the outside of the enclosure, next to the side access door. When manually activated, the CO2 fire extinguishing agents are discharged into the enclosure.

c. The CO2 discharge nozzles are located inside the enclosure, and are mounted on the crossbeam under the compressor front frame. There are two nozzles, one for initial discharge and one for extended discharge. The fire extinguish release inhibit switch is mounted above the FIRE ALARM pushbutton. When in the INACTIVE position, this switch prevents discharge of the CO2 extinguishing agent.

d. When a fire is sensed by the flame detectors or temperature switches or noted by a crewmember who operates the manual CO2 release switch, contacts close to activate the fire extinguishing system. The following simultaneous actions occur:
   1. The GT fuel shutdown valves close, shutting down the GT.
   2. The fuel supply to the GTM is shutoff in the ship's service system.
   3. The bleed air valve is closed.
   4. The secondary cooling air fan is shutdown.
   5. The secondary air vent damper is closed.
   6. The FIRE ALARM signal sounds.
   7. The enclosure lights flash.
   8. After a delay of 20 seconds, the initial CO2 discharge occurs. CO2 discharge can be prevented by positioning the release inhibit switch to the INACTIVE position during the time delay. The initial discharge delivers 150 pounds of CO2 at a rate of 50 lbs/min. If required, the extended CO2 discharge is manually activated. The extended discharge delivers 200 pounds of CO2 at the rate of 10 lbs/min.

1.3.8 Fire Detection, Alarm and Extinguishing FFG-7. (Ref: S9234-AD-MMO-010/LM2500)

The fire detection system consists of three flame detectors, a flame detector signal conditioner, and two temperature switches. The alarm system consists of a FIRE ALARM pushbutton. The extinguishing system consists of a single Halon discharge nozzle, connecting tubing and an extinguish release inhibit switch.

a. The uv type flame detectors sense the presence of fire in the enclosure and generate an electrical signal which is transmitted to the signal conditioner. The conditioner provides an enclosure fire signal to the ship's system. The temperature switches are mounted on the ceiling of the enclosure. Temperature above a preset value causes switch contacts to close and provide a Level 2 alarm.

b. The FIRE ALARM pushbutton is mounted on the outside of the enclosure, next to the side access door. When the pushbutton is pushed, contact closure signal is provided to the ship's system that sounds a Level 2 alarm.

c. The Halon discharge nozzle is located inside the enclosure, and is mounted on the underside of the crossbeam under the compressor front frame. This one nozzle provides both initial and standby Halon discharge. The fire extinguish inhibit switch is mounted above the FIRE ALARM pushbutton. When in the INACTIVE position, this switch provides a signal to the ship's system used to prevent discharge of the fire extinguishing agent.

d. If fire is sensed by the flame detectors, or the temperature switches detect enclosure temperature above preset limits, or the manual fire alarm pushbutton is activated, a Level 2 alarm sounds. Panel indicator lights also inform the ship's operator of the condition.

e. A fire in either enclosure is extinguished by filling the enclosure with Halon. The ship's Propulsion Control Console (PCC) contains a HALON FLOOD pushbutton for each enclosure. To prevent an enclosure from being flooded with Halon while personnel are inside, the safety disable switch (fire extinguish inhibit), located next to the enclosure access door, is positioned to INACTIVE.

f. Activation of the FLAME DET ALARM/HALON FLOOD switch on the PCC will provide the initial Halon discharge of 20 pounds at a rate of 1.45lb/sec. An additional 20 pounds, with same rate of discharge, is available on standby.

1.3.9 <u>Fire Detection, Alarm and Extinguishing DDG-51.</u> (Ref: S9234-AD-MMO-010/LM2500)

The fire detection system consists of three flame detectors, a flame detector signal conditioner, and two temperature switches. The alarm system consists of a FIRE ALARM pushbutton and a Halon warning bell. The extinguishing system consists of two Halon discharge nozzles, and connecting tubing.

a. The uv type flame detectors sense the presence of a fire in the enclosure and generate an electrical signal which is transmitted to the signal conditioner. The conditioner provides an enclosure fire signal to the Shaft Control Unit (SCU) and the Propulsion And Control Console (PACC).

b. The temperature switches are mounted on the ceiling of the enclosure. Temperature above a preset valve causes switch contacts to close, providing a signal to the SCU and PACC informing ship's personnel of the condition.

c. The FIRE ALARM pushbutton is mounted on the outside of the enclosure, next to the side access door. When manually activated, provides a signal to the SCU and PACC informing ship personnel of the condition.

d. A signal from a flame detector, temperature switch, or the manual FIRE ALARM pushbutton, sounds an alarm at the SCU and the PACC. Along with the alarm is an indicator light to inform the operator of the condition.

e. The fire is extinguished by filling the enclosure with Halon. The SCU contains a PRIMARY HALON

RELEASE pushbutton for each of the enclosures in that engine room. The PACC contains a PRIMARY HALON RELEASE pushbutton for each of the four enclosures. Halon can be discharged from either the SCU or the PACC.

f. When the PRIMARY HALON RELEASE pushbutton is depressed, the following actions will occur:

(1) The Halon release warning bell will sound inside the BEA. Upon hearing the bell all personnel must evacuate the enclosure.

(2) The secondary air-cooling fan is shutdown. The vent dampers will close when secondary air flow is stopped.

(3) The enclosure lights flash.

(4) After a delay of 30 seconds, the initial Halon discharge occurs. The initial discharge delivers 95 pounds at a rate of 6 lb/sec. An additional 95 pounds, with the same rate of discharge, is available on standby. The standby Halon is discharged by depressing the RESERVE HALON RELEASE.

g. The Halon discharge nozzles are located on the sidewalls, inside the enclosure. The nozzles are positioned 50 inches above the base surface, near the compressor rear frame. Each nozzle has two discharge holes at a 90 degree angle. Each nozzle is positioned with the two discharge holes pointing toward the GT and at a 45 degree angle with the base sidewalls.

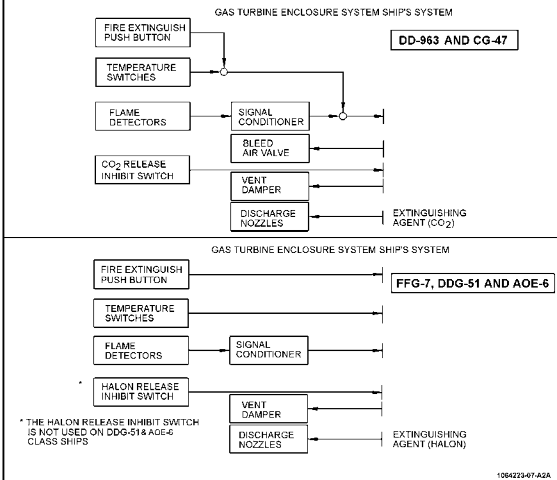

Figure 1-55. Fire Detection, Alarm and Extinguishing

1.3.10 Waterwash System (Ref: S9234-AD-MMO-010/LM2500)

The waterwash system consists of ship's waterwash/rinse supply tank and piping attached to the outside of the base enclosure. A flexible hose is attached from the inside base enclosure floor to the GG inlet duct at 6 o'clock position. The inlet duct is made with an internal passageway or manifold that distributes waterwash fluid to outlet spray orifices. The outlet spray orifices eject waterwash fluid into the air stream flowing through the inlet duct. The purpose of waterwashing is to remove contaminants from the inlet and compressor sections.

1.3.11 Enclosure Environment (Ref: S9234-AD-MMO-010/LM2500)

Within the enclosure, temperature is controlled by means of ventilating air and an electric heater. The ventilating air is provided by a ship's air duct that enters the ceiling of the enclosure. While the GT is operating, or if the temperature within the enclosure exceeds a preset limit, the vent damper in the enclosure ceiling opens and a fan in the ship's duct blows air into the enclosure. Cooling air exits from the enclosure around the GT exhaust duct through a secondary opening. The vent damper is opened and closed by an electrically controlled pneumatic actuator. The enclosure heater's primary purpose is to maintain minimum temperature for proper fuel viscosity.

a. The temperature sensor is located on the enclosure ceiling near the point where enclosure air exits into the ship's exhaust.

b. Enclosure illumination is provided by nine explosion-proof light fixtures, eight on the ceiling and one on the base. The lights are turned on with a rotary switch mounted on the exterior wall of the enclosure near the door. The switch has four positions: off, base light, ceiling lights, and base and ceiling lights. The DDG-51 is provided with two additional light fixtures in the intake plenum. These two lights are activated by pushing a button in light switch mounted on the exterior of forward panel.

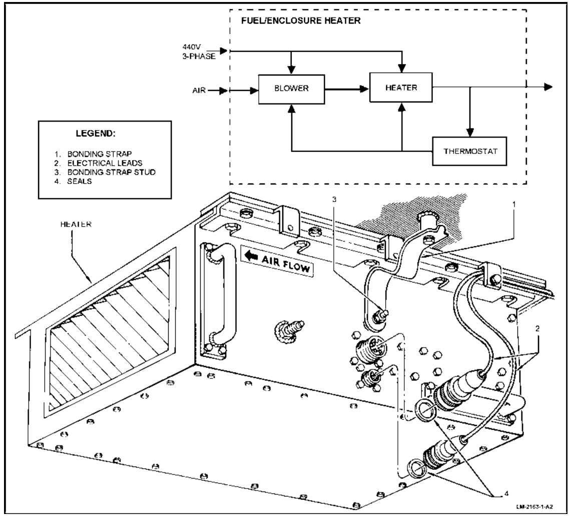

Figure 1-56. Fuel/Enclosure Heater

1.3.11.1 Enclosure Heater. The heater is ceiling-mounted and maintains the enclosure air temperature above 60 F so that a suitable fuel viscosity is maintained for GT starting. It is an electrically powered (440 VAC, 3 phase current), thermostatically controlled, forced-air space heater rated at 8 kW. The heater thermostat closes the heating element power circuit when the heater inlet air temperature is 60-70 F and opens the circuit when inlet air temperature is 85-95 F. Overtemperature protection and a manual reset are provided for the heating element. At temperatures below 125±5 F, air circulation is provided by blower motor operation. Operation ceases when temperature reaches 145 F.

1.3.11.2 Vent Damper. The vent damper admits ventilating (secondary cooling air) from the ship's intake system into the enclosure. It is opened and closed by an electrically controlled pneumatic actuator. The damper is open during GT operation and during post shutdown cooling period. Control air supplied to the damper actuator is 80-125 PSIG.

a. On DD-963, the vent damper opens in parallel with the start of the module cooling fan cooling air and the start of GT rotation. If the vent damper is still closed when the engine-on signal is received, the normal stop sequence will be initiated (five minutes at idle power before shutdown). Failure of the vent damper to remain open or loss of cooling air flow during GT operation will initiate a normal stop sequence of the GT. Shutdown may be interrupted if the damper is opened and cooling air flow is established within the five minute period of idle power operation.

b. Should an electrical failure be experienced on the solenoid, the vent damper will close. Should loss of air be experienced, the vent damper will remain in its last position.

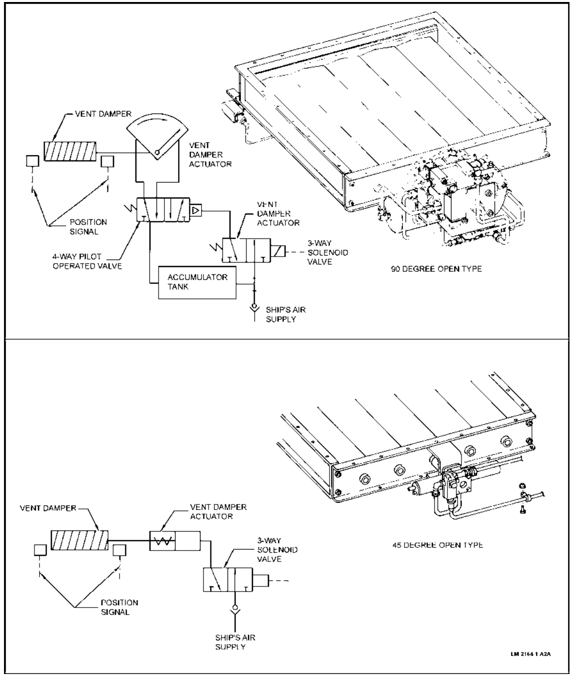

Figure 1-57. Vent Damper

c. There are two types of vent dampers, a 45 degree open type and a 90 degree open type.

d. On the 45 degree open type, should the air and the electric be lost simultaneously, the vent damper will close.

e. On the 90 degree type, should the air and the electric be lost simultaneously, the pilot pressure is vented to atmosphere causing the 4-way valve to shift and applying pressure to close the actuator while venting the open side of the actuator to atmosphere. Air trapped in the accumulator provides enough pressure to cycle the actuator to its alternate position.

1.3.12 Bleed Air (Ref: S9234-AD-MMO-010/LM2500).

1.3.12.1 Bleed Air Shutoff Valve. The bleed air shutoff valve is an on/off valve placed in the turbine bleed air line. It consists of a 3.5 in. butterfly driven open or closed by a 28 VDC electric motor working through a reduction gear train. On/off control of the motor is with a remote open/close switch. Position feedback is provided to indicate when the butterfly has physically moved to full open or full closed. The valve can be manually opened or closed by moving the override arm. The remote indicators will still show valve position even though the valve was operated manually. No resetting is required to return to automatic control. The actuator assembly consists of a Direct Current (DC) operated electrical motor, coupled to a gear train. The gear train is modular, with three spur gear stages and a three gear planetary system. The motor is a series type reversible motor, with the end of the armature shaft serrated to engage the input gear of the actuator assembly. Power is then transferred through an idler gear in the actuator to the input planetary of the actuator, which, in turn, drives the last-pass or output planetary. The output planetary drives the output shaft of the actuator through a clutch ring. The clutch ring is between the output planetary and the outside shaft. The output shaft operates the internal limit switches; thus, output shaft position controls the motor-gear train operating cycle. The position limiting system is unique in that it has a self-energizing clutch at the output end of the actuator that is released simultaneously with limit switch actuation by engagement with a symmetrical positive-stop system.

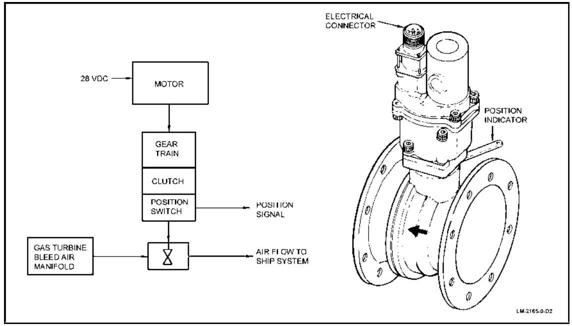

Figure 1-58. Bleed Air Shutoff Valve

1.3.13 Temperature Sensors (Ref: S9234-AD-MMO-010/LM2500).

1.3.13.1 Sensors. There are two types of temperature sensors on the GT module: RTD and thermocouples. The RTDs contain a platinum sensing element in which the resistance increases as the temperature increases. The thermocouples contain an alumel chromel element in which the voltage output increases as the temperature increases. There are nine RTDs and 11 thermocouples.

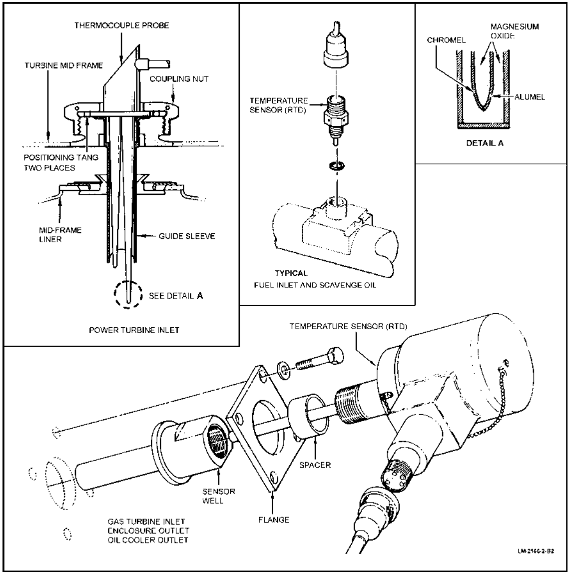

Figure 1-59. Temperature Sensors (Before GTC No. 96)

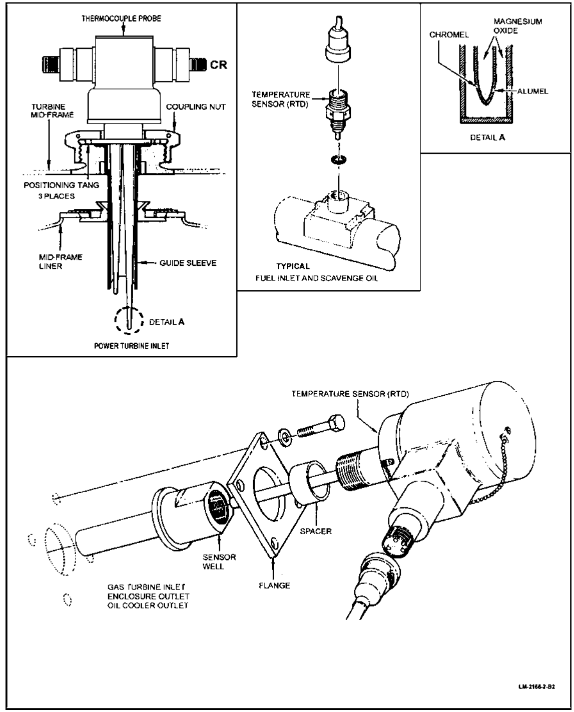

Figure 1-60. Temperature Sensors (After GTC No. 96)

1.3.13.2 Thermocouples. Eleven thermocouples are located in the turbine mid-frame and are connected together by a harness. The thermocouples sense PT inlet gas temperature (T5.4).

1.3.13.3 Resistance Temperature Detectors. Five RTDs sense temperature of scavenge oil from the sumps and the TGB, and are located in the scavenge oil lines near the lube and scavenge pump. An RTD senses fuel inlet temperature and is located in the fuel supply line near the enclosure floor. An RTD is located on the lube oil storage tank and senses the oil cooler discharge temperature. An RTD is located in the forward cross beam of the enclosure floor and it senses GT inlet air temperature (T2). An RTD is located on the aft end of the enclosure ceiling to sense enclosure cooling air exit temperature.

1.3.14 Airflow (Ref: S9234-AD-MMO-010/LM2500)

1.3.14.1 Primary Airflow. The GG compressor draws air from the ship's inlet, through the enclosure inlet plenum, inlet screen, inlet duct, and the front frame. After being compressed, the air enters the combustion section where some of it is mixed with fuel, and the mixture burned. The remainder of the air is used for centering the flame in the combustor and for cooling the combustor and some parts of the High Pressure Turbine (HPT). Some of the energy in the hot combustion gas is used to turn the HPT rotor that is coupled to and turns the compressor rotor. Upon leaving the HPT section, the gas passes into the power turbine section. Most of the remaining energy is extracted by the PT rotor that drives the high-speed flexible-coupling shaft. The shaft provides the power for the ship's MRG and drive system. The gas exits from the PT through the Turbine Rear Frame (TRF) and passes into the exhaust duct and out through the ship's exhaust.

1.3.14.2 Eighth Stage Bleed Air. Eighth stage air is bled from the compressor through hollow eighth stage vanes into an external manifold. From the manifold, the air is piped forward and aft to ejector nozzles. Each ejector contains a venturi through which the eighth-stage air passes. The air passing through the venturi draws enclosure air into the ejector. This gives the ejector a high volume output of low pressure and low temperature air. Air from the forward ejector is piped into the front frame hub where it pressurizes and cools the A-sump. Some of the A-sump air passes through holes in the compressor rotor front shaft, through the rotor air duct, and through holes in the rotor rear shaft, where it pressurizes and cools the B-sump. Air from the aft ejector is piped into the TRF hub, where it is used to pressurize and cool the D-sump. Part of the air entering the D-sump is bled into the flexible-coupling shaft tunnel for cooling. It then passes out the aft end of the exhaust duct. Some of the air passes through holes in the PT rear shaft rotor air tube, and holes in the rotor front shaft, where it pressurizes and cools the C-sump.

1.3.14.3 Ninth Stage Bleed Air. Ninth stage air is bled from the compressor through holes in the compressor casing at the ninth stage vanes and is piped to the Turbine Mid-Frame (TMF) and TRF. The air to the TMF enters the frame through all the struts. Some of the air exits through holes in the frame hub to cool the frame inner liner. The rest of the air enters the tubes of the C-sump air seals. After crossing the C-sump air seals, the air passes through the PT. The air to the TRF enters the frame through struts 2 and 8 and passes into an area between the forward air seals. This area acts as a balance chamber to reduce the aft loading on the no. 7 ball bearing.

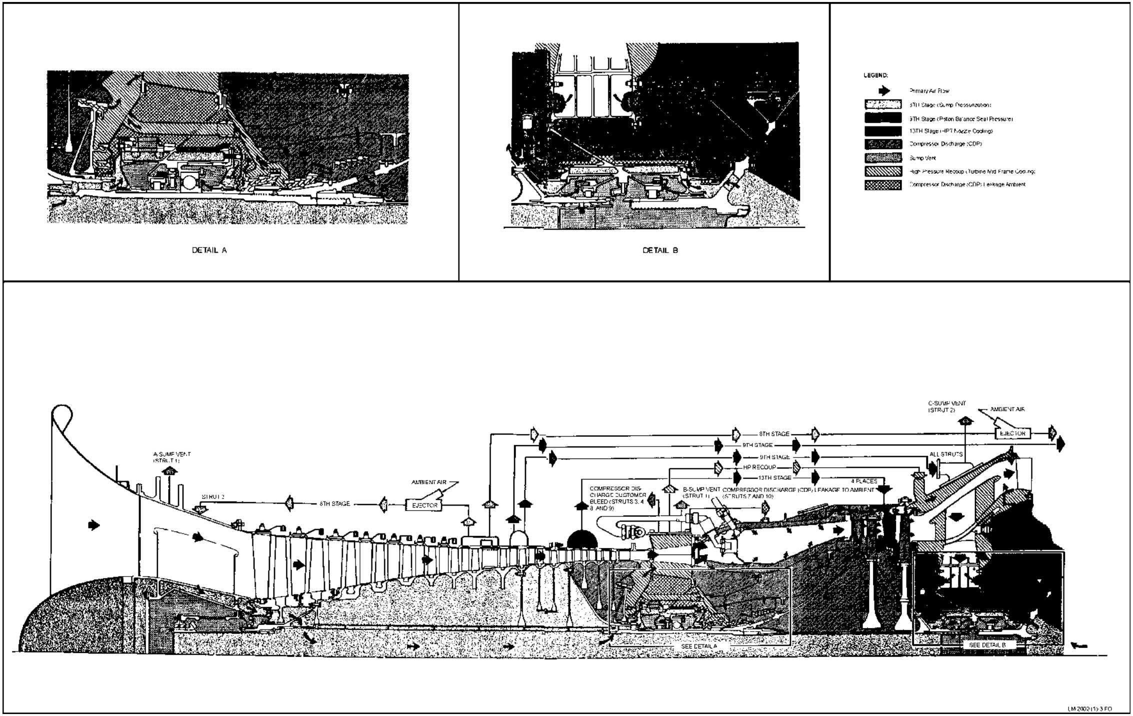

Figure 1-61.   Airflow Paired Blade

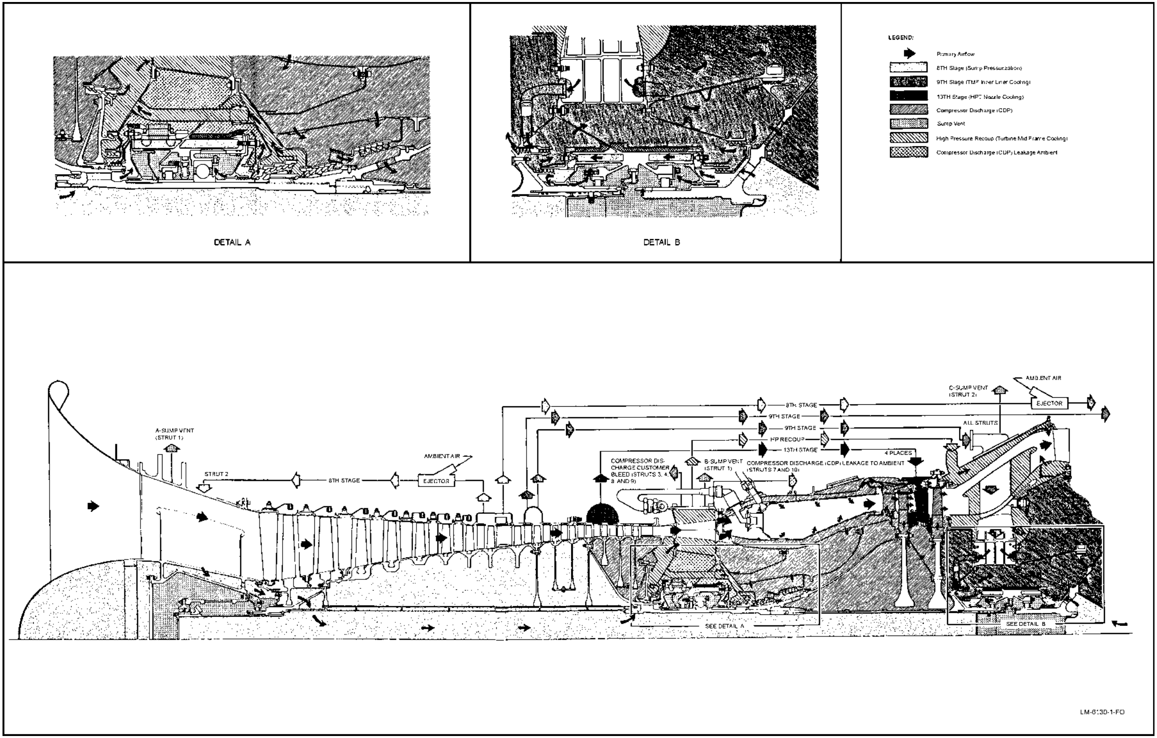

Figure 1-62. Airflow Single Shank/C-Sump Revent

1.3.14.4 Thirteenth Stage Bleed Air. Thirteenth stage air is bled from the compressor through holes in the casing into a manifold. The air is piped through the compressor rear frame casing and into the Stage 2 HPT shrouds and flows through and cools the Stage 2 nozzles. Some of the air exits through nozzle trailing edge holes, and the remainder is used for cooling the interstage seal, the aft side of the Stage 1 blade shanks, and the front side of the Stage 2 blade shanks.

1.3.14.5 Compressor Discharge Bleed Air. Some compressor discharge bleed air is taken through holes in the inner wall of the compressor rear frame and out through frame struts no. 3, 4, 8, and 9 to the bleed air valve. The bleed air valve is electrically operated and, in the open position, provides air for ship's use. It incorporates switches to signal open and closed positions. HPT blade cooling air is taken off through the Stage 1 HPT nozzle support. The remaining compressor discharge bleed air is used for cooling the combustion liner and the Stage 1 HPT nozzle vanes.

1.3.14.6 Customer Bleed Air. The customer bleed air system consists of a pneumatic shutoff valve and piping through which compressor discharge air is taken from the inner wall of the compressor rear frame for ship's services. The air flows from struts no. 3, 4, 8, and 9 of the frame into two manifolds, one mounted on each side of the frame. The manifolds connect to a common line that contains the shutoff valve. From the valve, the line is flange-connected to a base feed-through tube.

1.3.15 Gas Turbine Electronic Power Control System, DD-963 and CG-47 (Ref: S9234-AD-MMO-010/LM2500)

The GT electronic power control system consists of a GT mounted electromechanical Power Lever Angle (PLA) Actuator and a Free Standing Electronic Enclosure (FSEE) or Engine Control Module (ECM). The system provides the following functions:

a. Controls the PLA Actuator to position the power lever of the GT MFC in response to a ship-provided electrical command signal.

b. Limits PT output torque by utilizing various GT parameters to calculate torque, comparing the calculated torque to a preset limit, and overriding the command signal to reduce the setting of the MFC power lever if the preset limit is exceeded.

c. Limits NPT by comparing actual speed to a preset limit, and overriding the command signal to reduce the setting of the MFC power lever if the preset limit is exceeded.

d. Limits PT acceleration by comparing actual acceleration rate to a preset limit and overriding the command signal to reduce the demand to the MFC power lever if the preset limit is exceeded. (This function is not used in the FFG-7 class ship.)

e. Provides PT overspeed protection by monitoring two speed signals from the PT and de-energizing the GT fuel shutoff valves in the event of a PT overspeed or the loss of both speed signals.

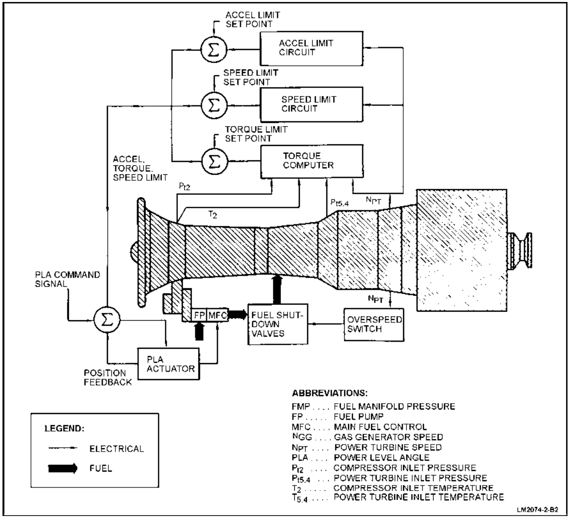

Figure 1-63. Gas Turbine Electronic Power Control System, DD-963/CG-47

1.3.15.1 Power Lever Angle Actuator, DD-963 and CG-47. The PLA Actuator is mounted on the fuel pump and is mechanically connected to the fuel control power lever. It is electrically connected to the FSEE. Signals from the PLA Actuator electronics, located in the FSEE, are converted by a servomechanism into mechanical action that positions the fuel control power lever. Feedback of PLA and rate of change is sent to the FSEE. A positive mechanical rig feature allows locking of the PLA Actuator output lever at a position of 113.5±1 degrees. This rig point, in conjunction with a corresponding rig point on the fuel control, is used to establish mechanical synchronization between the PLA Actuator and the MFC.

1.3.15.2 Free Standing Electronic Enclosure, DD-963 and CG-47. FSEE is located outside of the GT enclosure and is mounted on the ship's foundation. The enclosure is a metal cabinet that contains the Torque Computer (TC), PLA Actuator electronics, torque, speed and acceleration limiting electronics, PT overspeed switch, and signal conditioners. The enclosure contains the electronics required to provide control for two GTMs.

a. The TC monitors four GT parameters: Compressor Inlet Temperature (T2), Compressor Inlet Total Pressure (Pt2), Power Turbine Inlet Total Pressure (Pt5.4) and NPT. From these parameters it produces an electronic signal proportional to the output torque of the GT. The PLA Actuator electronics uses this signal to modulate the ship's input throttle command and drive the electromechanical actuator that is mounted on the GT.

b. In torque limiting, input power to the power turbine is a function of NGG. The output torque of the PT will increase whenever NGG or the load on the ship's drive train increases. The TC calculates the output torque of the power turbine and controls NGG to prevent the output torque from exceeding preset torque limits.

c. The PLA Actuator electronics receives a command signal from the ship. This signal, after being modified, is directed to the PLA Actuator, which positions the fuel control power lever, thereby controlling the

GT output power. Any one or all of the following signals may modify the command signal: rate and position feedback signals from the PLA Actuator, torque limiting signal, speed limiting signal, and acceleration limiting signal.

d. The speed limiting and acceleration electronics sense NGG from the no. 1 and no. 2 speed pickups. If the excessive power turbine speed or acceleration condition is present, a signal is directed to the PLA Actuator that repositions the fuel control power lever to limit NPT and acceleration.

e. The electronic overspeed switch senses NPT from the no. 1 and 2 speed pickups. When NPT reaches a preset limit, or if both speed signals are lost, the switch deenergizes both fuel shutoff valves, shutting down the GT. Loss of speed signal from one speed pickup will not cause de-energizing of fuel valves but will cause an indicator light to illuminate.

1.3.16 Gas Turbine Electronic Power Control System, DDG-51 (Ref: S9234-AD-MMO-010/LM2500)

The GT electronic power control system consists of an Engine Control Module (ECM), an Electronic Support Module (ESM), and a Cable Interface Module (CIM). Combined they form the Interim Integrated Electronic Control (IIEC). The IIEC is located outside the GT enclosure and is mounted on the ship's foundation. The system provides the following functions:

a. Controls the PLA Actuator that positions the power lever of the GT Main Fuel Control (MFC) in response to the ship provided electrical command signal.

b. Limits PT output torque by utilizing various GT parameters to calculate torque and compare to preset limits, and overriding the command signal to reduce the setting of the MFC power lever if the preset limit is exceeded.

c. Limits NPT by comparing actual speed to a preset limit, and overriding the command signal to reduce the setting of the MFC power lever if the preset limit is exceeded.

d. Provides PT overspeed protection by monitoring two speed signals from the PT and de-energizing the GT fuel shutoff valves in the event of a PT overspeed or the loss of both speed signals.

1.3.16.1 Power Lever Angle Actuator, DDG-51. The PLA Actuator is mounted on the fuel pump and is mechanically connected to the fuel control power lever. It is electrically connected to the IIEC. Signals from the PLA Actuator electronics, located in the IIEC, are converted by a servomechanism into mechanical action that positions the fuel control power lever. Feedback of PLA and rate of change are sent to the IIEC. A positive mechanical rig feature allows locking of the PLA Actuator output lever at a position of 113.5±1 degree. This rig point, in conjunction with a corresponding rig point on the fuel control, is used to establish mechanical synchronization between the PLA Actuator and fuel control.

1.3.17 Gas Turbine Electronic Power Control System, FFG-7 (Ref: S9234-AD-MMO-010/LM2500)

The GT electronic power control system consists of a GT mounted electromechanical PLA Actuator, Start/Stop Sequencer (S/SS) electronics and PLA Actuator electronics. The S/SS electronics, and PLA Actuator electronics are part of the FSEE or ECM.

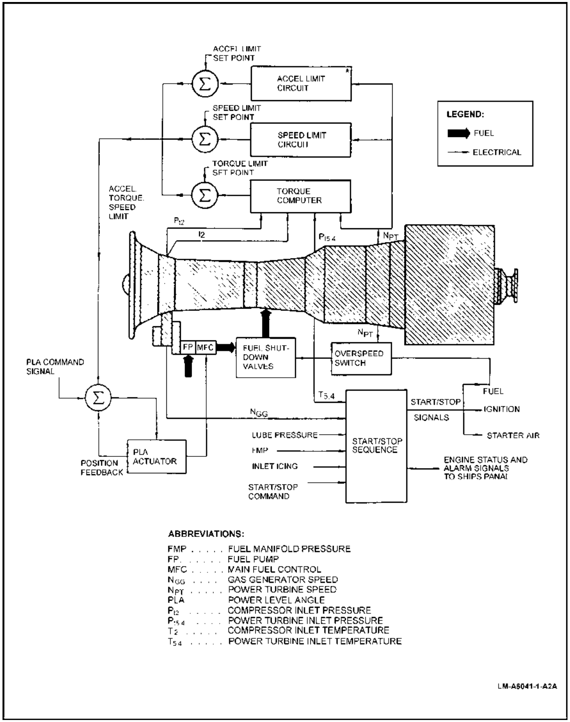

Figure 1-64. Gas Turbine Electronic Control System, FFG-7 and DDG-51

a. The system provides for independent manual and/or automatic remote control of startup, operation, and shutdown of the GT. The system monitors various parameters to ensure safe GT operation and provides the following functions:

(1) Controls the PLA Actuator to position the power lever of the GT MFC in response to a ship-provided electrical command signal.

(2) Limits PT output torque by utilizing various GT parameters to calculate torque, comparing the calculated torque to a preset limit, and overriding the command signal to reduce the setting of the MFC power lever if the preset limit is exceeded.

(3) Limits NPT by comparing actual speed to a preset limit, and overriding the command signal to reduce the setting of the MFC power lever if the preset limit is exceeded.

(4) Provides PT overspeed protection by monitoring two speed signals from the PT and de-energizing the GT fuel shutoff valves in the event of a PT overspeed or the loss of both speed signals.

1.3.17.1 Power Lever Angle Actuator, FFG-7. The PLA Actuator is mounted on the fuel pump and is mechanically connected to the MFC power lever. It is electrically connected to the FSEE. Signals from the PLA Actuator electronics, located in the FSEE, are converted by a servomechanism into mechanical action that positions the fuel control power lever. Feedback of PLA and rate of change is sent to the FSEE. A positive mechanical rig feature allows locking of the PLA Actuator output liver at a position of 113.5±1 degrees. This rig point, in conjunction with a corresponding rig point on the fuel control, is used to establish mechanical synchronization between the PLA Actuator and the fuel control.

1.3.17.2 Free Standing Electronic Enclosure, FFG-7. The FSEE is located remotely from the BEA. It contains the electronics for control of two GTs that drive a common ship's gearbox. The electronic enclosure contains PLA Actuator electronics, torque computer electronics, torque, speed and limiting electronics, PT overspeed switch electronics, signal conditioner electronics, DC power distribution, AC power distributor, and electronics for the S/SS.

a. The TC monitors four GT parameters: T2, Pt2, Pt5.4 and NPT. From these parameters it produces an electronic signal proportional to the output torque of the GT. The PLA Actuator electronics uses this signal to modulate the ship's input throttle command and drive the electromechanical actuator that is mounted on the GT.

b. In torque limiting, input power to the PT is a function of NGG, while the output power from the PT is equal to NPT times the output torque. The output torque will increase whenever NGG or the load on the ship's drive train increases. The torque computer calculates the output torque of the PT and controls NGG to prevent the output torque from exceeding preset torque limits.

c. The PLA Actuator electronics receives a command signal from the ship. This signal, after being modified, is directed to the PLA Actuator, which positions the MFC power lever, thereby controlling the output power. Any one or all of the following signals may modify the command signal: rate and position feedback signals from the PLA Actuator, torque limiting signal, speed limiting signal, and acceleration limiting signal.

d. The speed limiting electronics sense NPT from the no. 1 and 2 speed pickups. If excessive power turbine speed condition is present, a signal is directed to the PLA Actuator that repositions the fuel control power lever to limit NPT and acceleration.

e. The electronic overspeed switch senses NPT from the no. 1 and 2 speed pickups. When NPT reaches a preset limit, or if both speed signals are lost, the switch deenergizes both fuel shutdown valves, shutting down the GT.

1.3.17.3 Start/Stop Sequencer, FFG-7. The S/SS consists of electronics that provide for independent manual and automatic remote control of startup, operation, test and shutdown of the GTs. On command from the ship, an automatic startup of both GTs can be performed by using a programmed time sequence and monitoring GT speed, PT inlet temperature, fuel manifold pressure, and lube supply pressure. If an anomaly is detected at any time during startup, either an alarm will be provided or an immediate shutdown will be performed. Discrete signals are provided to indicate GT starting events for the operator's information.

1.3.18 Start/Stop and Operational Parameters (Ref: S9234-AD-MMO-020)

1.3.18.1 DD-963 and CG-47 Normal Start Sequence

NOTE

Engineering Operating Sequencing System (EOSS) will always be followed when performing all engineering evolutions.

0 NGG

1. Ensure that prestart checks are completed
2. Verify Vent Damper Open
3. Verify Enclosure Ventilation Fan On
4. Verify Electrical Power to Enclosure/Fuel Heater is Off.

CAUTION

Do not engage starter if NGG is above 3500 RPM. Damage to starter could occur.

NOTE

A start may be aborted at any time by deenergizing fuel shutoff valves, allowing GG to motor for 60 seconds, then closing starter air shutoff valves.

5. Starter air On (Note time to 1100 NGG 20 sec max). (Note time to 4500 NGG 90 sec max). Prior to start, air pressure should be 35-85 PSIG. Optimum pressure is 70-80 PSIG.
   a. Verify positive Lube Oil Pressure.

1200 +/- 100 NGG

1. Ignition On
2. Main Fuel Shutoff Valves No. 1 and No. 2 open. (Light Off fuel manifold pressure should be approximately 9-120 PSIG).

CAUTION

If T5.4 rapidly approaches or exceeds 1350 F, abort start. If indication of compressor stall is encountered, abort start. A start stall is characterized by a hung start, slow acceleration to idle, and/or higher than normal T5.4

NOTE

250 PSIG FMP is acceptable at initial T5.4 rise. Do not exceed maximum T5.4 temperature limits. If FMP exceeds 250 PSIG, troubleshoot per S9234-AD-MMO-030 and take corrective action If FMP on initial temperature rise exceeds 200 PSIG, but is less than 250 PSIG, continue start. At next opportunity, perform wet motor per S9234-AD-MMO-020.

3. Note time to light off (T5.4 above 400 F) 40 seconds max. If T5.4 does not reach 400 F within 40 seconds, terminate ignition and fuel and continue motoring for 60 seconds to clear GT of residual fuel. Troubleshoot and take corrective action.
4. Note Peak T5.4 during start. Normal maximum is approximately 800-900 degree F.

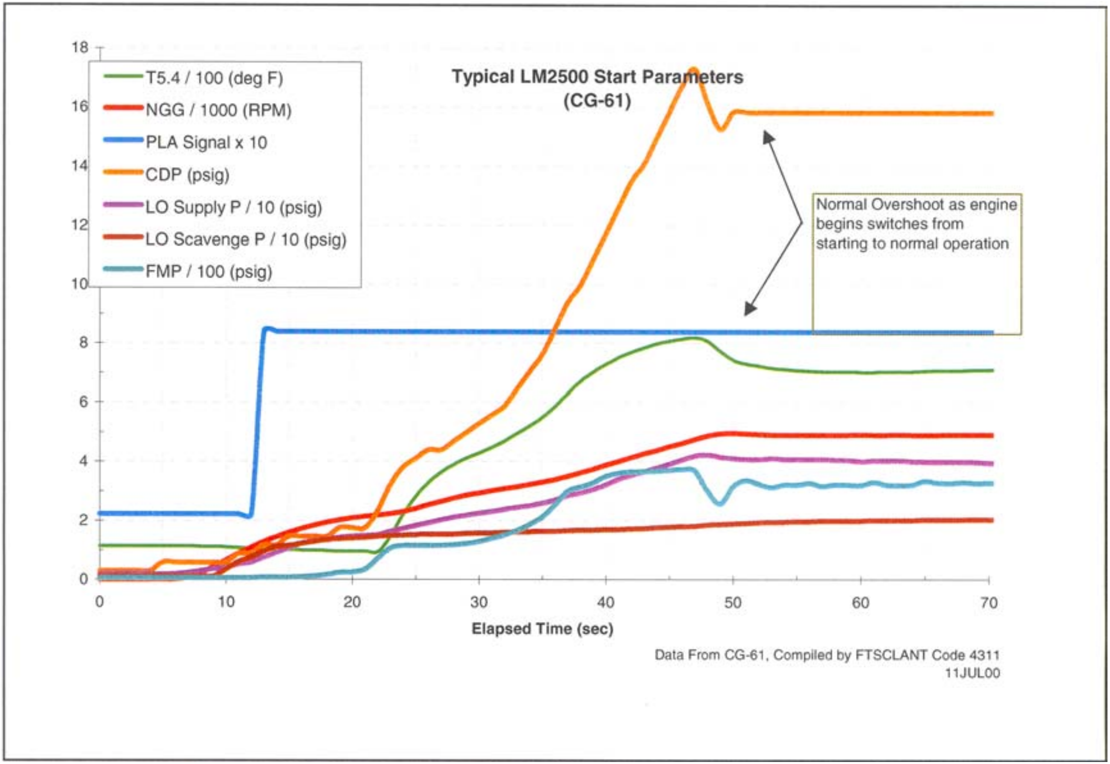

Figure 1-65. Typical LM2500 Start Parameters

4300 +/- 200 NGG

CAUTION

If starter regulator shutoff valve does not close at 4500±200 NGG, shutoff starter air supply using ship's control and deactivation ignition.

1. Starter air shutoff valve automatically closes.
2. Igniter Off
3. Note time to 4900 NGG. Time to IDLE 60 sec max. If NGG continues to increase, start may be continued for 30 more seconds provided T5.4 does not exceed limits.

4900 +/- 50

1. Startup is now complete. GT is at IDLE power. Normal start should take 40-45 seconds.

IDLE

1. FMP at 4900 NGG: 295-305 PSIG. Not to exceed 350 PSIG.
2. T5.4 at 4900 NGG: 750-850 degree F. (1000 max).
3. CDP at 4900 NGG: 13-16 PSIG.
4. PT5.4 at 4900 NGG: 15-17 PSIA.

1.3.18.2 DD-963 and CG-47 Shutdowns

NOTE

Engineering Operating Sequencing System (EOSS) will always be followed when performing all engineering evolutions.

1. Lube Oil Supply Pressure: 6 PSIG, L/O Pressure Low Trip.
2. T5.4: 1530 degrees F., PT Overtemp Trip. CG-47 Single Shank Turbine, 1625 degrees F., Overtemp Trip.
3. NPT: 3960 +/- 40 RPM, PT Overspeed Trip.
4. GG Vibration: 7 mils, GG VIB Stop.
5. PT Vibration: 10mils, PT VIB Stop.
6. Tach No. 1 and 2: Both signals< 100 RPM, Unidentified Stop.
7. Module Cooling System: Loss of Cooling System, Cooling System Failure.
8. Module Fire Detection: Fire sensed by UV sensor, Fire Stop.

CAUTION

Shutdown of the GT, without the normal five minute operation at idle and when T5.4 temperature during operation was 1000 degrees F. or higher and/or NGG was above 8000 RPM, may cause uneven cooling of the GT which could adversely affect operation. It is possible to induce bowed rotor vibration.

To minimize the effect of uneven cooling, perform procedures for one of the conditions listed below:

Condition 1: GT is to be restarted within four minutes after initiation of emergency shutdown

1. Restart GT using normal starting procedures.

2. If GT is to be shutdown after restart, allow five minutes at Idle prior to shutdown. If GT operation is to continue, proceed with normal operation.

Condition 2: GT cannot be restarted within four minutes after initiation of shutdown, but a startup will be required within the next six hour period.

1. Conditions permitting, motor engine for five minutes after GG stops rotation, within ten minutes after initiation of shutdown.
2. If GT cannot be motored within ten minutes after initiation of shutdown, perform a five minute motoring immediately prior to start.
3. When GT is restarted, operate at idle RPM for five minutes.

Condition 3: GT restart is not required for at least six hours.

1. If GT is not to be restarted for a period of six hours after shutdown, there are no restrictions on restart. Use normal startup procedures to put GT back on line.

Table 1-1. Normal Operating Limits DD-963 and CG-47

Items		Normal Operating Limits	Emergency Operation and Maintenance Required
1.	Starter		
a.	Starting duty cycle (air pressure 35-85 PSIG at the starter regulator/shutoff valve)	45 sec on, two min off, for any number of cycles or two min on, five min off, two min on, 21 min off in any 30 minute period	Any amount. Return starter to overhaul at first opportunity
b.	Motoring duty cycle (air pressure 20-22 PSIG at the starter regulator/shutoff valve)	Ten min on, 20 min off, for any number of cycles (max starter inlet air temperature 200 °F for ten min motoring) or five min on, two min off, five min on, 18 min in any 30 min period	Any amount. Return starter to overhaul at first opportunity

Table 1-1. Normal Operating Limits DD-963 and CG-47 - Continued

Items		Normal Operating Limits	Emergency Operation and Maintenance Required
c.	Starter Overspeed Switch	4300-4700 RPM N_{GG}	CAUTION Shutoff starter air supply using ship's control and deactivate ignition
		CAUTION If starter regulator shutoff valve does not close at IDLE, shutoff starter air supply	
d.	Starter Oil Consumption/Leakage	0.5 cc per hour of GT running time	
2.	Starter Air Valve Inlet Pressure	35-85 PSIG (starting) 20-22 PSIG (motoring)	
3.	Ignition Duty Cycle	**Normal Duty Cycle:** 45 sec on, 30 min off	
		Extended Duty Cycle: a. 75 sec on, 90 sec off for three cycles followed by 30 min off b. 45 sec on, two min off for four cycles followed by 30 min off	Extended duty cycle may be exceeded but life of ignition system will be reduced.
4.	GT starting		
		NOTE Routine motoring of GT before each lightoff is not required.	CAUTION Abort start if $T_{5.4}$ rapidly approaches or exceeds limits of MMO-020, Figure 3-6
a.	Lightoff	$T_{5.4} \geq 400$ °F within 40 sec max after initiation of ignition and fuel.	If $T_{5.4}$ does not reach 400 °F within 40 sec, terminate ignition and fuel and continue motoring for 60 sec to clear GT of residual fuel. Attempt second start. If unsuccessful, troubleshoot system. If lightoff is obtained and IDLE reached, troubleshoot at next opportunity.

Table 1-1. Normal Operating Limits DD-963 and CG-47 - Continued

Items		Normal Operating Limits	Emergency Operation and Maintenance Required
b.	FMP	250 PSIG FMP is acceptable at initial $T_{5.4}$ rise. Do not exceed maximum $T_{5.4}$ temperature limits of MMO-020, Figure 3-6.	CAUTION Abort start if $T_{5.4}$ rapidly approaches or exceeds 1350 °F.
			NOTE If FMP exceeds 250 PSIG, troubleshoot per MMO-030, Figure 5-6 and take corrective action. If successful start is obtained, do not replace MFC.
c.	Time To Reach Idle N_{GG} RPM	1200±100 RPM N_{GG} shall be obtained within 20 seconds after initiation of starter. Idle N_{GG} RPM shall be obtained 60 seconds max from starter initiation	If N_{GG} continues to increase, start may be continued for 30 more sec provided $T_{5.4}$ does not exceed limit shown in MMO-020, Figure 3-6. If all other parameters are normal, correct discrepancy at next opportunity.
5.	Torque		
a.	FULL POWER Mode		
(1)	Reference	31,000 FTLB	
(2)	Torque Limiting	31,620 to 35,340 FTLB	Reduce power to stay within limits. If reducing power does not bring parameters within limits, shutdown GT.
b.	SPLIT PLANT mode		
(1)	Reference	33,000 FTLB	
(2)	Torque Limiting	33,660 to 37,620 FTLB	Reduce power to stay within limits. If reducing power does not bring parameters within limits, shutdown GT.
c.	Idle	$P_{t5.4}$ bias is provided to prevent unstable TC operation. The output value at IDLE should be ignored	
6.	Full Power Rating		

Table 1-1. Normal Operating Limits DD-963 and CG-47 - Continued

Items		Normal Operating Limits	Emergency Operation and Maintenance Required
a.	Brake Horsepower (bhp)	21,500 bhp	
b.	N_{PT}	3600 RPM	
7.	N_{GG}		
a.	Idle	4900-5000 RPM	
b.	Maximum (operational)	9500 RPM. Alarm at 9700±100 RPM	If 10,122 RPM is exceeded, remove GG and send to overhaul for ovsp inspection.
c.	Speed Schedule	See MMO-020, Figure 3-7.	
d.	Windmilling (free rotation)	(1) 100 RPM max for two weeks provided each period is preceded by normal GT operation	
		(2) 100 to 1000 RPM for five min max provided each period is preceded by normal GT operation	
		NOTE Adequate cooling must be provided at the higher N_{GG} speeds.	
		(3) Any amount above 1000 RPM provided scavenge oil temperature is below 300 °F	
e.	Maximum N_{GG} with PT locked (brake engaged)	See MMO-020, Figure 3-8	
8.	N_{PT}		
a.	Idle (clutch and brake disengaged)	1600-2200 RPM	If all other parameters are normal, correct discrepancy at next opportunity.

Table 1-1. Normal Operating Limits DD-963 and CG-47 - Continued

Items		Normal Operating Limits	Emergency Operation and Maintenance Required
b.	Maximum (operational) Maximum (ovsp)	3600 RPM 3960±40 RPM	The ovsp trip setpoint is 3960±40 RPM. Determine cause of ovsp and take corrective action. In the event of a sheared shaft, High-Speed Coupling Shaft (HSCS) side, remove PT assembly and send to overhaul for inspection. If ovsp trip did not occur troubleshoot ovsp switch and associated circuitry. Determine cause of ovsp. Take corrective action before operating GT with new PT installed. Ovsp limiting occurs at 3672 RPM nominally (3636 to 3852 RPM). PLA Actuator lever will be automatically reduced above this N_{PT}. If ovsp limiting did not occur, troubleshoot PLA Actuator system
c.	Windmilling (free rotation)	(1) 400 RPM max for 20 hours provided each period is preceded by five min of normal GT operation at IDLE speed or above	If 4585 RPM is exceeded, remove PT and send to overhaul for ovsp inspection.
		(2) 1400 RPM max for ten hours provided each period is preceded by normal GT operation at IDLE speed or above	
d.	Locked Rotor (Brake Engaged)	Do not exceed limits of MMO-020, Figure 3-8	
9.	PT Inlet Temperature ($T_{5.4}$)		
		NOTE Normal operating temperature for the single shank turbine GG is slightly higher (10-20 °F) than for the paired blade turbine GG. The operating limits are the same for both.	
a.	Starts	See MMO-020, Figure 3-6.	
b.	Idle	1000 °F max	

Table 1-1. Normal Operating Limits DD-963 and CG-47 - Continued

Items		Normal Operating Limits	Emergency Operation and Maintenance Required
c.	Maximum	1500 °F (alarm) 1530 °F (automatic emergency shut-down)	Reduce power to stay within limits. If reducing power does not bring parameters within limits, shutdown GT
		NOTE When T_2 is above 120 °F, the throttle may have to be retarded to keep $T_{5.4}$ within limits.	
10.	Fuel System		
a.	Type Of Fuel	Marine diesel fuel oil, MIL-F-16884 or Turbine fuel MIL-T-5624, JP5	Adjust fuel control to the specific gravity of fuel being used. Refer to MMO-050, para. 7.8.2
b.	Inlet Temperature	30-100 °F	
c.	Inlet Pressure	10-50 PSIG	If all other parameters are normal, correct discrepancy at next opportunity
d.	Wet Prestart Manifold	80-200 PSIG	If all other parameters pressure are normal, correct discrepancy at next opportunity
e.	Idle FMP	230-350 PSIG	If all other parameters are normal correct discrepancy at next opportunity
		NOTE A minimum of 70 PSIG FMP is acceptable for ten seconds maximum during deceleration to IDLE setting.	
f.	Fuel Filter Differential	Alarm above 27 PSID. Seven PSID max at IDLE	If all other parameters are normal, correct discrepancy at next opportunity
11.	Lube Oil System		
a.	No Oil	No operation allowed	No operation allowed
b.	Oil Pressure		
(1)	Starts	Indication	Automatic emergency shutdown if oil pressure does not reach six PSIG after reaching IDLE

Table 1-1. Normal Operating Limits DD-963 and CG-47 - Continued

Items		Normal Operating Limits	Emergency Operation and Maintenance Required
(2)	Operating Speeds	Must be within limits of MMO-020, Figure 3-9. Alarm if below 15±1 PSIG	Perform normal shutdown. Troubleshoot system
c.	Oil Consumption	946 cc per hour max	Any amount if pressure is within limits. If all other parameters are normal, correct discrepancy at next opportunity
d.	Scavenge Oil Temperature	200-300 °F normal 340°F max. Alarm at 300 °F (applies to all reached, sumps)	If 340 °F max. temperature is reached perform normal GT shutdown. Troubleshoot system
e.	Heat Exchanger Lube Oil Outlet Temperature	135-220 °F normal 250°F max - Alarm	Reduce power to stay within limits. If reducing power does not bring parameters within limits, perform normal shutdown
f.	Scavenge Oil Filter Differential Pressure	Alarm above 20 PSID. Five PSID max at IDLE	If all other parameters are normal, correct discrepancy at next opportunity
g.	Lube Oil Supply Filter Differential Pressure	Alarm above 20 PSID. Five PSID max at IDLE	If all other parameters are normal differential pressure, correct discrepancy at next opportunity
h.	Oil Tank Level	19-24 gallons (service when below 19 gallon sight glass)	Eight gallons min if lube pressure is within limits
12.	Vibration		
		NOTE There are two vibration pickups. One is located on the GG and the other is on the PT. Each pickup senses both GG and PT vibrations depending on vibration frequency. Limits apply to frequency and not pickup location.	**NOTE** For operation with a non functioning vibration system or expired metcal stickers, see MMO-020, Table 3-15, Table 3-27 or Table 3-41, as applicable
a.	GG FREQ	Alarm above four mils. Normal shutdown above seven mils	Reduce power to stay within limits. If reducing power does not bring parameters within limits, shutdown GT
b.	PT FREQ	Alarm above seven mils. Normal shutdown above ten mils	Reduce power to stay within limits. If reducing power does not bring parameters within limits, shutdown GT
13.	CDP (Ps3)	250 PSIG max	If all other parameters are normal, correct discrepancy at next opportunity

Table 1-1. Normal Operating Limits DD-963 and CG-47 - Continued

Items		Normal Operating Limits	Emergency Operation and Maintenance Required
14.	Fluid Leakage		
		NOTE For purposes of leakage measurement, one cc is equal to 25 drops. Fuel leakage limits do not apply to shutdown valve drainage during GT shutdown or purge valve during purge operations.	
a.	Fuel leakage		
(1)	Fuel Manifold Shroud	None allowed	Perform normal shutdown. Correct discrepancy
(2)	Vane Actuator	Two cc per minute max per actuator	Perform normal shutdown. Correct discrepancy
(3)	Fuel Control Throttle Shaft	One cc per minute max	Perform normal shutdown. Correct discrepancy
(4)	Fuel Shutoff Valves No. 1 and 2	15 cc per minute max per valve	Perform normal shutdown. Correct discrepancy
(5)	Fuel Pump Drive	Three cc per minute max	Perform normal shutdown. Correct discrepancy
(6)	Fuel Purge Valve	1/2 cc per hr max	Perform normal shutdown. Correct discrepancy
b.	Drive Pad Oil Leakage	**NOTE** Drive pad drains are located at starter, fuel pump, auxiliary and lube and scavenge pump output drives	
		20 cc per hour max combined (Five cc per hour per pad)	Any amount. Correct at next opportunity
c.	B- and C-Sump Seal Oil Leakage	25 cc per hour per sump	Any amount. Correct at next opportunity
d.	Air-Oil Separator Exhaust Duct Drainage	50 cc per hour max	5000 cc per hour. Correct at next opportunity

Table 1-1. Normal Operating Limits DD-963 and CG-47 - Continued

Items		Normal Operating Limits	Emergency Operation and Maintenance Required
15.	Pre-Shutdown Stabilization Time	IDLE for five minutes before shutdown2	Emergency shutdown from any power level. Repeated emergency shutdown will reduce engine life and performance level. Bowed rotor vibration may be caused by emergency shutdown. Refer to MMO-020, Table 3-10 for correct action
		NOTE Routine motoring of the GT after each shutdown is not required.	
16.	Enclosure Environmental System		
a.	Exit Air Temp	Variable	Alarm above 350 °F. Trouble shoot and take corrective action
b.	Damper	Open during GT operation. Closed when ventilation air temperature is below 70 °F if GT is not operating	If damper closes during start, abort start. Open manually and block open if damper closes during operation. Correct fault and return damper system to normal operation after emergency is over. If ship's AC power is lost (and cooling air flow) the damper must be closed immediately. Open damper when AC power (and cooling air flow) is restored
c.	Enclosure Temperature Switches	Closes at 400 °F. MODULE FIRE alarm signal is generated	Automatic emergency engine shutdown occurs
d.	Enclosure/Fuel Heater		
(1)	Heater Assembly	Energized when engine shutdown and ambient temp below 70 °F. Deenergized when engine operating	
(2)	Heater Element Circuit	Open at 90±5 °F heater inlet temp Closed at 65±5 °F heater inlet temp	

Table 1-1. Normal Operating Limits DD-963 and CG-47 - Continued

Items		Normal Operating Limits	Emergency Operation and Maintenance Required
(3)	Heater Blower	Operating when heater inlet temp is below 120 °F Not operating when heater inlet temp is above 145 °F	
(4)	Heater Overtemp Cutout Switch	Setpoint 350 °F	

1.3.18.3 DDG-51 Normal Start Sequence

NOTE

Engineering Operating Sequencing System (EOSS) will always be followed when performing all engineering evolutions.

0 NGG

1. Ensure that prestart permissives are met.
2. Verify the Vent Damper is in Auto Vent Control position.
3. Verify the Fan is in standby.
4. Verify Electrical Power to Enclosure/Fuel Heater is Off.

NOTE

A start may be aborted after lightoff by activating the emergency stop signal. Start abort is automatic if lightoff is not obtained within 40 seconds after fuel/ignition application.

5. Starter air On (Note time to 1100 NGG 20 sec max). (Note time to 4500 NGG 90 sec max). Prior to start, air pressure should be 35-85 Psig. Optimum pressure is 70-80 PSIG.

a. If six PSIG lube oil pressure is not reached within 45 seconds, an automatic shutdown will occur.

1200 +/- 100 NGG

1. Ignition On
2. Main Fuel Shutoff Valves No. 1 and No. 2 open. (Light Off fuel manifold pressure should be approximately 9-120 PSIG).

CAUTION

If T5.4 rapidly approaches or exceeds 1350 F, abort start. If indication of compressor stall is encountered, abort start A start stall is characterized by a hung start, slow acceleration to idle, and/or higher than normal T5.4

NOTE

250 PSIG FMP is acceptable at initial T5.4 rise. Do not exceed maximum T5.4 temperature limits. If FMP exceeds 250 PSIG, troubleshoot per S9234-AD-MMO-030 and take corrective action. If FMP on initial temperature rise exceeds 200 PSIG, but is less than 250 PSIG, continue start. At next opportunity, perform wet motor per S9234-AD-MMO-020.

3. Note time to lightoff. If FMP is not greater than 50 PSIG and T5.4 is not greater than 400 +/- 10 degree F within 40 seconds the following will occur.
    1. The fuel valves deenergize.
    2. The ignitors deenergize.
    3. The GG continues to motor for 60 seconds to purge the engine of residual fuel.
    4. After the GG motors for 60 seconds an automatic shutdown will occur.
4. Note Peak T5.4 during start. Normal maximum is approximately 800-900 degree F.

4300 +/- 200 NGG

CAUTION

If starter regulator shutoff valve does not close at 4500±200 NGG, shutoff starter air supply using ship's control and deactivation ignition.

1. Starter air shutoff valve automatically closes.
2. Igniter Off
3. Note time to 4900 NGG. Time to IDLE 60 sec max. If NGG continues to increase, start may be continued for 30 more seconds provided T5.4 does not exceed limits.

4900 +/- 50

1. Startup is now complete. GT is at IDLE power. Normal start should take 40-45 seconds.

IDLE

1. FMP at 4900 NGG: 295-305 PSIG. Not to exceed 350 PSIG.
2. T5.4 at 4900 NGG: 750-850 degree F. (1000 max).

3. CDP at 4900 NGG: 27-31 PSIA.
4. PT5.4 at 4900 NGG: 15-17 PSIA.

1.3.18.4 DDG-51 Shutdowns

NOTE

Engineering Operating Sequencing System (EOSS) will always be followed when performing all engineering evolutions.

1. Lube Oil Supply Pressure: 6 PSIG, L/O Pressure Low Trip.
2. T5.4: 1625 degrees F., Overtemp Trip.
3. NPT: 3960 +/- 40 RPM, PT Overspeed Trip.
4. GG Vibration: 7 mils, GG VIB Stop.
5. PT Vibration: 10mils, PT VIB Stop.
6. Tach No. 1 and 2: Both signals < 100 RPM, Unidentified Stop.
7. Module Fire Detection: Fire sensed by UV sensor, Fire Stop.
8. Flameout: T5.4 < 400 degree F. or < 50 PSI fuel manifold pressure with NGG above 4500 RPM. Shutdown.

CAUTION

Shutdown of the GT, without the normal five minute operation at idle and when T5.4 temperature during operation was 1000 degrees F. or higher and/or NGG was above 8000 RPM, may cause uneven cooling of the GT which could adversely affect operation. It is possible to induce bowed rotor vibration.

To minimize the effect of uneven cooling, perform procedures for one of the conditions listed below:

Condition 1: GT is to be restarted within four minutes after initiation of emergency shutdown
1. Restart GT using normal starting procedures.
2. If GT is to be shutdown after restart, allow five minutes at Idle prior to shutdown. If GT operation is to continue, proceed with normal operation.

Condition 2: GT cannot be restarted within four minutes after initiation of shutdown, but a startup will be required within the next six hour period.
1. Conditions permitting, motor engine for five minutes after GG stops rotation, within ten minutes after initiation of shutdown.
2. If GT cannot be motored within ten minutes after initiation of shutdown, perform a five minute motoring immediately prior to start.
3. When GT is restarted, operate at idle RPM for five minutes.

Condition 3: GT restart is not required for at least six hours.
1. If GT is not to be restarted for a period of six hours after shutdown, there are no restrictions on restart. Use normal startup procedures to put GT back on line.

Table 1-2. Propulsion Gas Turbine Module Operating Limits, DDG-51 and AOE-6

Item		Normal Operating Limits	Emergency Operation and Maintenance Required
1.	Starter		
a.	Starting duty cycle (air pressure 35-85 PSIG at starter air regulating valve)	45 sec on, Two min off, for any number of cycles or Two min on, Five min off, Two min on, 21 min off in any 30 min period	Any amount. Return starter to overhaul at first opportunity
b.	Motoring duty cycle DDG-51 (air pressure 20-22 PSIG at the starter air regulator valve inlet)	Ten min on, 20 min off for any number of cycles (max starter inlet air temperature of 200 °F for Ten min motoring) or Five min on, Two min off, Five min on 18 min off in any 30 min period	Any amount. Return starter to overhaul at first opportunity
c.	Motoring duty cycle AOE (air pressure 35-85 PSIG at the air regulating valve)	Ten min on, 20 min off for any number of cycles (max starter inlet air temperature of 200 °F for Ten min motoring) or Five min on, Two min off, Five min on 18 min off in any 30 min period	Any amount. Return starter to overhaul at first opportunity
d.	Starter overspeed switch	4300-4700 RPM N_{GG}	
		CAUTION If starter air regulating valve does not close at IDLE, shutoff starter air supply	**CAUTION** Shutoff starter air supply using ship's control and deactivated ignition
e.	Starter oil consumption/leakage	0.5 cc per hour of GT running time	
2.	Starter Air Valve Inlet Pressure	DDG-51 35-85 PSIG (starting) 20-22 PSIG (motoring) AOE 35-85 PSIG (starting and motoring)	
3.	Ignition Duty Cycle:	**Normal Duty Cycle:** 45 sec on, 30 min off	
		Extended Duty Cycle: a. 75 sec on, 90 sec off for three cycles followed by 30 min off. b. 45 sec on, Two min off for three cycles followed by 30 min off. 90 sec on, 90 sec off for two cycles followed by 25 min off.	

Table 1-2. Propulsion Gas Turbine Module Operating Limits, DDG-51 and AOE-6 - Continued

Item		Normal Operating Limits	Emergency Operation and Maintenance Required
4.	GT starting	Motoring prior to a restart is not required if the GT has been shutdown for less than 60 minutes	Abort start if $T_{5.4}$ rapidly approaches or exceeds limits of MMO-020, Figure 3-19
a.	Time to reach 1200 RPM N_{GG}	20 sec from starter initiation	
b.	Lightoff	$T_{5.4}$ ≥400 °F within 40 sec max after initiation of ignition and fuel	
c.	FMP	250 PSIG FMP is acceptable at initial $T_{5.4}$ rise. Do not exceed maximum $T_{5.4}$ temperature limits of MMO-020, Figure 3-19	**CAUTION** Abort start if $T_{5.4}$ rapidly approaches or exceeds 1350 °F
			NOTE If FMP exceeds 250 PSIG, troubleshoot per MMO-030 Figure 5-6 and take corrective action. If start is successful, do not replace MFC.
d.	Time to reach 4500±100 RPM N_{GG}	50 sec from starter initiation	If RPM stops accelerating, abort start. If it takes longer than 50 seconds to reach 4500±100 RPM, start may be continued not to exceed maximum time of 90 seconds from starter initiation provided $T_{5.4}$ does not exceed limit shown in MMO-020, Figure 3-19. If all other parameters are normal, correct discrepancy at next opportunity
e.	Time to reach IDLE N_{GG} RPM	1200±100 RPM N_{GG} shall be obtained within 20 seconds after initiation of starter. Idle N_{GG} 4900-5000 RPM shall be obtained 60 seconds from starter initiation	If N_{GG} continues to increase, start may be continued for 30 more seconds provided $T_{5.4}$ does not exceed limit shown in MMO-020, Figure 3-19
			If all other parameters are normal, correct discrepancy at next opportunity
5.	Torque		
a.	Reference	36,900 FTLB	

Table 1-2. Propulsion Gas Turbine Module Operating Limits, DDG-51 and AOE-6 - Continued

Item		Normal Operating Limits	Emergency Operation and Maintenance Required
b.	Torque limiting	47,616 FTLB	Reduce power to stay within limits. If reducing power does not bring parameters within limits, shutdown GT
6.	Full Power Rating		
a.	Brake Horsepower	26,250	
b.	N_{PT}	3600 RPM	
7.	N_{GG}		
a.	Idle	4900-5000 RPM (IDLE speed signal on at 4950±50 RPM, OFF at 5150±50 RPM)	
b.	Max Operational Limit	9500 RPM	If speed exceeds 10,122 RPM, remove GG and send to overhaul for ovsp inspection
c.	Speed Schedule	See MMO-020, Figure 3-20	
d.	Windmilling (free rotation)	(1) 100 RPM max for two weeks provided each period is preceded by normal GT operation	
		(2) 100 RPM max for two weeks provided each period is preceded by normal GT operation	
		NOTE Adequate cooling must be provided at the higher N_{GG} speeds.	
		(3) Any amount above 1000 RPM provided scavenge oil temperature is below 300 °F	
e.	Maximum N_{GG} with PT locked (brake engaged)	See MMO-020, Figure 3-21	
8.	N_{PT}		

Table 1-2. Propulsion Gas Turbine Module Operating Limits, DDG-51 and AOE-6 - Continued

Item		Normal Operating Limits	Emergency Operation and Maintenance Required
a.	IDLE (clutch locked out and brake disengaged)	1600-2200 RPM	If all other parameters are normal, correct discrepancy next opportunity
b.	Maximum (operational)	3600 RPM	Ovsp trip setpoint is 3960±40 RPM. If PT ovsp trip occurs, determine cause and take corrective action. In the event of a sheared shaft, HSCS side, remove PTA and send to overhaul for inspection. If ovsp trip did occur, troubleshoot ovsp switch and associated circuitry. Determine cause of ovsp. Take corrective action before operating GT with new PT installed. Ovsp limit setpoint is 3672 RPM nominal (3672-3852 RPM). If N_{PT} exceeds setpoint the PLA Actuator lever will be automatically reduced. If ovsp limiting did not occur, troubleshoot PLA Actuator system
c.	Windmilling (free rotation)	(1) 400 RPM max for 2.5 hours provided GT is operated at IDLE or above for a period of at least five minutes preceding the windmilling	If 4585 RPM is exceeded, remove PT and send to overhaul for ovsp inspection
		(2) 1000 RPM max for 2.0 hours provided GT is operated at IDLE or above for a period of at least five minutes preceding the windmilling	
		(3) 1400 RPM max for 1.5 hours provided GT is operated at IDLE or above for a period of at least five minutes preceding the windmilling	
		NOTE The above windmilling requirements are with the GG secured (rotating below 100 RPM).	
d.	Locked Rotor (brake engaged)	Do not exceed limits of MMO-020, Figure 3-21	
9.	$T_{5.4}$		

Table 1-2. Propulsion Gas Turbine Module Operating Limits, DDG-51 and AOE-6 - Continued

Item		Normal Operating Limits	Emergency Operation and Maintenance Required
a.	Starts	See MMO-020, Figure 3-19	
b.	IDLE	1000 °F (max)	
c.	Maximum	1600 °F (alarm), 1625 °F (automatic shutdown)	Reduce power to stay within limits. If reducing power does not bring parameters within limits, shutdown GT
		NOTE When T_2 is above 120 °F, the throttle may have to be retarded to keep $T_{5.4}$ within limits.	
10.	Fuel System		
a.	Type of Fuel	Marine diesel fuel oil, MIL-F-16884 or Turbine fuel MIL-T-5624 (JP5)	Adjust MFC to the specific gravity of fuel being used. Refer to MMO-060, para. 7.262
b.	Inlet Pressure	10-50 PSIG	If all other parameters are normal, correct discrepancy at next opportunity
c.	Inlet Temperature	30-100 °F	
d.	Wet Prestart Manifold Pressure	80-200 PSIG	If all other parameters are normal, correct discrepancy at next opportunity
e.	Idle Manifold Pressure	230-350 PSIG	If all other parameters are normal, correct discrepancy at next opportunity
		NOTE A minimum of 70 PSIG FMP is acceptable for ten seconds maximum during deceleration to IDLE setting.	
f.	Fuel Filter Differential Pressure	Seven PSID max at IDLE	If all other parameters are normal, correct discrepancy at next opportunity
11.	Lube System		

Table 1-2. Propulsion Gas Turbine Module Operating Limits, DDG-51 and AOE-6 - Continued

Item		Normal Operating Limits	Emergency Operation and Maintenance Required
a.	Type of Oil	MIL-L-23699	
b.	No Oil	No operation allowed	No operation allowed
c.	Oil Pressure		
(1)	Starts	Automatic shutdown if oil pressure does not reach 6±1 PSIG within 45 seconds after start initiation	
(2)	Operating Speeds	Must be within limits of MMO-020, Figure 3-22 for engines without 3R/5R damper bearings or MMO-020, Figure 3-23 for engines with 3R/5R damper bearing configuration (GGAs 804, 536 through 553, 1019 through 1999 and 2003 and higher). Alarm if below 15±1 PSIG	Perform normal shutdown. Troubleshoot system
d.	Oil Consumption	946 cc per hour max	Any amount if pressure is within limits. If all other parameters are normal, correct discrepancy at next opportunity
e.	Scavenge Oil Temperature	200-300 °F normal 340 °F max. Alarm at 300 °F (applies to all sumps)	If 340 °F max temperature is reached, perform normal GT shutdown. Troubleshoot system
f.	Heat Exchanger Lube Oil Outlet Temperature	150-170 °F normal. Alarm above 250 °F	Reduce power to stay within limits. If reducing power does not bring parameters within limits, shutdown engine
g.	Lube Scavenge Filter Differential Pressure	Five PSID max at IDLE. 20 PSID max above IDLE	If all other parameters are normal, correct discrepancy at next opportunity
h.	Lube Supply Oil Filter Differential Pressure	Five PSID max at IDLE. 20 PSID max above IDLE	If all other parameters are normal, correct discrepancy at next opportunity
i.	Oil Tank Level	Usable range 8-24 gallons. Full level 32 gallons. Low level alarm 9.6 gallons	Service when below 19 gallon sight glass
12.	Vibration		

Table 1-2. Propulsion Gas Turbine Module Operating Limits, DDG-51 and AOE-6 - Continued

Item		Normal Operating Limits	Emergency Operation and Maintenance Required
		NOTE There are two vibration pickups. One on the GG and one on the PT. Each pickup senses both GG and PT frequency vibration. Limits apply to frequency not pickup location.	**NOTE** For operation with a non functioning vibration monitoring system or expired metcal stickers, see MMO-020, Table 3-15, Table 3-27, or Table 3-41 as applicable
a.	GG	Alarm above four mils. Emergency shutdown above seven mils	Reduce power to stay within limits. If reducing power does not bring parameters within limits, shutdown engine
b.	PT	Alarm above seven mils. Emergency shutdown above ten mils	Reduce power to stay within limits. If reducing power does not bring parameters within limits, shutdown engine
13.	CDP (P_{S3})	250 PSIG max	If all other parameters are normal, correct discrepancy at next opportunity
14.	Fluid Leakage		
		NOTE • For purposes of leakage measurement, one cc is equal to 25 drops. • Fuel leakage limits do not apply to shutoff valve drainage during GT shutdown or purge valve during purge operations.	
a.	Fuel Leakage		
(1)	Fuel Manifold	None allowed	Perform normal shutdown. Correct discrepancy
(2)	Vane Actuator	Two cc per minute max per actuator	Perform normal shutdown. Correct discrepancy
(3)	Fuel Control Throttle Shaft	One cc per minute max	Perform normal shutdown. Correct discrepancy
(4)	Fuel Shutoff Valves No. 1 and 2	15 cc per minute max per value	Perform normal shutdown. Correct discrepancy
(5)	Fuel Pump Drive	Three cc per minute max	Perform normal shutdown. Correct discrepancy
(6)	Fuel Purge Valve	1/2 cc per hour max	Perform normal shutdown. Correct discrepancy
b.	Drive Pad Oil Leakage	**NOTE** Drive pad drains are located at starter, fuel pump, auxiliary, and lube and scavenge pump output drives	
		25 cc per hour max combined (Five cc per hour per pad)	Any amount. Correct next opportunity
	B- and C-Sump Seal Oil Leakage	25 cc per hour per sump	Any amount. Correct next opportunity
d.	Air-Oil Separator Exhaust Duct Drainage	50 cc per hour max	5000 cc per hour. Correct next opportunity
15.	Pre-Shutdown Stabilization Time	IDLE for five minutes before shutdown	Emergency shutdown from any power level. Bowed rotor vibration may be caused by emergency shutdown. Repeated emergency shutdown will reduce GT life and performance level. Refer to MMO-020, Table 3-25 for correct action
		NOTE Routine motoring of the GT after each shutdown is not required.	
16.	Enclosure Environmental System		
a.	Exit Air	Variable	
b.	Damper	Open during GT operation. Closed when ventilation air temperature is below 70 °F if GT is not operating	If damper closes during start, abort start. If damper closes during operation open manually and block open. Correct fault and return damper system to normal operation after emergency is over

Table 1-2. Propulsion Gas Turbine Module Operating Limits, DDG-51 and AOE-6 - Continued

Item		Normal Operating Limits	Emergency Operation and Maintenance Required
c.	Enclosure Temperature Switches	Closes at 400 °F. Enclosure high temperature signal is generated	Visually observe GT through BEA door window for evidence of fire. If confirmed, actuate manual FIRE EXTINGUISH pushbutton
d.	Enclosure/Fuel Heater		
(1)	Heater Assembly	Energized when engine shutdown and ambient temp below 70 °F Deenergized when GT operating	
(2)	Heater Element Circuit	Open at 90±5 °F heater inlet temp Closed at 65±5 °F heater inlet temp	
(3)	Heater Blower	Operating when heater inlet temp below 120 °F Not operating when heater inlet temp above 145 °F	
(4)	Heater Overtemp Cutout Switch	Setpoint 350 °F	

1.3.18.5 <u>FFG-7 Normal Start Sequence</u>

NOTE

Engineering Operating Sequencing System (EOSS) will always be followed when performing all engineering evolutions.

0 NGG

1. Ensure that prestart permissives are met.
2. Verify the Vent Damper is in Auto Vent Control position.
3. Verify the Fan is in standby.
4. Verify Electrical Power to Enclosure/Fuel Heater is Off.

NOTE

A start may be aborted after lightoff by activating the emergency stop signal. Start abort is automatic if lightoff is not obtained within 40 seconds after fuel/ignition application.

5. Starter air On (Note time to 1100 NGG 20 sec max). (Note time to 4500 NGG 90 sec max). Prior to start, air pressure should be 35-85 PSIG. Optimum pressure is 70-80 PSIG.
   a. If six PSIG lube oil pressure is not reached within 45 seconds, an automatic shutdown will occur.

1200 +/- 100 NGG

1. Ignition On
2. Main Fuel Shutoff Valves No. 1 and No. 2 open. (Light Off fuel manifold pressure should be approximately 9-120 PSIG).

CAUTION

If T5.4 rapidly approaches or exceeds 1350 F, abort start. If indication of compressor stall is encountered, abort start. A start stall is characterized by a hung start, slow acceleration to idle, and/or higher than normal T5.4.

NOTE

250 PSIG FMP is acceptable at initial T5.4 rise. Do not exceed maximum T5.4 temperature limits. If FMP exceeds 250 PSIG, troubleshoot per S9234-AD-MMO-030 and take corrective action. If FMP on initial temperature rise exceeds 200 PSIG, but is less than 250 PSIG, continue start. At next opportunity, perform wet motor per S9234-AD-MMO-020.

3. Note time to lightoff. If FMP is not greater than 50 PSIG and T5.4 is not greater than 400 +/- 10 degree F within 40 seconds the following will occur.
    1. The fuel valves deenergize.
    2. The ignitors deenergize.
    3. The GG continues to motor for 60 seconds to purge the engine of residual fuel.
    4. After the GG motors for 60 seconds an automatic shutdown will occur
4. Note Peak T5.4 during start. Normal maximum is approximately 800-900 degree F.

4300 +/- 200 NGG

CAUTION

If starter regulator shutoff valve does not close at 4500±200 NGG, shutoff starter air supply using ship's control and deactivation ignition.

1. Starter air shutoff valve automatically closes.
2. Igniter Off
3. Note time to 4900 NGG. Time to IDLE 60 sec max. If NGG continues to increase, start may be continued for 30 more seconds provided T5.4 does not exceed limits.

4900 +/- 50

1. Startup is now complete. GT is at IDLE power. Normal start should take 40-45 seconds.

IDLE

1. FMP at 4900 NGG: 295-305 PSIG. Not to exceed 350 PSIG.
2. T5.4 at 4900 NGG: 750-850 degree F. (1000 max).
3. CDP at 4900 NGG: 27-31 PSIA.
4. PT5.4 at 4900 NGG: 15-17 PSIA.

1.3.18.6 FFG-7 Shutdowns

NOTE

Engineering Operating Sequencing System (EOSS) will always be followed when performing all engineering evolutions.

1. Lube Oil Supply Pressure: 6 PSIG, L/O Pressure Low Trip.
2. T5.4: 1625 degrees F., Overtemp Trip.
3. NPT: 3960 +/- 40 RPM, PT Overspeed Trip.
4. GG Vibration: 7 mils, GG VIB Stop.
5. PT Vibration: 10mils, PT VIB Stop.
6. Tach No. 1 and 2: Both signals< 100 RPM, Unidentified Stop.

7. Module Fire Detection: Fire sensed by UV sensor, Fire Stop.
8. Flameout: T5.4 < 400 degree F. or < 50 PSI fuel manifold pressure with NGG above 4500 RPM. Shutdown.

CAUTION

Shutdown of the GT, without the normal five minute operation at idle and when T5.4 temperature during operation was 1000 degrees F. or higher and/or NGG was above 8000 RPM, may cause uneven cooling of the GT which could adversely affect operation. It is possible to induce bowed rotor vibration.

To minimize the effect of uneven cooling, perform procedures for one of the conditions listed below:

Condition 1: GT is to be restarted within four minutes after initiation of emergency shutdown

1. Restart GT using normal starting procedures.
2. If GT is to be shutdown after restart, allow five minutes at Idle prior to shutdown. If GT operation is to continue, proceed with normal operation.

Condition 2: GT cannot be restarted within four minutes after initiation of shutdown, but a startup will be required within the next six hour period.

1. Conditions permitting, motor engine for five minutes after GG stops rotation, within ten minutes after initiation of shutdown.
2. If GT cannot be motored within ten minutes after initiation of shutdown, perform a five minute motoring immediately prior to start.
3. When GT is restarted, operate at idle RPM for five minutes.

Condition 3: GT restart is not required for at least six hours.

1. If GT is not to be restarted for a period of six hours after shutdown, there are no restrictions on restart. Use normal startup procedures to put GT back on line.

Table 1-3. Propulsion Gas Turbine Module Operating Limits, FFG-7

Item		Normal Operating Limits	Emergency Operation and Maintenance Required
1.	Starter		
a.	Starting Duty Cycle (air pressure 35-85 PSIG at the starter regulator/shutoff valve)	45 sec on, two min off, for any number of cycles or two min on, five min off, two min on, 21 min off in any 30 min period	Any amount. Return starter to overhaul at first opportunity
b.	Motoring Duty Cycle (air pressure 20-22 PSIG at the starter regulator/shutoff valve)	Ten min on, 20 min off any number of cycles (max starter inlet air temperature 200 °F for ten min motoring) or five min on, two min off, five min on, 18 min off in of any 30 min period	Any amount. Return starter to overhaul at first opportunity
c.	Starter Overspeed Switch	4300-4700 RPM N_{GG}	
			CAUTION If starter regulator shutoff valve does not close at IDLE, shutoff starter air supply. Shutoff starter air supply using ship's control and deactivate ignition.
d.	Starter Oil Consumption/Leakage	0.5 cc per hour of GT running time	
2.	Starter Air Valve Inlet Pressure	35-85 PSIG (starting) 20-22 PSIG (motoring)	
3.	Ignition Duty Cycle	**Normal Duty Cycle:** 45 sec on, 30 min off	

Table 1-3. Propulsion Gas Turbine Module Operating Limits, FFG-7 - Continued

Item		Normal Operating Limits	Emergency Operation and Maintenance Required
		Extended Duty Cycle: a. 75 sec on, 90 sec off for three cycles followed by 30 min off b. 45 sec on, two min off for four cycles followed by 30 min off c. 90 sec on, 90 sec off for two cycles followed by 25 min off	Extended duty cycle may be exceeded but life of ignition system will be reduced.
4.	GT Starting	**NOTE** • Routine motoring prior to lightoff is required until the fuel shutoff valve has been modified by LM2500 GTC No. 57 or IGTC No. 63. Motor for 30 seconds after reaching 2200 RPM. Motoring prior to a restart is not required if LM2500 GTM has been secured for less than 60 minutes. • Motoring prior to a restart is not required if the GT has been shutdown for less than 60 minutes.	**CAUTION** Abort start if $T_{5.4}$ rapidly approaches or exceeds limits of MMO-020, Figure 3-32
a.	Lightoff	$T_{5.4}$ ≥400 °F within 40 sec max after initiation of ignition and fuel	When operating in manual mode, if there is no indication of $T_{5.4}$ within 40 sec, terminate ignition and fuel and continue motoring for 60 sec to clear GT of residual fuel. Attempt second start. If unsuccessful, troubleshoot system. If lightoff is obtained and IDLE reached, troubleshoot at next opportunity
b.	FMP	250 PSIG FMP is acceptable at initial $T_{5.4}$ rise. Do not exceed maximum $T_{5.4}$ temperature limits of MMO-020, Figure 3-32	**CAUTION** Abort start if $T_{5.4}$ rapidly approaches or exceeds 1350 °F.
			NOTE If FMP exceeds 250 PSIG, troubleshoot per MMO-030 Figure 5-6 and take corrective action. If successful start is obtained, do not replace MFC.

Table 1-3. Propulsion Gas Turbine Module Operating Limits, FFG-7 - Continued

Item		Normal Operating Limits	Emergency Operation and Maintenance Required
c.	Time to Reach 4500±100 RPM N_{GG}	50 sec from starter initiation	If RPM stops accelerating, abort start. If it takes longer than 50 seconds to reach 4500±100 RPM, start may be continued not to exceed a maximum time of 90 seconds from starter initiation provided $T_{5.4}$ does not exceed limit shown in MMO-020, Figure 3-32. If all other parameters are normal, correct discrepancy at next opportunity
d.	Time to Reach IDLE N_{GG} RPM	1200±100 RPM N_{GG} shall be obtained within 20 seconds after initiation of starter. Idle N_{GG} 4900-5000 RPM shall be obtained 60 seconds from starter initiation	If N_{GG} continues to increase, start may be continued for 30 more seconds provided $T_{5.4}$ does not exceed limit shown in MMO-020, Figure 3-32. If all other parameters are normal, correct discrepancy at next opportunity
5.	Torque		
a.	One engine mode		
(1)	Reference	36,900 FTLB	
(2)	Torque Limiting	37,638-42,066 FTLB	Reduce power to stay within limits. If reducing power does not bring parameters within limits, shutdown GT
b.	Two engine mode		
(1)	Reference	31,000 FTLB	
(2)	Torque Limiting	31,620-35,340 FTLB	Reduce power to stay within limits. If reducing power does not bring parameters within limits, shutdown GT
6.	Full Power Rating		
a.	Brake Horsepower	20,500	

Table 1-3. Propulsion Gas Turbine Module Operating Limits, FFG-7 - Continued

Item		Normal Operating Limits	Emergency Operation and Maintenance Required
b.	N_{PT}	3600 RPM	
7.	N_{GG}		
a.	IDLE	4900-5000 RPM (IDLE speed signal on at 4950±50 RPM. Off at 5150±50 RPM)	
b.	Maximum (operational)	9500 RPM. Alarm at 9700±100 RPM	If 10,122 RPM is exceeded, remove GG and send to overhaul for ovsp inspection
c.	Speed Schedule	See MMO-020, Figure 3-33	
d.	Windmilling (free rotation)	(1) 100 RPM max for two weeks provided each period is preceded by normal GT operation	
		(2) 100 to 1000 RPM for five min max provided each period is preceded by normal GT operation	
		NOTE Adequate cooling must be provided at the higher N_{GG} speeds.	
		(3) Any amount above 1000 RPM provided scavenge oil temperature is below 300 °F	
e.	Maximum N_{GG} with PT locked (with brake engaged)	See MMO-020, Figure 3-34	
8.	N_{PT}		
a.	IDLE (clutch locked out and brake disengaged)	1600-2200 RPM	If all other parameters are normal, correct discrepancy at next opportunity

Table 1-3. Propulsion Gas Turbine Module Operating Limits, FFG-7 - Continued

Item		Normal Operating Limits	Emergency Operation and Maintenance Required
b.	Maximum (operational) Maximum (ovsp)	3600 RPM 3960±40 RPM	The ovsp trip setpoint is 3960±40 RPM. If ovsp trip occurs, determine cause and take corrective action. In the event of a sheared shaft, HSCS side, remove PTA and send to overhaul for inspection. If ovsp trip did not occur, troubleshoot ovsp switch and associated circuitry. Determine cause of ovsp. Take corrective action before operating GT with new PT installed. Ovsp limiting occurs at 3672 RPM nominally (3636-3852 RPM). PLA Actuator lever will be automatically reduced above this N_{PT}. If ovsp limiting did not occur, troubleshoot PLA Actuator system
c.	Windmilling (free rotation)	(1) 400 RPM max for 2.5 hours provided GT is operated at IDLE or above for a period of at least five minutes preceding the windmilling	If 4585 is exceeded, remove PT and send to overhaul for ovsp inspection.
		(2) 1000 RPM max for 2.0 hours provided GT is operated at IDLE or above for a period of at least five minutes proceeding the windmilling	
		(3) 1400 RPM max for 1.5 hours provided GT is operated at IDLE or above for a period of at least five minutes preceding the windmilling	
		NOTE The above windmilling requirements are with the GG secured (rotating below 100 RPM).	
d.	Locked Rotor (brake engaged)	Do not exceed limits of MMO-020, Figure 3-34	
9.	$T_{5.4}$		

Table 1-3. Propulsion Gas Turbine Module Operating Limits, FFG-7 - Continued

Item		Normal Operating Limits	Emergency Operation and Maintenance Required
		NOTE Normal operation temperature for the single shank turbine GG is slightly higher (10-20 °F) than for the paired blade turbine GG. The operating limits are the same for both.	
a.	Starts	See MMO-020, Figure 3-32	
b.	IDLE	1000 °F max	
c.	Maximum	1500 °F (alarm) 1530°F (automatic shutdown)	Reduce power to stay within limits. If reducing power does not bring parameters within limits, shutdown GT
		NOTE When T_2 is above 120 °F, the throttle may have to be retarded to keep $T_{5.4}$ within limits.	
10.	Fuel System		
a.	Type of Fuel	Marine diesel fuel oil, MIL-F-16884 or Turbine fuel MIL-T-5624, JP5	Adjust MFC to the specific gravity of fuel being used. Refer to MMO-050, para. 7.8.2
b.	Inlet Pressure	10-50 PSIG	If all other parameters are normal, correct discrepancy at next opportunity
c.	Inlet Temperature	300-100 °F	
d.	Wet Prestart Manifold Pressure	80-200 PSIG	80-200 PSIG. If all other parameters are normal correct discrepancy at next opportunity
e.	Idle Manifold Pressure	230-350 PSIG	If all other parameters are normal correct discrepancy at next opportunity
		NOTE A minimum of 70 PSIG FMP is acceptable for ten seconds maximum during deceleration to IDLE setting.	

Table 1-3. Propulsion Gas Turbine Module Operating Limits, FFG-7 - Continued

Item		Normal Operating Limits	Emergency Operation and Maintenance Required
f.	Fuel Filter Differential Pressure	Seven PSID max at IDLE	If all other parameters are normal, correct discrepancy at next opportunity
11.	Lube System		
a.	Type of Oil	MIL-L-23699	
b.	No Oil	No operation allowed	No operation allowed
c.	Oil Pressure		
(1)	Starts	Automatic shutdown if oil pressure does not reach 6±1 PSIG within 45 seconds after start initiation	
(2)	Operating Speeds	Must be within limits of MMO-020, Figure 3-35. Alarm if below 15±1 PSIG	Perform normal shutdown. Troubleshoot system
d.	Oil Consumption	946 cc per hour max	Any amount if pressure is within limits. If all other parameters are normal, correct discrepancy at next opportunity
e.	Scavenge Oil Temperature	200-300 °F normal 340 °F max Alarm at 300 °F (applies to all sumps)	If 340 °F max temperature is reached, perform normal GT shutdown. Troubleshoot system
f.	Heat Exchanger Lube Oil Outlet Temperature	135-220 °F normal Alarm above 250 °F	Reduce power to stay within limits. If reducing power does not bring parameters within limits, shutdown engine
g.	Lube Scavenge Filter Differential Pressure	Five PSID max at IDLE 20 PSID max above IDLE	If all other parameters are normal, correct discrepancy at next opportunity
h.	Lube Supply Oil Filter Differential Pressure	Five PSID max at IDLE Alarm above 20 PSID	If all other parameters are normal, correct discrepancy at next opportunity
i.	Oil Tank Level	Usable range eight to 24 gallons. Full level 32 gallons. Low level alarm 9.6 gallons	Service when below 19 gallon sight glass
12.	Vibration		

Table 1-3. Propulsion Gas Turbine Module Operating Limits, FFG-7 - Continued

Item		Normal Operating Limits	Emergency Operation and Maintenance Required
		NOTE There are two vibration pickups. One is located on the GG and the other is on the PT. Each pickup senses both GG and PT frequency vibs. Limits apply to frequency and not pickup location.	**NOTE** For operation with a non functioning vibration system or expired metcal stickers, see MMO-020, Table 3-15, Table 3-27, or Table 3-41 as applicable
a.	GG	Alarm above four mils. Emergency shutdown above seven mils	Reduce power to stay within limits. If reducing power does not bring parameters within limits, shutdown engine
b.	PT	Alarm above seven mils. Emergency shutdown above ten mils	Reduce power to stay within limits. If reducing power does not bring parameters within limits, shutdown engine
13.	Ps_3	250 PSIG max	If all other parameters are normal, correct discrepancy at next opportunity
14.	Fluid Leakage		
	NOTE • For purposes of leakage measurement, one cc is equal to 25 drops. • Fuel leakage limits do not apply to shutdown valve drainage during GT shutdown or purge valve during purge operations.		
a.	Fuel Leakage		
(1)	Fuel Manifold Shroud	None allowed	Perform normal shutdown. Correct discrepancy
(2)	Vane Actuator	Two cc per minute max per actuator	Perform normal shutdown. Correct discrepancy
(3)	Fuel Control Throttle Shaft	One cc per minute max	Perform normal shutdown. Correct discrepancy
(4)	Fuel Shutoff Valves No. 1 and 2	15 cc per minute max per valve	Perform normal shutdown. Correct discrepancy
(5)	Fuel Pump Drive	Three cc per minute max	Perform normal shutdown. Correct discrepancy
(6)	Fuel Purge Valve	1/2 cc per hour max	Perform normal shutdown. Correct discrepancy

Table 1-3. Propulsion Gas Turbine Module Operating Limits, FFG-7 - Continued

Item		Normal Operating Limits	Emergency Operation and Maintenance Required
b.	Drive Pad Oil Leakage Drives.	**NOTE** Drive pad drains are located at starter, fuel pump, auxiliary, and lube oil and scavenge pump output	
		20 cc per hour max combined (Five cc per hour per pad)	Any amount. Correct next opportunity
c.	B- and C-Sump Seal Oil Leakage	25 cc per hour per sump	Any amount. Correct next opportunity
d.	Air-Oil Separator Exhaust Duct Drainage	50 cc per hour max	5000 cc per hour. Correct next opportunity
15.	Pre-Shutdown Stabilization Time	Idle for five minutes before shutdown	Emergency shutdown from any power level. Repeated emergency shutdown will reduce GT life and performance level. Bowed rotor vibration may be caused by emergency shutdown. Refer to MMO-020, Table 3-37 for correct action
		NOTE Routine motoring of the GT after each shutdown is not required.	
16.	Enclosure Environmental System		
a.	Exit Air Temperature	Variable	
b.	Damper	Open during GT operation. Closed when ventilation air temperature is below 70 °F if GT is not operating	If damper closes during start, abort start. Open manually and block open if damper closes during operation. Correct fault and return damper system to normal operation after emergency is over
c.	Enclosure Temperature Switches	Closes at 400 °F. ENCLOSURE HIGH TEMPERATURE signal is generated	Visually observe GT through BEA door window for evidence of fire. If confirmed, actuate manual FIRE EXTINGUISH pushbutton
d.	Enclosure/Fuel Heater		

Table 1-3. Propulsion Gas Turbine Module Operating Limits, FFG-7 - Continued

Item		Normal Operating Limits	Emergency Operation and Maintenance Required
(1)	Heater Assembly	Energized when engine shutdown and ambient temp below 70 °F. Deenergized when GT operating	
(2)	Heater Element Circuit	Open at 90±5 °F heater inlet temp. Closed at 65±5 °F heater inlet temp	
(3)	Heater Blower	Operating when heater inlet temp below 120 °F. Not operating when heater inlet temp above 145 °F	
(4)	Heater Overtemp Cutout Switch	Setpoint 350 °F	

1.4 FUNDAMENTALS SECTION REVIEW QUESTIONS

(Answers are located the last section of the Handbook)

1. What are the major components of the Compressor?
2. What stages of Compressor Stator Vanes are variable?
3. What stages of blades in the Compressor are titanium?
4. Bleed air extracted from the ninth stage of the Compressor is used for what purposes?
5. What are the four major parts of the Combustor?
6. What number bearings support the front and rear end of the HP Turbine Rotor?
7. What is the primary configuration difference between paired blade and single shank HP Turbine Blades?
8. How are the HP Turbine Blades cooled?
9. What are the major parts of the Second Stage Nozzle Assembly?
10. Where are the PT First-Stage Turbine Nozzles located?
11. What components are mounted on the Transfer Gearbox?
12. Why do all six stages of PT Blades contain interlocking tip shrouds?
13. What bearing is housed in the Turbine Rear Frame?
14. What is the purpose of the High-Speed Coupling Shaft Anti-Deflection Rings?
15. What are the types of Oil Seals used in the LM2500?
16. What are the types of Air Seals used in the LM2500?
17. How many Resilient Mounts are located under the GTM Module?
18. What is the purpose of the Pressurizing Valve mounted on the Fuel Control outlet port?
19. What are the two types of fuel flow within the Main Fuel Control?
20. What fuel manifold pressure does the Fuel Nozzle Flow Divider open at?
21. What are the primary inputs to the Main Fuel Control for Fuel Scheduling?
22. Name the three LM2500 Lube Oil Sub Systems?
23. What Technical Directive adds magnetic drain plugs to the Lube and Scavenge Pump Inlet Screens?
24. What is the purpose of the Lube Oil Scavenge Check Valve?
25. How are the LM2500 Gas Turbine Engine Sumps pressurized?
26. How are the Air-Oil Separator Labyrinth Seals pressurized?
27. The Ignition Exciter operates on what input power?
28. What prevents accumulation of carbon in interior passages of the Spark Igniters?
29. What conditions will cause an Icing condition?
30. What are the two types of Vibration Detection Systems used on LM2500 engines?
31. Where is the Flame Detector Signal Conditioner located?
32. How many Flame Detectors and Temperature Switches are used in the LM2500 Fire Detection System?

33. What class ships use Halon as a LM2500 Module Fire Extinguishing agent?
34. Where are the LM2500 Water Wash System Manifold and Outlet Spray Orifices located?
35. What is the primary purpose of the Enclosure Heater?
36. What are the two types of temperature sensors used in the LM2500 Module?
37. Describe the flow of Thirteenth Stage Air?
38. What is the primary purpose of the Eighth Stage Air Ejectors?
39. What are the two major components of the Electronic Power Control System?
40. What are the signals that modify the command directed to the PLA Actuator?
41. During a LM2500 start what is the maximum time allowed to reach 4500 NGG?
42. What is the maximum T5.4 allowable during LM2500 start?
43. What is the maximum allowable LM2500 T5.4 at idle?
44. What are the LM2500 GG and PT vibration alarm limits?
45. What is the L/O pressure low alarm set point?

CHAPTER 2

PLANNED MAINTENANCE SYSTEM AND INSPECTION PROCEDURES

2.1 3-M SYSTEM

The 3-M system is the nucleus for managing maintenance aboard all ships. It is imperative that all hands recognize the importance of this system, and understand the role each plays in assisting management in maintaining the material readiness of equipment in the fleet at the designated levels of reliability.

2.1.1 Maintenance Personnel Maintenance personnel are responsible to the work center supervisor. Their 3-M system duties include, but are not limited to the following:

a. Perform assigned scheduled maintenance requirements using MRCs, Tag Guide Lists (TGLs), and equipment Guide Lists (EGLs) as indicated by the weekly schedule.

b. When performing PMS, promptly notify the work center supervisor when:

(1) Anything on an MRC is not fully understood, appears to be incorrect or cannot be accomplished as written.

(2) Tools, materials, etc., prescribed by the MRC are not available.

(3) Any doubt exists about capability, training or experience to properly perform the MR as prescribed.

(4) Factors exist which would make performance of the MR unwise or dangerous (e.g., disassembly of equipment needed for operations, radiation when prohibited, situations causing safety hazard to exist, ect.)

(5) Equipment deficiencies or casualties are discovered.

c. Inform the work center supervisor when planned maintenance requirements are completed and sign the accountability log. The work center supervisor must be informed of any problems encountered under current schedules and/or MRCs.

d. When performing corrective maintenance (repair);

(1) Notify the work center supervisor of the details of the corrective action. Particular attention must be given to the cause code and remarks/description entries.

(2) Report additional deficiencies found to the work center supervisor.

(3) Initiate or update all 3-M documents as required.

e. Prepare the documentation for reporting deferrals, completions, material usage, and PMS feedback for review by the work center supervisor.

f. Maintain working knowledge of all equipment deficiencies within the work center. Conduct periodic review of the CSMP or Ships Force Work List/Job Sequence Number (SFWL/JSN) Log.

g. When delivering equipment to or receiving equipment from Intermediate Maintenance Activity (IMA) and depot work centers, use the provided automated scheduling report.

2.2 HOURS-BASED MAINTENANCE SCHEDULING AID

(Ref: Hours-Based PMS Spreadsheet, Navy Gas Turbines Web Site, www.navygasturbines.org)

The Hours-Based Maintenance scheduling aid was developed by MGTI GSCM(SW) Henn. He developed the spreadsheet to assist ships in properly tracking and performing hour based and conditional maintenance. Most LM2500 gas turbine maintenance has shifted from calendar to hour-based maintenance.

The scheduling aid is an Excel based spreadsheet designed around shipboard routine. It is tailored to all classes of gas turbine ships. The program tracks recurring inspection requirements and automatically predicts maintenance due dates.

MGTIs, FTSC representatives, ATG, INSURV and the maintenance community have all applauded the ships that are using this as an effective preventative tool to assist in keeping maintenance and inspections in periodicity. They can tell the difference in material readiness between those who use it (or something like it) and those who don't.

NOTE

During inspections and assessments, inspectors will down equipment when ships force cannot demonstrate that they are tracking hours and performing the hour based and conditional maintenance.

The Hours-Based PMS spreadsheet is available for download at www.navygasturbines.org. There are spreadsheets for all classes of gas turbine ships including instructions and examples.

2.2.1 Highlights The scheduling aid tracks all of your engine hours and starts in relation to PMS and technical directive inspections. It uses existing shipboard routine. Oil Kings collect this information, anyway, so have them provide engine hours for this spreadsheet also. When somebody does maintenance or an inspection, simply enter the currently displayed TSN hours and all of the numbers update themselves.

The scheduling aid automatically figures and shows when your PMS is coming due. Algorithms closely predict your next due dates; cells change colors at pre-determined thresholds providing visual alerts of upcoming maintenance.

It makes it easy for you to order your parts as you see the upcoming requirement for PMS. It gives you time to schedule your inspections before they are overdue. Algorithms closely predict when your next GTBs/AYBs are due and the cells change colors at pre-determined thresholds, providing visual alerts of upcoming inspections. There should be no reason to request a DFS, or become the subject of RBOs, because of out of periodicity inspections.

The following is an example of a PMS spreadsheet.

Table 2-1. Sample PMS Spreadsheet

	GTM 2A	Current TSN	3260.7	Average Hours/Mo	148.2	Next Deployment	20Mar02
MIP	2340/00470	Current starts	413	Average Starts/Mo	17		

MRC	Description	Periodicity	Getting Close	Target	Overdue	Last Done	Next Due	Hrs/Days Since Last	To Next	Projected Date
R-1	Water wash	48-100 hours	48-72	72-100	>100	3246.7	3346.7	14.0	86.0	18Dec03
R-2	Clean and Insp. W.W. Module	Each 8 W.W.	6	8	9	410	419	3	6	
R-3M	Change starter lube oil	Each 25 starts	20	25	>25	401	426	12	13	23Dec03
R-4	Inspect starter stator	Each starter removal				0		413		
R-6	Inspect L/O Pmp Mag Plg	750+/-125 hours	625-750	750-875	>875	2703.1	3453.1	557.6	192.4	08Jan04
R-9	Demo full power	On failure to achieve				0.0		3260.7		
R-6	Check L/O pump strainers	750+/-125 hours	625-750	750-875	>875	2703.1	3453.1	557.6	192.4	08Jan04
R-7	Clean scavenge L/O filter	1500+/-250 hours	1250-1500	1500-1750	>1750	2654.4	4154.4	606.3	893.7	29May04
R-8	Clean L/O supply filter	1500+/-250 hours	1250-1500	1500-1750	>1750	2654.4	4154.4	606.3	893.7	29May04
R-9	Demo full power	On failure to achieve				0.0		3260.7		
R-11	Check bellmouth spray	750+/-125 hours	625-750	750-875	>875	3176.1	3926.1	84.6	665.4	13Apr04
R-12	Inspect inlet components	750+/-125 hours	625-750	750-875	>875	3176.1	3926.1	84.6	665.4	13Apr04
R-13	Borescope	750+/-125 hours	625-750	750-875	>875	3176.1	3926.1	84.6	665.4	13Apr04
R-14	GTB 24R1, TMFL clocking	6000 hours	5500-6000	6000-6500	>6500	0.0	6000.0	3260.7	2739.3	07Jun05
R-15	Replace F/O filter element	1500+/-250 hours	1250-1500	1500-1750	>1750	2505.1	4005.1	755.6	744.4	29Apr04
R-16	Inspect bleed air manifold	1500+/-250 hours	1250-1500	1500-1750	>1750	2505.1	4005.1	755.6	744.4	29Apr04
R-17	Lubricate vent damper	1500+/-250 hours	1250-1500	1500-1750	>1750	2446.7	3946.7	814.0	686.0	17Apr04

Table 2-1. Sample PMS Spreadsheet - Continued

R-18	Inspect VSV system	1500+/-250 hours	1250-1500	1500-1750	>1750	3260.7	4760.7	0.0	1500.0	29Sep04
R-20	Inspect BEA interior	1500+/-250 hours	1250-1500	1500-1750	>1750	2654.4	4154.4	606.3	893.7	29May04
R-21	Clean flame arrestor	1500+/-250 hours	1250-1500	1500-1750	>1750	3260.7	4760.7	0.0	1500.0	29Sep04
R-22	Inspect exhaust, 6th stage	1500+/-250 hours	1250-1500	1500-1750	>1750	3260.7	4760.7	0.0	1500.0	29Sep04
R-23	Clean drains, check lugs	3000+/-500 hours	2500-3000	3000-3500	>3500	3260.7	6260.7	0.0	3000.0	30Jul05
R-24	Clean CIT sensor	Prior to deployment	01Feb02	15Feb02	02Mar02	13Mar02	15Feb02	628	-71	
R-25	Inventory SSE	Prior to deployment	01Feb02	15Feb02	02Mar02	05Mar02	15Feb02	636	-71	
R-26	Inspect mod ground strap	Prior to deployment	01Feb02	15Feb02	02Mar02	05Mar02	15Feb02	636	-71	
R-27	Water wash external	750 +/- 125 hours	625-750	750-875	>875	2622.9	3372.9	637.8	112.2	23Dec03
OPNAV	GTE GROOM/Assessment	Prior to deployment/SRA	01Feb02	15Feb02	02Mar02	03Oct02	15Feb02	424	-71	
MIP	2513/007									
R-5	Clean W/W nozzles	400+/-100 hours	425-500	500-575	>575	3176.1	3676.1	84.6	415.4	23Feb04
R-6	Blow in door operation	400+/-100 hours	425-500	500-575	>575	3176.1	3676.1	84.6	415.4	23Feb04
R-7	Inspect air intake system	1500+/-250 hours	1250-1500	1500-1750	>1750	1598.2	3098.2	1662.5	-162.5	29Oct03
R-8	Lubricate blow-in doors	400+/-100 hours	425-500	500-575	>575	3176.1	3676.1	84.6	415.4	23Feb04

2.2.2 Prior To Deployment The following 2340 MIP, MRCs are required to be accomplished prior to deployment or with GROOM Inspection prior to a deployment of 90 days or longer.

a. **R-6**, Inspect and Clean Gas Turbine Lube Oil and Scavenge Pump Inlet Strainers and Magnetic Drain Plugs.

b. **R-11**, Inspect Gas Turbine Bellmouth Spray Pattern.

c. **R-12**, Inspect Inlet Plenum, Inlet Screen, Inlet Duct (Bellmouth) and Centerbody (Bulletnose).

d. **R-13**, Inspect Gas Turbine Interior (Borescope Inspection) and Turbine Mid-Frame Thermocouple and Total Pressure Probes (T5.4 and PT5.4).

e. **R-15**, Replace Gas Turbine Fuel Filter Element.

f. **R-16**, Clean and Inspect Bleed Air Manifold Assembly.

g. **R-17**, Lubricate Ventilation Damper and Inspect Ventilation Dampers for Leaks.

h. **R-18**, Inspect Main Fuel Control Variable Stator Vane Feedback Lever and Actuation System, Inspect VSV Feedback Cable Rig, Inspect MFC/Feedback Cable Lever Rig Marks and VSV Actuation System Operation and Check Side to Side Play of MFC Feedback Lever.

i. **R-20**, Inspect Gas Turbine and Base Enclosure Interior and Inspect Base Enclosure Exterior.

j. **R-21**, Clean and Inspect Flame Arrestor.

k. **R-22**, Inspect Exhaust Duct Assembly and Power Turbine Sixth Stage.

l. **R-23**, Clean and Inspect Module Floor Fluid Drains; Inspect Welds on Exhaust Collector Forward/Aft Support Lugs and Port/Starboard Side Stiffeners.

m. **R-24**, Clean Gas Turbine CIT Sensor Filters.

n. **R-25**, Inspect and Inventory Condition of LM2500 Special Support and Test Equipment.

o. **R-26**, Inspect module base bonding/grounding straps.

p. **R-27**, Detergent Wash Gas Turbine; External.

2.3 USE OF S9234-AD-MMO-060/LM2500 INSPECTION TABLES

(Ref: S9234-AD-MMO-060/LM2500)

The LM2500 technical manual provides inspection criteria necessary to evaluate the condition of the propulsion gas turbine equipment and the detailed instructions required to make repairs within shipboard capabilities.

Damage can be evaluated only by thorough inspection. Inspection for defects shall be visual, with the aid of magnification, or the use of special processes specified at the beginning of each inspection table.

Inspection tables in the technical manual generally treat each component as a separate item in order that a maximum amount of information can be provided. The inspection and repair information contained in the tables are often revised as experience is gained through increased service time of the equipment. An explanation of the table headings follows:

NOTE

The terms "Maximum Serviceable Limit", "Maximum Repairable Limit" and "Corrective Action" apply only at the level of maintenance (Shipboard and Shore-Based) at which the inspection is being conducted. For example, corresponding entries of "Not Repairable" and "Replace Part" respectively in the "Maximum Repairable Limit" and "Corrective Action" columns in the Shipboard level of maintenance inspection/repair tables shall be interpreted as not repairable at the Shipboard level of maintenance. The replaced part may be repairable at the next higher level of maintenance.

Observed Condition/Discrepancy Column	Defines given areas of a part with associated conditions/discrepancies which may be observed.
Maximum Serviceable Limit Column	Defines the maximum departure from the manufacturer's established new equipment standards that will not materially reduce the usability of the part, or that will have no significant bearing on the effective use or operation of the equipment between scheduled maintenance intervals.
Maximum Repairable Limit Column	Defines the extent of repair that can be performed on a part to return it to a serviceable condition. If there is no entry in this column it does not mean that the part cannot be repaired, but that to date, no repair procedure has been established. When a repair procedure has not been established, or when an existing procedure is considered inadequate, analyze the difficulty, determine the cause and frequency and notify the Propulsion Gas Turbine Module contractor. If a repair procedure should be developed to the satisfaction of the local cognizant authority, notify the Propulsion Gas Turbine Module contractor immediately so that it may be reviewed and evaluated. If the phrase "not repairable" is entered in this column, it means that no repair is feasible and that no attempt should be made to repair it under any circumstances at the level of Maintenance for which the inspection/repair table is applicable. See preceding Note.
Corrective Action Column	Defines if the part should be replaced or denotes the paragraph in which the corrective action is described. If the repair materials are not available or if the part to be replaced is not available, it is permissible to replace the next higher assembly.

MANUAL TERM	ASSOCIATED TERMS
ABRASION A wearing, grinding or rubbing away of small amounts of material. Surface finish may be smooth or rough.	Chafing, Fretting, Rub, Scuff, Wear
BLISTER A raised portion of a surface caused by separation of the outer layers of the parent material or of a coating applied to it.	Bubble, Flaking, Oxide formation, Peeling, Scale, Slag inclusion (Weld)
BRINELL (TRUE) Often related to ball and roller bearings having been improperly installed or subjected to extremely high shock or impact loads at zero revolutions per minute. Usually occurs as a series of shallow depressions in the load area of the raceway.	Dent
BRINELL (FALSE) A specialized form of fretting recognized by the occurrence of a series of shallow indentations in the race at each roller position on the loaded side of the bearing. Often red oxide of iron may be found where this has occurred.	
BRITTLE A Change in the resiliency of the parent material, usually due to aging, extreme heat, extreme cold, chemical action, or cold working (metal).	Cold worked, Hard (like an old O-ring), Stiff
BUCKLE A large-scale deformation of the original contour of a part, usually due to pressure or impact from a foreign object, structural stresses, excessive localized heating, high pressure differentials, or any combination of these.	Ballooning, Bend, Blister (incorrect see Blister), Bulge, Crease, Curl, Dent (not to be confused with small-area defect in heavy material: see Dent), Depression, Distortion (usually refers to heavy material), Elongated (usually refers to "out-of-round") Fold, Indentation, Kink (usually results in crack: See Crack), Protrusion (hollow), Rupture (result of excessive buckling), uneven, Warpage, Wrinkle
BULGE A raised portion or outward swelling on a surface as from pressure	Hump, protuberance
BURN A rapid, destructive, oxidizing action usually caused by higher temperatures than the parent material can structurally withstand. Change in color and appearance often indicates this condition.	Burn out (see Missing piece), Erosion (chemical or grit), Guttered, Heat-check, Heat curled, Heat deterioration, Hole (burn), Hot spot, Overheated, Oxidation
BURR A rough edge or a sharp protrusion on the edge or surface of the parent material.	
CHAFING A rubbing action between parts having limited relative motion (as in vibration).	Abrasion, Fretting, Rub, Wear
CHIP A breaking away of the edge of the parent material, usually caused by heavy impact from a foreign object.	Break, Nick (similar to Chip, but no parent material is removed: see Nick)
COKING An accumulation of carbon	Carbon build-up
CORROSION — The gradual conversion of material to another compound due to chemical attack. It appears as a mass of small pits due to the loss of the formed compound from the affected surface which cumulatively creates a cavity (usually shallow) in the surface of the parent material.	
CRACK A parting of the parent material.	Break, Crater (usually found in castings), Fatigue damage, Fissure, Fracture, Inclusion (usually found in castings), Lap (usually found in forgings), Rupture, Separation, Shear (not usually considered a crack: see Missing Piece), Slit, Tear
CRAZE A mesh of fine cracks on a surface or glaze defined as numerous superficial surface cracks which have no visual width or depth.	Fine cracks around bolt holes or surface edges that are subject to stresses or pressure. Fine cracks in metal, paint surfaces, seal edges, plastics, windows, sight glasses, etc.
DENT A completely smooth surface depression caused by pressure or impact from a smooth ball-like foreign object. The parent material is displaced, but usually none is separated.	Peen
DEVIATION A condition which causes a part to differ from the manufacturer's blue print.	Damage, Defect, Flaw, Imperfection, Irregularity
EROSION — The gradual wearing away of material caused by the hot flow of gases, or foreign particles. An eroded surface may appear similar to a corroded surface.	
FLAKE A thin chiplike or scalelike layer of metal.	
FRETTING Wear, in a rippled pattern, caused by friction	Chafing, abrasion
GALL A defect caused by the movement of two surfaces in contact with each other. In most cases an accumulation of foreign material is deposited on the parent material.	See Pickup
GOUGE A wide, rough scratch or group of scratches, usually with one or more sharply impressed corners, and frequently accompanied by deformation or removal of parent material.	
GROOVE A long, narrow, continuous cavity or impression caused by pressure of a moving surface in contact with the parent material.	If impression is shallow and smooth: see Wear

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Figure 2-1. Definition of Terms (A Through G)

MANUAL TERM	ASSOCIATED TERMS
IMBALANCE The state of being out of balance. An unequal distribution of weight about the axis of rotation.	
LOOSE Abnormal movement of a part.	Backed out, Excessive movement, Excessive play, Insecure, Leaks, Loose fit, Not tight, Not torqued, Shakes, Sloppy, Rattles, Unbottomed, Unpinned
MISALIGNED A mismatching or malformation of any parts which either prevents perfect assembly or results in faulty operation and/or ultimate part failure.	Eccentric, Not axial, Not concentric, Out-of-round, Unmatched, Unsquare
MISSING PIECE Removal or loss of a portion of parent material due to a combination of defects or damage.	Break (two or more pieces), Burn (burned away), Burn-out, Corrosion (eaten away), Erosion (worn away), Guttered, Hole, Rusted (rusted away), Sheared, Smashed, Torn (torn away)
NICK A surface impression with sharp corners or bottom, usually caused by pressure or impact from a sharp-edged foreign body. The parent material is displaced, but usually none is separated.	Chip (see Chip), Dent (see Dent), Notch (see Chip)
NOISY An abnormal sound condition of moving parts, usually an increase in volume or a change of pitch.	Bumps (sound), Chatters, Clicks, Grates (usually gears), Grind, Hums, Loud, Rattles (usually loose parts), Rubs (sound of rubbing), Scrapes (sound of scraping), Screeches, Squeals, Thumps (sound), Whistles
OBSTRUCTED Prevention of free flow of a fluid (air, oil, fuel, water) because of a foreign material in the flow-path or malformation in the flow member.	Clogged, Contaminated, Plugged, Restricted
OXIDATION A surface deterioration by the chemical reaction between oxygen in the air and the metal surface. Attack is manifested as red rust in iron and low alloy steels when formed at ambient temperature. The oxides which form on super alloys are complex and can be green or black depending on material composition and temperature at which it is formed.	
PICKUP Transfer of one material into or upon the surface of another, caused by contact between moving parts or deposits of molten material on a cooler material.	Burr (usually tool-rub leaving high parent material), Gall, High spot, Imbedment, Inclusion (usually pick-up of a dissimilar foreign material), Pile-up, Protrusion (deposit on parent material), Metalization
PINCHED Distortion of one or more surfaces of the parent material, caused by pressure.	Bound, Compressed, Flattened, Seized (see Seizure), Smashed (without separation into pieces), Squashed, Squeezed, Tight
PIT A minute depression or cavity, with no sharp high stress corners, in the surface of the material. Pits are usually caused by chemical reaction (rusting, chemical corrosion).	Corrosion, Crater (usually in weld or casting), Dent (incorrect: see Dent), Electrolytic cavity, Erosion (usually results in hole: see Burns), Fretting (see Wear), Inclusion (as in sand castings), Oxidation, Perforation (usually in weld), Pock-marked, Spalled, Roughness
RUB A surface cavity or impression caused by two surfaces moving against each other.	If impression is shallow and smooth: (see Wear), If impression is sharp: (see Scratch),
SCRATCH A long, narrow sharp-cornered impression caused by the movement of a sharp object across the surface of the parent material.	Abrasion, Chafe, Furrow, Groove, Rub, Scarf, Score
SCUFF A surface roughened by wear.	Scrape, Scratch
SEIZURE A welding or binding of two surfaces which prevents further movement.	Bound up, Frozen, Tight (see Pinched), Tight (fit), Wedged, Welded (without external assistance)
SHEET-METAL DENT A large-area smooth depression in the parent material.	See Buckle
SHINGLING Two adjacent surfaces overlapping when normal position is edge-to-edge or face-to-face contact.	
SPALL Broken or crushed material due to heat, mechanical or structural causes. Chipping off of small fragments under the action of abrasion.	Chip
SPATTER A thin deposit of molten metal, usually on an airfoil surface downstream from a burn area	Splatter, Splash
SULFIDATION A form of hot corrosion in heat resistant alloys by the reaction at the metal surface of sodium chloride (sea air) and sulfur (from the fuel). Attack usually occurs over a broad front and can be identified as gray to black blisters (early stage) or surface delamination (advanced stages).	

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Figure 2-2. Definition of Terms (I Through S)

MANUAL TERM	ASSOCIATED TERMS
TIP ROLLOVER Airfoil tip has rubbed a stationary surface causing deformation of the tip outside the surface of the airfoil, usually in the form of a burr.	
TIP CLANGING Contact between tips of adjacent blades. Blade deflection causes contact between the leading edge tip of one blade and convex side of the adjacent blade. It indicates that a severe compressor stall has occurred. (See figure 8.4-14)	
UNLATCHING Two adjacent, interlocking surfaces disengage from their normal position.	
VARNISH FILM A hard surface-film on metal, straw-color to very dark brown, build up by exposure to dry chemicals or fluids (commonly oil) while the part is heated above the breakdown point of the chemical or fluid.	Banded, Discolored, Oxidized, Stained
WARPED Not true in plane or in line; out of true shape	Distorted, bent, twisted, buckled contorted

MANUAL TERM	ASSOCIATED TERMS
WEAR Relatively slow removal of parent material from any cause, frequently not visible to the naked eye.	Abrasion attrition (normal usage wear), Brinnelled, Burnished, Chafe, Chattering, Erosion (slow process by oxidation), Frayed, Fretting, Friction (Interference), Gall, Glazed, Groove (smooth impression), Interference, Oxidation, Roughness, Rub, Scarfed, Scraped, Scuffed, Touching, Uneven wear, Wear, Worn thin

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Figure 2-3. Definition of Terms (T Through Z)

2.3.1 <u>Crack Description</u> The following defined terms are used generally in crack description.

Axial: General direction parallel to the centerline of the GT or part.

Radial: General direction perpendicular to the centerline of the GT or part.

Transverse: General direction perpendicular to the length of the weld.

Longitudinal: General direction parallel to the length of the weld.

Cracks in the heat affected zone shall be considered weld cracks. Cracks beyond the heat affected zone shall be considered parent metal cracks. The heat affected zone in the area in which the microstructure of the material and/or its physical characteristics are affected by the heat of welding. The heat affected zone is established as being 0.06 inch wide for materials 0.045 inch thick or thinner and 0.09 inch wide for materials thicker than 0.045 inch.

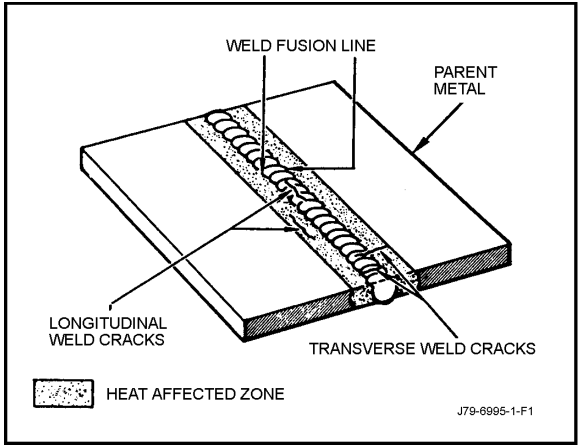


Figure 2-4. Weld Heat Affected Zone and Weld Crack Definition

2.3.2 <u>Use of Inspection and Repair Tables − Shipboard Level of Maintenance</u>

a. The data contained in the inspection and repair tables is equally applicable when performing scheduled (preventative) or corrective (unscheduled) maintenance. When performing scheduled (preventative) maintenance inspections, inspect the equipment for evidence of discrepancies defined by the applicable maintenance requirement card of PMS. If other conditions/discrepancies are noted during either scheduled (preventative) or corrective (scheduled) maintenance actions, refer to the inspection/repair tables to determine if the observed condition/discrepancy is serviceable, repairable or requires parts replacement.

b. The inspection/repair tables also contain data which is applicable only if parts are removed, thus exposing surfaces not visible if the part was installed. Disassembly for the singular purpose of inspection is not required, the part replacement procedure will refer to these tables if necessary.

c. One of the three general terms is used to broadly define the maximum serviceable limit. The terms are defined below to assure proper comprehension of their intended meaning.

Serviceable	Within the limitations specified (if any), the observed condition/discrepancy will not impair continued unrestricted operation of the equipment until the next scheduled inspection of the part.
Limited Service	Allows increased operational use of the equipment. Where specified, the observed condition/discrepancy is judged to not impair the unrestricted operation of the equipment for a limited period of time. If in the judgement of the engineering officer further deterioration is not imminent, corrective action can be scheduled for first opportunity consistent with mission requirements. The condition must be monitored for continued serviceability and recorded to insure compliance.
Not Serviceable	The observed condition/discrepancy is judged not acceptable for continued operation of the equipment without proper corrective action.

2.4 BORESCOPE INSPECTION

(Ref: MRC 2340, R13 Borescope Inspection and S9234-AD-MMO-060/LM2500)

MRC check 2340, R13 Inspect Gas Turbine Interior (Borescope Inspection) must be accomplished every 750+/-125 operating hours and prior to a deployment of 90 days or greater. In addition it is required if the following conditions occur:

a. Gas Turbine Overtemperature.

b. Gas Turbine Overspeed.

c. Gas Turbine Stall above 7500 RPM.

d. High Gas Turbine Vibration.

e. After Post Shutdown Fire.
Always refer to and follow the MRC requirements when performing borescope inspection. For Gas Turbine Stall and Overtemperature Inspection refer to S9234-AD-MMO-060/LM2500. General Gas Turbine Bulletin (GGTB) 21, directs that any additional requisitions for borescope kits will be supported on Allowance Equipage List (AEL) 2-870005232. The following is general overview for performing Borescope inspection (Ref S9234-AD-MMO-060/LM2500 and MRC 2340, R13).

2.4.1 Gas Turbine Stall Inspection Perform a visual inspection of the components and defects listed below, if GT stall occurred above 7500 RPM. When conducting borescope inspection due to a stall, a complete GTE borescope IAW 2340

R-13 is not required unless damage is noted. Follow Gas Turbine Stall Inspection guidance in S9234-AD-MMO-060. Do not count this borescope as a completed Maintenance Requirement Check.

WARNING

• The GT must be shutdown and allowed to cool to a surface temperature below 120 F, before performing borescope inspection.

• Module door and top hatch are to be open.

• Assure that fire extinguisher inhibit switch is in INACTIVE position.

• Assure that all personnel are clear of GG rotating parts, during borescope inspection.

NOTE

If GT steady state or transient stall occurred below 7500 RPM refer to S9234-AD-MMO-030 for corrective action. If gas turbine stall occurred above 7500 RPM, it will be necessary to carefully inspect compressor blades in stages 3 through 6. Closely observe the convex (back-side) of blades for blade tip clanging contact marks. Clanging marks are the result of leading edge tip (corner) of one blade striking the convex airfoil of the next blade. This is a serious condition and must be reported.

a. In order to obtain maximum field of view during borescope inspection, position Variable Stator Vanes (VSV) to full open position as follows:

(1) Disconnect variable stator head-end and rod-end tubes from head-end and rod-end hoses, at connections above Main Fuel Control (MFC).

CAUTION

• To avoid damaging the equipment, check the VSV feedback system carefully to make sure there is no interference before applying pressure.

• Pressurizing unit shall be filled with GT lube oil, MIL-L-23699.

(2) Connect pressurizing unit, PN 1C3569, to the rod-end and head-end tubes.

(3) Actuate the vanes to the full open position (actuator rod fully extended) by applying a maximum of 200 PSIG pressure to the head-end of actuator. Make sure vanes remain in the full open position during entire inspection.

b. Remove the four nuts and washers from the Transfer Gearbox (TGB) drive pad cover plate, remove plate and discard O-ring. (Reference applicable Maintenance Requirements Card (MRC) listed in Planned Maintenance System (PMS) for detailed borescope procedure and figure.)

c. Insert a ratchet with a 3-inch, 3/4-drive, extension.

CAUTION

- To prevent foreign objects from entering the GT, keep borescope ports covered when they are not being used. Open one port at a time.
- To prevent borescope probe damage, keep borescope probe perpendicular to GG, and avoid borescope probe contact with rotating parts during borescope inspection.

NOTE

Each rotor stage to be inspected must be indexed through use of the stage's blade locking lugs. Indexing of each rotor stage is required so that it can be determined when the compressor rotor has completed one revolution during borescope inspection. It will be necessary to make several revolutions to examine each blade from the platform to tip.

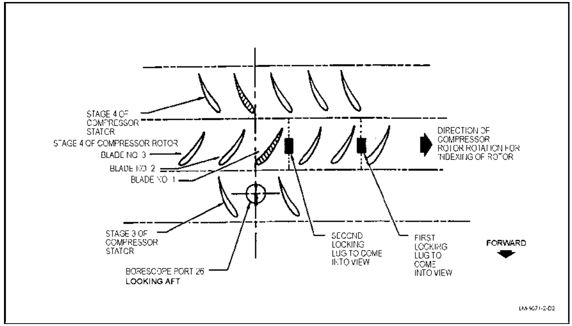


Figure 2-5. Zero Indexing Compressor Rotor

d. Index compressor rotor stage 3 blades as follows:

(1) Remove safety-wire and plug from borescope port 27 of the compressor stator.

(2) Insert applicable borescope probe of borescope set, PN 1C6811. Look aft and observe stage 3 rotor blade platforms.

(3) Rotate compressor rotor with ratchet counterclockwise (CCW) (aft looking forward), until the first compressor blade locking-lug is visible. Disregard the fact the GG runs clockwise.

(4) Continue to rotate compressor CCW until the second locking-lug, which is two blades past the first locking lug, appears.

(5) Position the first compressor blade CCW from the second locking-lug, so that its leading edge

is in line with the leading edge of the stator vane directly aft of the compressor blade

CAUTION

If any tip clanging contact is found, do not operate engine. Contact Marine Gas Turbine Inspector (MGTI) or Fleet Technical Support Center (FTSC).

NOTE

• During borescope inspection, compressor rotor blades are identified by counting CCW from the second locking lug. The first rotor blade CCW from the second locking-lug is blade number 1.

• Closely observe stages 3 through 6 blade convex airfoil tips and blade leading edge tips for evidence of tip clanging contact. Gas Turbine Change No. 46 removes the platform corner on the concave locking blade in stage 7. This is not damage.

e. Rotate compressor rotor CCW and perform borescope inspection as follows:

(1) Identify compressor rotor blades by number, and record blade defects that are observed.

(2) Compare recorded inspection data with the limits defined in S9234-AD-MMO-060/LM2500.

(3) Install borescope plug per PMS.

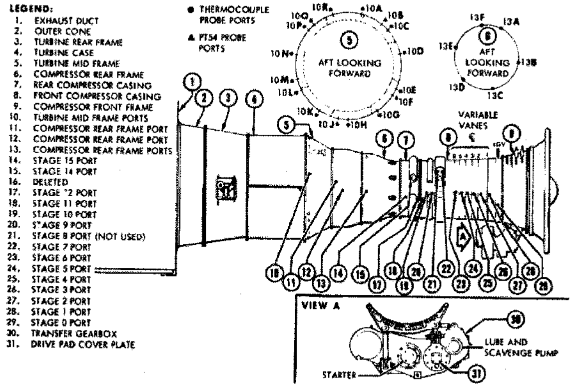


Figure 2-6. LM2500 Borescope Port Locations

f. Index compressor rotor stage 4 blades as follows:

(1) Remove safety-wire and plug from borescope port 26 of the compressor stator.

(2) Insert applicable borescope probe of borescope set, PN 1C6811 or equivalent. Look aft and observe stage 4 rotor blade platforms.

(3) Complete blade indexing and blade inspection.

g. Index compressor rotor stage 5 blades as follows:

(1) Remove safety-wire and plug from borescope port 25 of the compressor stator.

(2) Insert applicable borescope probe of borescope set, PN 1C6811 or equivalent. Look aft and observe stage 5 rotor blade platforms.

(3) Complete blade indexing and blade inspection.

h. Index compressor rotor stage 6 blades as follows:

(1) Remove safety-wire and plug from borescope port 24 of the compressor stator.

(2) Insert applicable borescope probe of borescope set, PN 1C6811 or equivalent. Look aft and observe stage 6 rotor blade platforms.

(3) Complete blade indexing and blade inspection.

i. Inspect compressor rotor blades stages 9 and 10 as follows:

(1) Remove safety-wire and plug from borescope port 20 of the compressor stator.

(2) Insert applicable borescope probe of borescope set, PN 1C6811 or 01-471-0286. Look forward and aft, and inspect stages 9 and 10 blades per limits defined in S9234-AD-MMO/060/LM2500. If any discrepancies are found, index applicable stage and record blade position and defect.

j. Inspect compressor rotor blades stages 15 and 16 as follows:

(1) Remove safety-wire and plug from borescope port 14 of the compressor stator.

(2) Insert applicable borescope probe of borescope set, PN 1C6811 or equivalent. Look forward and aft, and inspect stages 15 and 16 blades per limits defined in S9234-AD-MMO/LM2500. If any discrepancies are found, index applicable stage and record blade position and defect.

Table 2-2. Compressor Blade Count

COMPRESSOR	
STAGE	BLADES
1	36
2	26
3	42
4	45
5	48
6	54
7	56
8	64
9	66
10	66
11	76
12	76
13	76
14	76
15	76
16	76

k. After completion of compressor rotor borescope inspection, perform the following tasks:

(1) Remove the ratchet and extension form the TGB drive pad.

(2) Install new O-ring; install drive pad cover plate, four nuts and washers. Torque nuts to 55-70 inlb.

(3) Inspect compressor casing to verify that all borescope plugs have been installed per PMS.

(4) Disconnect pressurizing unit, PN 1C3569, from variable stator actuator rod-end and head-end tubes.

(5) Connect variable stator head-end and rod-end tubes to head-end and rod-end hoses. Torque 1/2-inch line to 450-500 inlb. Torque 3/8-inch line to 270-300 inlb.

(6) Record and report stall inspection discrepancies in accordance with PMS borescope MRC.

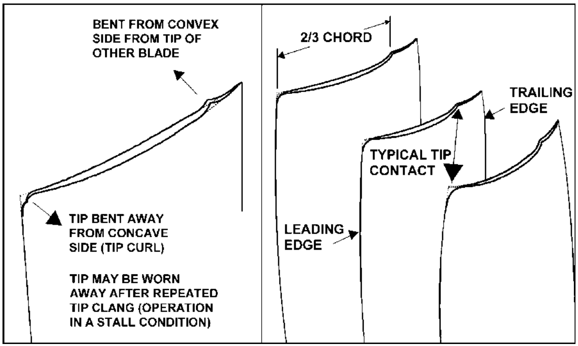


Figure 2-7. Compressor Blade Tip Clanging Contact (Stages 3-6)

Table 2-3. Compressor Blades And Vane

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
COMPRESSOR BLADES			
STAGE 1 (See Figure 2-8)			
1. All Areas for:			
a. Cracks	Not serviceable	Not repairable	Replace by IMA*
2. Midspan Shroud Interlock Surface Carboloy Wear Pad for: (See Figure 2-9 and Figure 2-10)			
a. Chipped pad	10 percent of pad may be missing.	Any amount	Replace blade**
b. Cracked pad	Not serviceable	Any amount	Replace blade**
c. Pad wear, smooth or stepped	0.005 inch pad thickness remaining.	Any amount	Replace blade**
d. Missing pad	Not serviceable	Any amount	Replace blade**
e. Circumferential gap between midspans (see note)	None allowed	Not repairable	Replace blade**
NOTE When a circumferential end-gap exists due to loose blades, inspect for end-gap with wooden shims (round, wooden toothpicks for example). Install shim between the retainer and disk to force each blade dovetail aft and outward against disk dovetail. Insert shim from forward side with one shim on each side of blade tang. No cumulative gap is permitted. After inspection, remove shims. (See Figure 2-10.)			
3. Area Outside Blend Areas for:			
a. Surface defects scratches, nicks and pits	Any number not to exceed 0.003 inch deep and 0.5 inch long in longitudinal direction and separated by 0.1 inch. No transverse nicks or scratches allowed.	Not repairable	Replace by IMA*
4. Blend Area (Leading and Trailing Edges) for:			
a. Dents	Any number, 0.02 inch deep with a minimum root radius of 0.020 inch, separated by 3/8-inch of unaffected metal.	Not repairable	Replace by IMA*

Table 2-3. Compressor Blades And Vane - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
b. Nicks and pits	Any number, 0.005 inch deep and 0.010 inch in either length or diameter.	Not repairable	Replace by IMA*
5. Airfoil Tip Corners for:			
a. Damage	Deformed or missing to 0.03 inch from original contour.	Not repairable	Replace by IMA*
6. Squealer Tip for:			
a. Cracks, nicks and dents	Not serviceable	Not repairable	Replace by IMA*
b. Heat discoloration due to rub	Any color or amount within 0.06 inch of blade tip.	Not repairable	Replace by IMA*
c. Burrs	Not serviceable	Not repairable	Replace by IMA*
STAGE 2 (See Figure 2-11)			
1. All Areas for:			
a. Cracks	Not serviceable	Not repairable	Replace by IMA*
2. Area Outside Blend Area for:			
a. Surface defects, scratches, nicks and pits	Any number not to exceed 0.003 inch deep and 0.5 inch long in longitudinal direction and separated by 0.1 inch. No transverse nicks or scratches allowed.	Not repairable	Replace by IMA*
3. Blend Area (Leading and Trailing Edges) for:			
a. Dents	Any number, 0.02 inch deep with a minimum root radius of 0.020 inch, separated by 3/8-inch of unaffected material.	Not repairable	Replace by IMA*
a. Nicks and pits	Any number, 0.005 inch deep and 0.010 inch in either length or diameter.	Not repairable	Replace by IMA*
4. Airfoil Tip Corners for:			

Table 2-3. Compressor Blades And Vane - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
a. Damage	Deformed or missing to 0.03 inch from original contour.	Not repairable	Replace by IMA*
5. Squealer Tip for:			
a. Cracks, nicks and dents	Not serviceable	Not repairable	Replace by IMA*
b. Heat discoloration due to rub	Any color or amount within 0.06 inch of blade tip.	Not repairable	Replace by IMA*
c. Burrs	Not serviceable	Not repairable	Replace by IMA*
STAGE 3 - 16 (See Figure 2-12)			
1. All Areas for:			
a. Cracks	Not serviceable	Not repairable	Replace by IMA*
b. Aluminum or abrasive deposits on blades (leading edge especially)	Any amount unless compressor stall occurs.	See Corrective Action column.	Troubleshoot for stalls as required.
2. Area A (Critical) for:			
a. Surface defects	Any number not to exceed 0.003 inch deep and 0.5 inch long in the longitudinal direction if separated by 0.1 inch. No transverse nicks or scratches allowed.	Not repairable	Replace by IMA*
b. Leading and trailing edge damage	Not serviceable	Not repairable	Replace by IMA*
3. Blend Area (Leading and Trailing Edge) for:			
a. Dents	Any number, 0.020 inch deep with a minimum root radius of 0.020 inch, separated by 0.4 inch unaffected material.	Not repairable	Replace by IMA*
b. Nicks and scratches	Not serviceable	Not repairable	Replace by IMA*
c. Erosion (See Figure 2-13)	Any amount provided tip chord is X inches greater and both leading and trailing edge thicknesses are 0.008 inch or greater.	Not repairable	Replace by IMA*

Table 2-3. Compressor Blades And Vane - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
NOTE A maximum of one-half of the total blades per stage may be operated to serviceable limits.			
4. Area B for:			
a. Nicks, dents and pits	Any number, 0.003 inch deep and 0.030 inch in either length or diameter and no opposing defects.	Not repairable	Replace by IMA*
b. Scratches	Any number, 0.003 inch deep, 0.5 inch long.	Not repairable	Replace by IMA*
5. Airfoil Tip Corners for:			
a. Damage	Not serviceable	Not repairable	Replace by IMA*
6. Squealer Tip for:			
a. Cracks, nicks and dents	Not serviceable	Not repairable	Replace by IMA*
b. Heat discoloration due to rub	Any color or amount within 0.06 inch of blade tip.	Not repairable	Replace by IMA*
c. Burrs and high metal due to rub	Not serviceable	Not repairable	Replace by IMA*
d. Erosion (See Figure 2-13)	Any amount provided tip chord is X inches greater and both leading and trailing edge thicknesses are 0.008 inch or greater.	Not repairable	Replace by IMA*
e. Metal missing from trailing edge tip corner	Not serviceable	Not repairable	Replace by IMA*
f. Tip clanging stages 3-6 (See MMO-060, Figure, 7-580)	Not serviceable	Not repairable	Replace by IMA*
7. Blade Platforms for:			
a. Accumulated circumferential gap	Total accumulated clearance between blade platforms shall not exceed 0.040 inch at narrowest width at that point	Not repairable	Replace narrow platform blades as required, with wide platform blades.
8. Rotor and Stator Airflow Path Surfaces for:			

Table 2-3. Compressor Blades And Vane - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
a. Corrosion and dirt on air flow path surfaces	Any amount	See Corrective Action column.	Waterwash compressor as required or when specified as a scheduled maintenance action.
b. Abrasive coating missing from rotor hub or stator case	Any amount unless performance ($T_{5.4}$, torque or compressor stall) is adversely affected.	See Corrective Action column.	Troubleshoot for stalls as required.
COMPRESSOR STATOR VANES - IGV, STAGES 1-6			
1. Variable Vanes:			
a. Looseness	Serviceable 0.000"- 0.015" side to side movement (Check IAW PMS)	Not repairable	No corrective action required until next 1500 hour inspection. Continued engine operation is authorized.
	Serviceable 0.016"- 0.019" side to side movement (Check IAW PMS)		No corrective action required until next 1500 hour inspection unless directed by MGTI or FTSC during pre-deployment Groom Inspection. Continued engine operation is authorized.
	Not Serviceable 0.020" or more side to side movement (Check IAW PMS)		Schedule Intermediate Maintenance Activity to replace bushings/ washers within 50 hours of engine operation, contact FTSC. Replace by IMA*
b. Actuation ringspacers loose or out of adjustment (Visually inspect on compressor case OD)	Not serviceable	Any amount	Adjust to obtain clearances, case to spacer: IGV 0.002-0.004 Stg 1 0.002-0.004 Stg 2 0.002-0.004 Stg 3 0.002-0.004 Stg 4 0.005-0.007 Stg 5 0.010-0.012 Stg 6 0.014-0.016 Torque 70-80 inlb
c. Cracked or torn material	Not serviceable	Not repairable	Replace by IMA*

Table 2-3. Compressor Blades And Vane - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
d. General damage (peppering)	Any amount, up to 0.015 inch deep provided vane is not cracked, damage does not break through and vane is not distorted. None allowed in fillets.	Not repairable	Replace by IMA*
e. Nicks and scratches	Any number 0.015 inch deep 1/2-inch long, with a minimum separation of 1/16-inch. None allowed in transverse direction.	Not repairable	Replace by IMA*
f. Dents	3/64-inch deep provided damage is of smooth contour and does not form a crease.	Not repairable	Replace by IMA*
g. Tip curl	1/4-of chord length provided it does not engage rotating parts during operation and there is no other distortion.	Not repairable	Replace by IMA*
COMPRESSOR STATOR VANES - STAGES 7 - 15 AND OGV			
1. Fixed Vanes for:			
a. Cracked or torn material			
(1) All vanes except stage 8	Not serviceable	Not repairable	Replace GG.
(2) Stage 8 vanes	One radial inward crack per vane, 1/4-inch long on stage 8 vane tips only.	Not repairable	Replace GG.
b. General damage (peppering)	Any amount, up to 0.015 inch deep provided vane is not cracked, damage does not break through and vane is not distorted. None allowed in fillets.	Not repairable	Replace GG.
c. Nicks and scratches	Any number 0.015 inch deep 1/2-inch long, with a minimum separation of 1/16-inch. None allowed in transverse direction.	Not repairable	Replace GG.
d. Dents	3/64-inch deep provided damage is of smooth contour and does not form a crease.	Not repairable	Replace GG.

Table 2-3. Compressor Blades And Vane - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
e. Tip curl	1/4 of chord length provided it does not engage rotating parts during operation and there is no other distortion.	Not repairable	Replace GG.
* Special Shipboard Maintenance Manual, S9234-BF-MMI-010/LM2500			

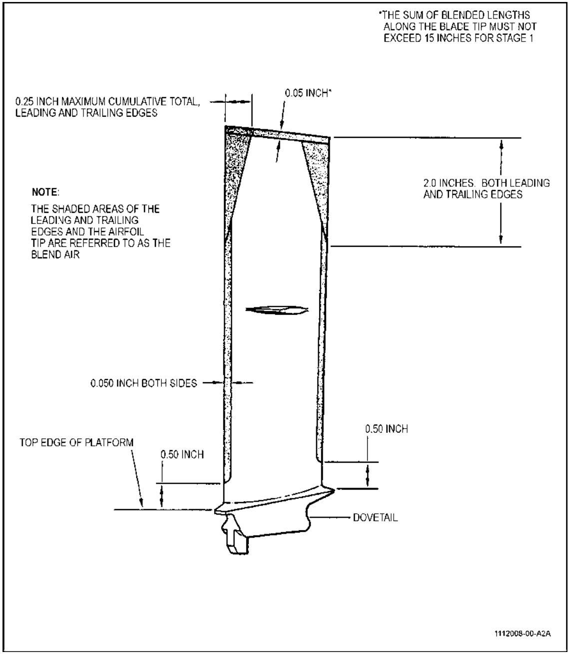


Figure 2-8. Stage 1 Compressor Blade Inspection Limits

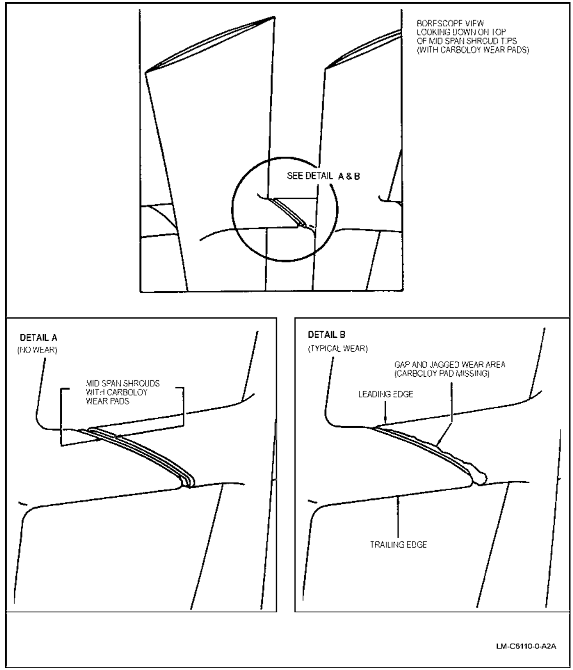


Figure 2-9. Stage 1 Compressor Blade - Midspan Shroud Wear

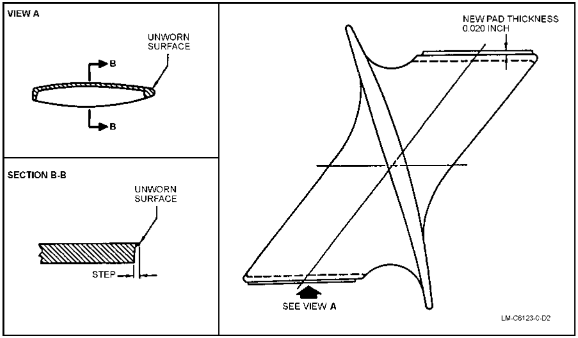


Figure 2-10. Stage 1 Compressor Blade - Midspan Shroud Wear (Cont.)

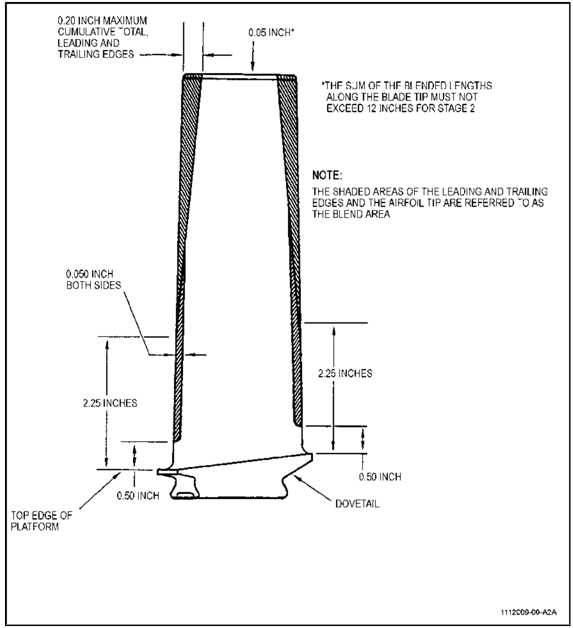
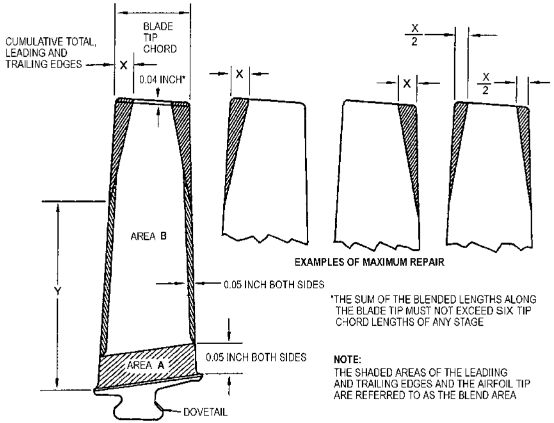


Figure 2-11. Stage 2 Compressor Blade Inspection Limits



STAGE	DIM Y	DIM X	STAGE	DIM Y	DIM X
3	1-7/8	0.15	11	5/8	0.10
4	1-19/32	0.15	12	9/16	0.10
5	1-3/8	0.14	13	1/2	0.10
6	1-3/16	0.14	14	1/2	0.10
7	1	0.12	15	1/2	0.10
8	3/4	0.12	16	9/32	0.10
9	3/4	0.11			

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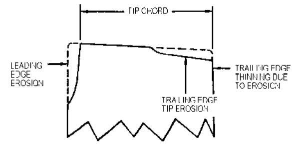
Figure 2-12. Stages 3 - 16 Compressor Blade Inspection Limits



TIP CHORD-INCHES		
STAGE	X	Y
3	1.57	1.53
4	1.42	1.38
5	1.34	1.30
6	1.22	1.18
7	1.13	1.09
8	1.05	1.01
9	1.02	0.98
10	1.03	0.98
11	0.89	0.85
12	0.89	0.85
13	0.89	0.85
14	0.89	0.85
15	0.89	0.85
16	0.89	0.85

LM-9342-0-F2

Figure 2-13. Stage 3 - 16 Compressor Blade Tip Erosion

NAVSEA PHILADELPHIA Ship Systems Engineering Station

Gas Turbine Interior Inspection

Tip Clang

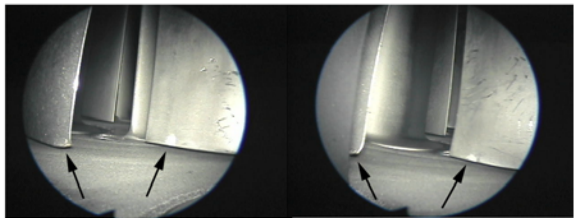


Figure 2-14. Tip Clang

Gas Turbine Interior Inspection

FOD

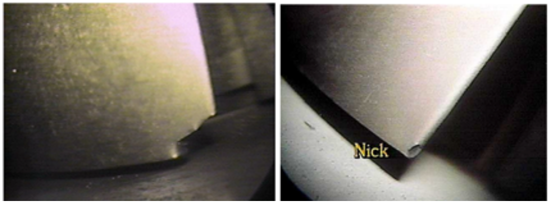


Figure 2-15. Compressor FOD Damage

Gas Turbine Interior Inspection

FOD

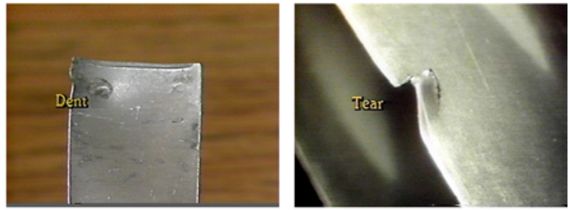


Figure 2-16. Compressor FOD Damage

Gas Turbine Interior Inspection

FOD

Figure 2-17. Compressor FOD

Gas Turbine Interior Inspection

Rotor Rub

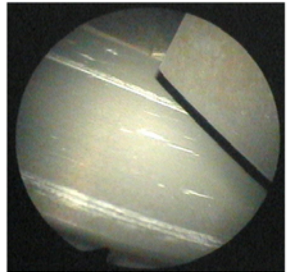


Figure 2-18. Compressor Rotor Rub

2.4.2 Gas Turbine Overtemperature Inspection Perform a visual inspection of the components and defects listed below. When conducting borescope inspection due to an overtemp, a complete GTE borescope IAW 2340 R-13 is not required unless damage is noted. Follow Gas Turbine Overtemperature Inspection guidance in S9234-AD-MMO-060. Do not count this borescope as a completed Maintenance Requirement Check.

a. High Pressure Turbine (HPT) Rotor Inspection. Blade count for single shank engines will differ in the high-pressure turbine section. Refer to following table. To index the HP turbine rotor, use stage 10 compressor rotor.

Table 2-4. HP Turbine Blade Count

HPT	
STAGE	BLADES
Paired Blade	
1	108
2	116
Single Shank	
1	88
2	90

(1) Stage 1 Blades:

(a) Leading edge tip for melting.

(b) Squealer tip cap for braze separation.

(c) Leading edge for cracks at nose holes.

(d) Trailing edge for cracks.

(e) Blade airfoil for evidence of burning or melting.

(2) Stage 2 Blades:

(a) Leading edge tip for melting.

(b) Squealer tip cap for braze separation.

(3) Look for buildup of aluminum coating on airfoils and aluminum residue in HPT rotor. If buildup or residue is detected, inspect compressor rotor hub and casing ID for rubs.

b. HPT Nozzle Inspection.

(1) Stage 1 Nozzle:

(a) Outer and inner platform segment for cracks between vanes.

(b) Outer and inner platform for burning or melting.

(c) Vane airfoil for burning or melting.

(d) Vane airfoil for cracks and plugged cooling air holes.

(2) Stage 1 Shrouds:

(a) Inspect for burning or melting.

(3) Stage 2 Nozzle:

(a) Outer and inner segment platform for cracks between vanes.

(b) Outer and inner platform for burning.

(c) Vane airfoil for burning or melting.

(d) Vane airfoil for cracks and plugged cooling air holes.

(4) Stage 2 Shrouds:

(a) Inspect for burning or melting.

(5) Inspect for aluminum residue in cooling air passages. If residue is detected, inspect compressor rotor hub and compressor casings ID for rubs.

c. Turbine Mid-Frame (TMF) Inspection.

(1) Liner for burning, melting, cracks, and distortion. When damage is noted during borescope inspection refer to the MRC figures or to S9234-AD-MMO-060/LM2500 for guidance to determine serviceability. Utilize the known dimensions in the figures provided. Known dimensions are useful in estimating dimensions of observed defects. Best results are obtained when dimensions are the same direction and distance from borescope as the defects. Avoid comparing axial direction defects with radial known features because unreliable observations will result due to distortions produced by differences in contour and perspective. Avoid comparing trailing edge defects with leading edge known features because distortion due to magnification of the borescope will make such comparisons unreliable. If necessary insert a long piece of lockwire for comparison when trying to determine damage size. Report all defects and request outside assistance if required to assist in evaluation.

Table 2-5. High Pressure Turbine Nozzles

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
FIRST STAGE HIGH PRESSURE TURBINE NOZZLE			
1. Vane Airfoil for:			
a. Axial cracks in trailing edge (concave side only) or in air slot adjacent to trailing edge	One per slot 5/16-inch long, or 2 per vane 3/4-inch long, provided they are 5/16-inch apart, or one crack 1 1/2-inch long with two 1/2-inch long provided they are 5/16-inch apart. The 1 1/2-inch long crack cannot extend axially beyond the first row of gill holes.	Not repairable	Replace by IMA*
NOTE To assist in visually gaging observed defects by comparison, the center-to-center dimension between nose or gill holes in any given row (radial direction) is approximately 3/32-inch.			
b. Axial cracks in leading edge	Any number 1/2-inch long, separated by 1/4-inch or any number cracks interconnecting the cooling holes provided total length of interconnecting cracks does not exceed six gill holes. Cracks extending aft of gill holes on convex side are not allowed.	Not repairable	Replace by IMA*
c. Radial cracks in concave surface between inner and outer platforms	Any number 1/2-inch long, or two per vane 3/4-inch long provided they are 5/16-inch apart.	Not repairable	Replace by IMA*
d. Radial cracks in convex surfaces between inner and outer platforms	One crack allowed, 3/4-inch long.	Not repairable	Replace by IMA*
e. Buckling or bowing of trailing edge	Any number 5/16-inch from original contour.	Not repairable	Replace by IMA*
f. Axial cracks in concave surface	Two cracks per vane extending aft from aft row of gill holes to (not through) slot in trailing edge.	Not repairable	Replace by IMA*

Table 2-5. High Pressure Turbine Nozzles - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
g. Corrosion, burns and cracks on concave and convex side including trailing edge	Not to exceed an area of 1 1/5-inch long and one inch wide per vane, max. of four vanes per 90° arc. Missing metal in inserts (inner liner) not allowed.	Not repairable	Replace by IMA*
h. Burns or sparing on vane leading edge	1/2-inch diameter per vane. Max. of four vanes affected per 90° arc. No missing metal in inserts allowed.	Not repairable	Replace by IMA*
i. Craze cracking	Any amount		
NOTE Craze cracking is defined as numerous superficial surface cracks which have no visual width or depth.			
j. Nicks and dents	Any amount provided there is no missing metal.	Not repairable	Replace by IMA*
k. Tears	Any amount provided there is no missing metal and vane insert is not exposed.	Not repairable	Replace by IMA*
2. Inner and Outer Platform for:			
a. Cracks in welds between vanes	2/3-length of weld at outer platform provided weld at inner platform has no cracks, or 1/3-length of original weld if inner platform has crack of any length.	Not repairable	Replace by IMA*
b. Cracks in parent metal	Any number, 5/8-inch max. length. Max. cumulative length any amount, provided no metal is missing.	Not repairable	Replace by IMA*
c. Nicks, scores, scratches and dents on platform surface	Any number, 1/16-inch deep.	Not repairable	Replace by IMA*
d. Corrosion, erosion and burns on vane platform	1/2-inch wide any length max. of six vanes per 90°. No burn through allowed.	Not repairable	Replace by IMA*

Table 2-5. High Pressure Turbine Nozzles - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
e. Corrosion, erosion and burns on inner platform trailing edge (Loss of metal)	Six vanes per 90° arc, 1/4-inch, two per vane.	Not repairable	Replace by IMA*
SECOND STAGE HIGH PRESSURE TURBINE NOZZLE			
1. Vane Airfoil for:			
a. Axial cracks in trailing edge	Any number, 3/32-inch long, two per vane, 1/2-inch long, provided they are 1/4-inch apart.	Not repairable	Replace GG.
b. Axial cracks in leading edge	Not serviceable	Not repairable	Replace GG.
c. Cracks in concave surfaces	Two cracks, 1 1/2 max inch length.	Not repairable	Replace GG.
d. Craze cracking	Any amount		
NOTE Craze cracking is defined as numerous superficial surface cracks which have no visual width or depth.			
e. Buckling of trailing edge	Any number, 1/16-inch from original contour.	Not repairable	Replace GG.
f. Burns on airfoil surfaces	One inch square area with no through holes.	Not repairable	Replace GG.
g. Corrosion	Any amount provided corrosion is not completely through metal thickness.	Not repairable	Replace GG.
2. Inner and Outer Platform for:			
a. Cracks between vanes	Any number 5/8-inch long separated by 1/4-inch.	Not repairable	Replace GG.
b. Craze cracking	Any amount		
NOTE Craze cracking is defined as numerous superficial surface cracks which have no visual width or depth.			

Table 2-5. High Pressure Turbine Nozzles - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
c. Cracks in outer band trailing edge	Two cracks, 3/8-inch long, any number 1/8-inch long.	Not repairable	Replace GG.
STAGE 1 AND STAGE 2 TIP SHROUD			
1. Shroud for:			
a. Wear	Any amount as long as backing strip is not damaged.	Not repairable	Replace GG.
b. Erosion	Total eroded area missing not to exceed 10 percent provided missing area is not completely across axial width of shroud; no single area to exceed one square inch.	Not repairable	Replace GG.
c. Axial cracks	Two per shroud segment 1/4-inch long; one per shroud segment one SQIN.	Not repairable	Replace GG.
d. Distortion- Stage 2 only	Free state distortion allowable, provided proper assembly and blade clearance can be maintained.	Not repairable	Replace GG.
* Special Shipboard Maintenance Manual, S9234-BF-MMI-010/LM2500			

Table 2-6. High Pressure Turbine Rotor Blades - Paired Blade Turbine Configuration (See Figure 2-19)

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
NOTE See Figure 2-21 for HPT rotor stage 1 blade borescope reference measurements. These reference dimensions have been rounded off to 1/32-inch. Known dimensions are useful in estimating dimensions of observed defects. Best results are obtained when dimensions are the same direction and distance from borescope as the defects. Avoid comparing axial direction defects with radial known feature because unreliable observations will result due to distortions produced by differences in contour and perspective. Avoid comparing trailing edge defects with leading edge known features because distortion due to magnification of the borescope will make such comparisons unreliable.			
STAGE 1 BLADES			
1. Leading Edge for:			
a. Cracks propagated from nose holes	Any amount allowed in holes above bottom four holes in each eow, provided cracks do not extend into gill holes. None allowed in bottom four holes of each row.	Not repairable	Replace by IMA*
b. Clogged air passages	Any number provided limits of 1.a. and 1.c. are met.	Not repairable	Replace by IMA*
c. Erosion/corrosion	Any amount in area A, provided wall is not penetrated.	Not repairable	Replace by IMA*
	Any amount in area B, provided it is not through coating. If coating in area B is penetrated, GG must be replaced within 1800 hours and borescope inspected at 600 hour intervals prior to replacement.	Not repairable	Replace by IMA*
2. Trailing Edge for:			

Table 2-6. High Pressure Turbine Rotor Blades - Paired Blade Turbine Configuration (See Figure 2-19) - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
a. Cracks	None allowed in 16th hole and below (towards platform). Any number above 16th hole (towards trip) provided cracks do not extend into concave or convex surface.	Not repairable	Replace by IMA*
b. Clogged air passages	Any number provided limits of 2.a. and 2.c. are met.	Not repairable	Replace by IMA*
Erosion/corrosion	Any amount in area A provided cooling holes are not penetrated from either concave or convex walls. If coating in area B is penetrated, GG must be replaced within 1800 hours and borescope inspected at 600 hour intervals prior to replacement.	Not repairable	Replace by IMA*
3. Concave and Convex Surfaces for:			
a. Cracks at gill holes or air-foil surface in area A	Any number 3/16 inch long provided cracks are not adjacent to a leading edge crack.	Not repairable	Replace by IMA*
b. Cracks at gill holes or air-foil surface in area B	Not serviceable	Not repairable	Replace by IMA*
c. Blocked gill holes	Any number provided limits of 3.a., 3.b., and 3.d. are met.	Not repairable	Replace by IMA*
d. Erosion/corrosion	Any amount allowed as long as tip and root regions of corrosion do not meet and walls are not penetrated. If they meet, GG must be replaced within 1200 hours. If penetration of wall has occurred, replace GG immediately.	Not repairable	Replace by IMA*
e. Distortion or evidence of burning or melting	Not serviceable	Not repairable	Replace by IMA*

Table 2-6. High Pressure Turbine Rotor Blades - Paired Blade Turbine Configuration (See Figure 2-19) - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
4. Leading and Trailing Edges in Area A for:			
a. Nicks and dents	Any amount provided there is no torn metal or cracks.	Not repairable	Replace by IMA*
b. Tears	Not serviceable	Not repairable	Replace by IMA*
5. Concave and Convex Surfaces in Area A for:			
a. Nicks and dents	Any amount provided there is no torn metal or cracks.	Not repairable	Replace by IMA*
6. All Area B Including Root Radius for:			
a. Nicks and dents	Not serviceable	Not repairable	Replace by IMA*
7. Blade tip for:			
NOTE On paired blades the blade tip is the area from tip of blade down to 3/32-inch above top gill hole.			
a. Cracks	(1) Any number of radial cracks 5/16-inch long	Not repairable	Replace by IMA*
	(2) One axial crack allowed provided it is no longer than 1/2-inch	Not repairable	Replace by IMA*
b. Bent or curled blade tip	Two areas, 1/4-inch long.	Not repairable	Replace by IMA*
c. Dents in leading edge of blade tip	Any depth if metal is not torn.	Not repairable	Replace by IMA*
d. Missing pieces	Any amount above blade tip cap.	Not repairable	Replace by IMA*
STAGE 2 BLADES			

Table 2-6. High Pressure Turbine Rotor Blades - Paired Blade Turbine Configuration (See Figure 2-19) - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
NOTE See Figure 2-22 for HPT rotor stage 2 blade borescope reference measurements. These reference dimensions have been rounded off to 1/32-inch.			
1. Leading and Trailing Edges in Area A for:			
a. Nicks and dents	Any amount provided there is no torn metal or cracks.	Not repairable	Replace by IMA*
b. Tears	Not serviceable	Not repairable	Replace by IMA*
c. Corrosion and/or coating chips, pits, spatter particles	Any amount provided wall is not penetrated.	Not repairable	Replace by IMA*
2. Concave and Convex Surface in Area A for:			
a. Nicks and dents	Any amount provided there is no torn metal or cracks.	Not repairable	Replace by IMA*
b. Corrosion and/or coating chips, pits, spatter particles	Any amount provided wall is not penetrated.	Not repairable	Replace by IMA*
3. Concave and Convex Surfaces in Area B, Including Root Radius for:			
a. Nicks	Not serviceable	Not repairable	Replace by IMA*
b. Dents	Superficial marks allowed provided there is no raised/deformed metal around indication.	Not repairable	Replace by IMA*
c. Corrosion and/or coating chips, pits, spatter particles	Any amount provided coating is not penetrated.	Not repairable	Replace by IMA*
4. Leading and Trailing Edges in Area B for:			
a. Nicks and dents	Not serviceable	Not repairable	Replace by IMA*
b. Corrosion and/or coating chips, pits, spatter particles	Any amount provided coating is not penetrated.	Not repairable	Replace by IMA*

Table 2-6. High Pressure Turbine Rotor Blades - Paired Blade Turbine Configuration (See Figure 2-19) - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
5. All Areas for:			
a. Cracks	Not serviceable	Not repairable	Replace by IMA*
6. Blade Tip for:			
a. Cracks in stage 2 blade tips	(1) Any number of radial cracks 5/16-inch long.	Not repairable	Replace by IMA*
	(2) One axial crack allowed provided it is no longer than 1/2-inch.	Not repairable	Replace by IMA*
b. Bent or curled blade tip	Two areas, 1/4-inch long.	Not repairable	Replace by IMA*
c. Dents in leading edge of blade tip of stage 1	Any depth if metal is not torn.	Not repairable	Replace by IMA*
d. Missing pieces	Any amount above blade tip cap.	Not repairable	Replace by IMA*
* Maintenance Manual, S9234-BF-MMI-010/LM2500			

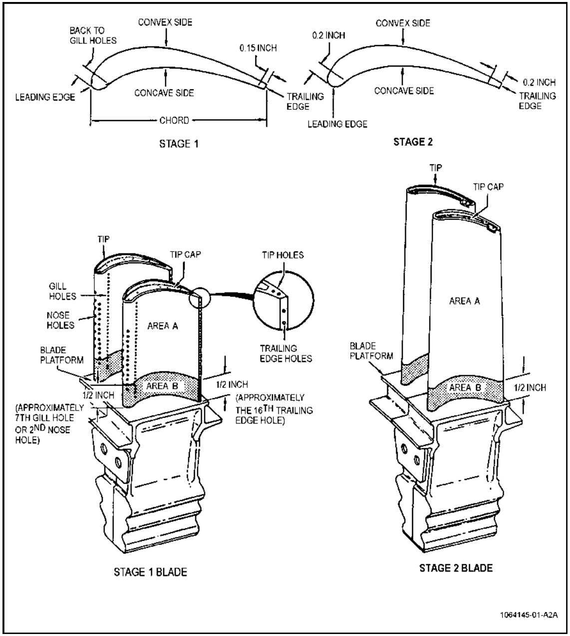


Figure 2-19. High Pressure Turbine Rotor Blades - Paired Blade

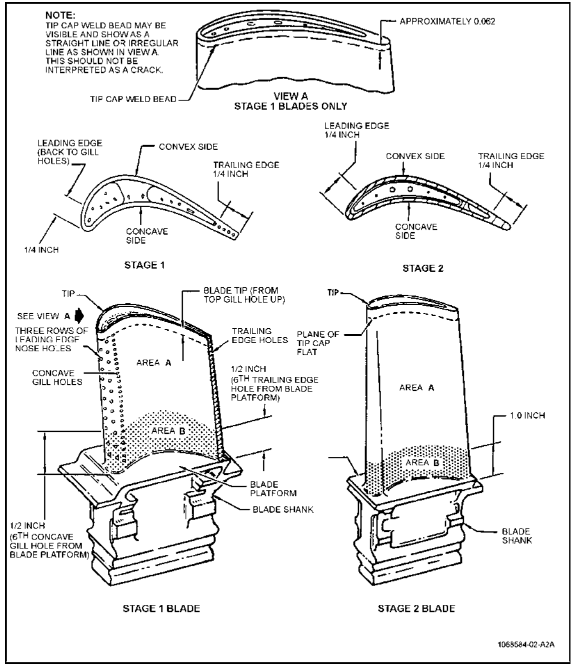
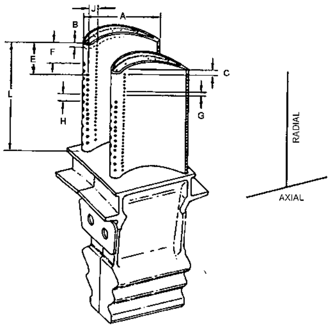


Figure 2-20. High Pressure Turbine Rotor Blades - Single Shank

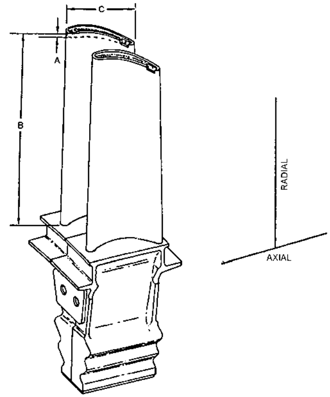


STAGE ONE BLADE

LEGEND:
A. BLADE CHORD, 1-9/32 INCHES
B. DISTANCE FROM TIP TO CAP, 1/8 INCH (REFERENCE)
C. DISTANCE FROM TIP TO CENTER OF CONCAVE GILL HOLE, 3/16 INCH
D. DISTANCE FROM TIP TO CENTER OF CONVEX GILL HOLE, 3/16 INCH (NOT ILLUSTRATED)
E. DISTANCE FROM TIP TO CENTER OF CONCAVE NOSE HOLE, 7/16 INCH
F. DISTANCE FROM TIP TO CENTER OF CONVEX NOSE HOLE, 3/8 INCH
G. RADIAL DISTANCE BETWEEN GILL HOLES, 1/16 INCH
H. RADIAL DISTANCE BETWEEN NOSE HOLES, 1/8 INCH
I. AXIAL DISTANCE BETWEEN CONVEX GILL HOLE CENTERS AND CONVEX NOSE HOLE CENTERS, 3/16 INCH (NOT ILLUSTRATED)
J. AXIAL DISTANCE BETWEEN CONCAVE GILL HOLE CENTERS AND CONCAVE NOSE HOLE CENTERS, 1/8 INCH
K. DIAMETER OF GILL AND NOSE HOLES, 1/64 INCH (NOT ILLUSTRATED)
L. BLADE LENGTH, 1-29/32 INCHES

1068427-01-B2

Figure 2-21. High Pressure Turbine Stage 1 Blade Boroscope Reference Measurements (Approximate) (Paired Blade Turbine Configuration)



STAGE 2 BLADE

NOTE:

STAGE 2 BLADES

A DISTANCE FROM TIP TO TIP CAP (1/8 INCH REFERENCE)
B BLADE LENGTH, (3 5/32) INCH
C BLADE CHORD (1-9/32) INCH

LM-C6125-0-B2

Figure 2-22. High Pressure Turbine Stage 2 Blade Boroscope Reference Measurements (Approximate) (Paired Blade Turbine Configuration)

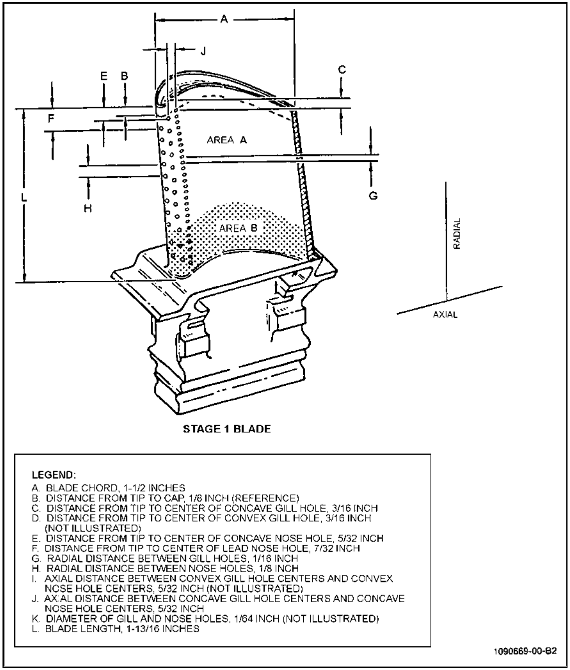


Figure 2-23. High Pressure Turbine Stage 1 Blade Boroscope Reference Measurements (Approximate) (Single Shank Turbine Configuration)

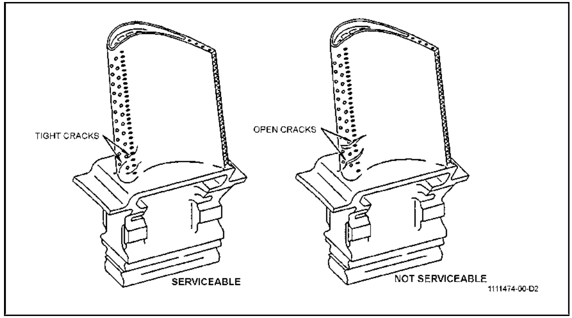


Figure 2-24. Cracks at Stage 1 Blade Root

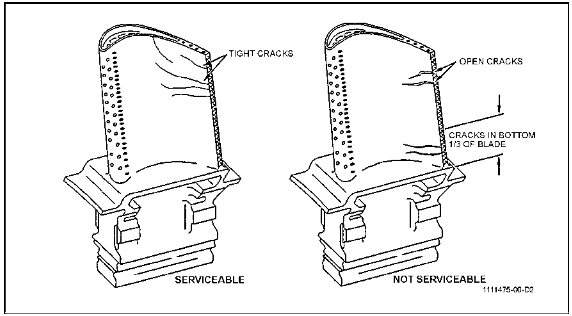


Figure 2-25. Cracks at Stage 1 Blade Trailing Edge

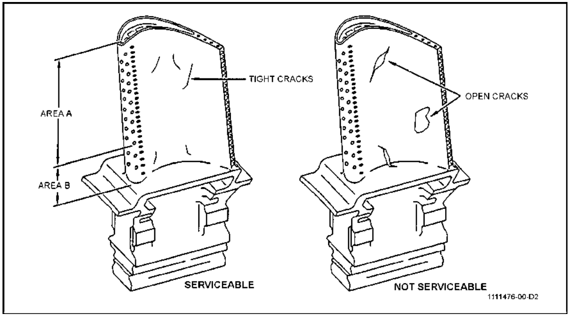


Figure 2-26. Cracks in Stage 1 Blade Concave Surface

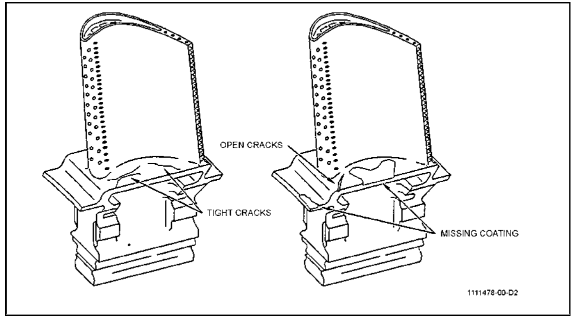


Figure 2-28. Cracks at Stage 1 Blade Platform

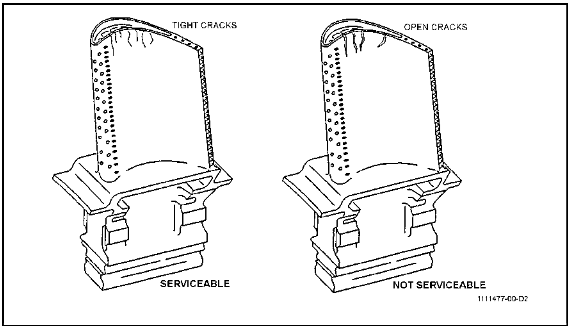


Figure 2-27. Cracks at Stage 1 Blade Tip

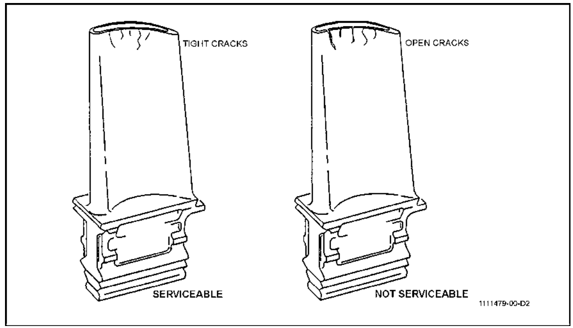


Figure 2-29. Cracks at Stage 2 Blade Tip

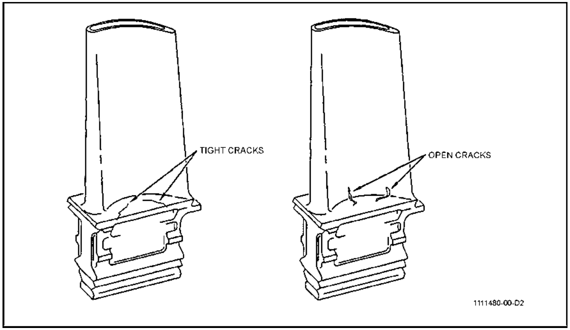


Figure 2-30. Cracks at Stage 2 Blade Platform

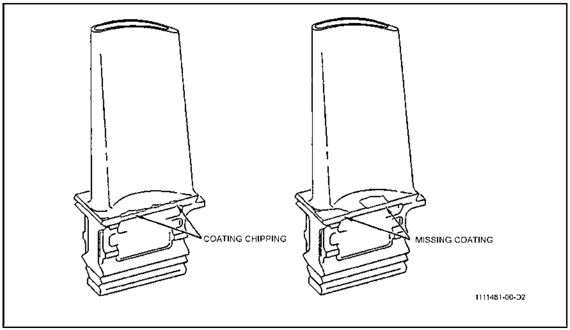


Figure 2-31. Missing Coating at Stage 2 Blade Platform

Figure 2-32. Typical Burn Through

Figure 2-33. Typical Radial Cracking

Figure 2-34. HPT Blade Crack Serviceable

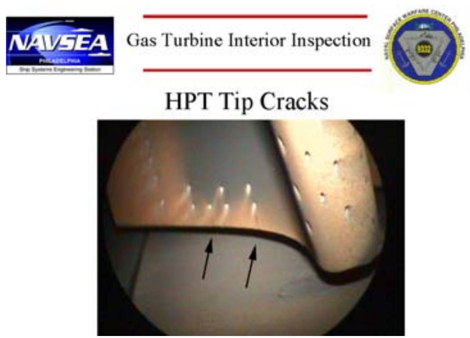


Figure 2-35. HPT Tip Cracks

Figure 2-36. HPT Blade Erosion

Figure 2-37. HPT Coating Loss

Figure 2-38. HPT FOD

2.4.3 Combustion Liner Inspection Perform an inspection of the components listed below. Remove lockwire and combustion liner assembly borescope port plug numbers 13A − F.

a. Combustion liner for discoloration and carbon accumulation.

b. Riveted joints for loose cracked, or missing rivets, and cracked or torn rivet holes in cowl and skirts.

c. Dome band and dome plate for axial cracks and circumferential cracks.

d. Trumpet and swirl cup for cracks and distortion of trumpet.

e. Dome assembly for missing metal.

f. Igniter ferrule for cracks.

g. Inner and outer skirts for circumferential cracks, axial cracks, burns and distortion.

h. Cowl for burns at fuel nozzle eyelet and cracks.

i. Fuel nozzle for carbon deposits.

j. High-pressure turbine stage 1 vanes for cracks, clogged air passages, corrosion or erosion.

k. Record discrepancies and identify area. Remove borescope.

l. Apply medium coat of antisieze compound to borescope port plug threads; reinstall plugs and washers, torque to 80-100 in-lb. and lockwire.

Table 2-7. Combustion Liner Assembly And Fuel Nozzles

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
COMBUSTION LINER			
1. All Surfaces for:			
a. Discoloration	Serviceable		
b. Carbon accumulation	Any amount		
2. Riveted Joints for: (See MMO-060, Figure 7-582)			
a. Loose, cracked or missing rivets	Six non-adjacent rivets in each rivet circle may be loose, cracked or missing.	Not repairable	Replace by IMA*
b. Cracked or torn rivet holes in cowl and skirts	One crack, 0.030 inch long per hole; 20 holes max per rivet circle.	Not repairable	Replace by IMA*
3. Dome Band and Dome Plate for: (See MMO-060, Figure 7-583)			

Table 2-7. Combustion Liner Assembly And Fuel Nozzles - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
a. Axial cracks	Any number less than 1 1/4-inch long; one crack greater than 1 1/4-inch in each swirl cup location, max length of 2 1/4-inch not to exceed eight per dome.	Not repairable	Replace by IMA*
b. Circumferential cracks	Any number less than 3/4-inch long. Five cracks 2 1/4-inches long separated by one inch from any other crack greater than 3/4-inch long.	Not repairable	Replace by IMA*
4. Trumpet and Swirl Cup for: (See MMO-060, Figure 7-584)			
a. Cracks	Four cracks, 1 1/4-inch long per item; any number less than 1/2-inch long.	Not repairable	Replace by IMA*
b. Distortion of trumpet	Any amount		
c. Swirler Bore Wear	Any amount	Not repairable	No action required.
5. Dome Assembly (Dome Band, Dome Plate and Trumpet) for: (See MMO-060, Figure 7-585)			
a. Burn through or missing metal	Any amount less than 180° of burn through the trumpet and/or dome plate around any one swirl cup. Any amount of trumpet distress is allowed, max of ten square inches (SQIN) per dome.	Not repairable	Replace by IMA*
NOTE Burn through in the combustor dome will reduce the cooling flow to the High Pressure Turbine (HPT) vanes. Inspect the HPT vanes to the limits of Table 2-5.			
6. Dome Igniter Tube for: (See MMO-060, Figure 7-586)			
a. Cracks	Any number 1/4-inch long.	Not repairable	Replace by IMA*

Table 2-7. Combustion Liner Assembly And Fuel Nozzles - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
b. Burns	1/8-inch burn permissible on bottom of ferrule (flame side).	Not repairable	Replace by IMA*
c. Wear	3/4-inch Inner Diameter (ID) max.	Not repairable	Replace by IMA*
7. Inner and Outer Liners for: (See MMO-060, Figure 7-589 through Figure 7-591)			
a. Circumferential cracks	Any number non-interconnecting cracks per band, each one inch long separated by two inches from any other crack. Total length of all circumferential cracks in any band shall not exceed seven inches.	Not repairable	Replace by IMA*
b. Axial cracks	Six cracks per skirt, max length not to exceed two adjoining bands (three rows of cooling holes), any number of cracks 1 1/4-inch per band. Axial and circumferential cracks, one inch or longer must have a minimum separation of two inches.	Not repairable	Replace by IMA*
c. Burns and missing metal	Six burned through areas of 3/4-inch by one inch per skirt separated by 2 1/2-inches.	Not repairable	Replace by IMA*
d. Distortion	Any amount within 1/2-inch from original contour.	Not repairable	Replace by IMA*
8. Cowl for:			
a. Burns at fuel nozzle eyelet (fuel nozzle removed)	Accept three burn through areas of 1/4x1 inch.	Not repairable	Replace by IMA*
b. Cracks	Any number 1/4-inch long.	Not repairable	Replace by IMA*
FUEL NOZZLE			

Table 2-7. Combustion Liner Assembly And Fuel Nozzles - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
1. Fuel Nozzle Shroud and Discharge Orifices for:			
a. Carbon deposits	Not serviceable	Any amount	Contact FTSC.
b. Nozzle tip wear	Any amount	Not repairable	No action required.
* Special Shipboard Maintenance Manual, S9234-BF-MMI-010/LM2500			

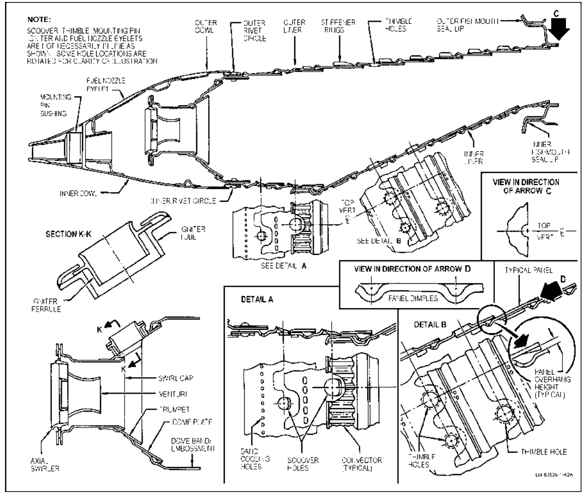


Figure 2-39. Combustion Liner Assembly (Typical)

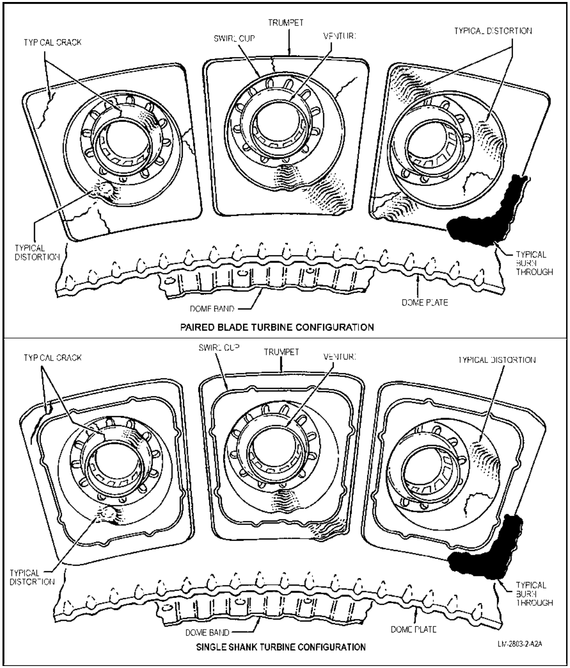


Figure 2-40. Trumpet and Swirl Cup

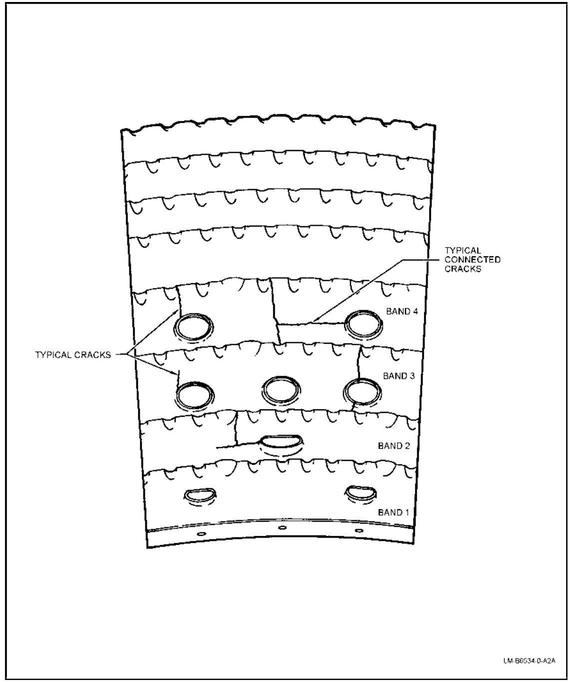


Figure 2-41. Inner/Outer Liner Axial Cracks

NAVSEA PHILADELPHIA Ship Systems Engineering Station

Gas Turbine Interior Inspection

Missing Material

Figure 2-42. Trumpet Area Missing Material

NAVSEA PHILADELPHIA Ship Systems Engineering Station

Gas Turbine Interior Inspection

Converging Cracks

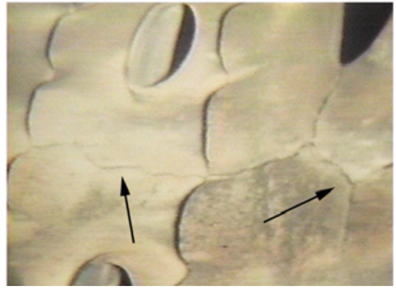


Figure 2-43. Combustion Liner Converging Cracks

Figure 2-44. Combustion Liner Cracks

2.5 VARIABLE STATOR VANE (VSV) SYSTEM INSPECTION

(Ref: S9234-AD-MMO-060/LM2500 and MRC 2340, R-18 Main Fuel Control Variable Stator Vane Feedback Lever and Actuation System Inspection).

MRC check 2340, R18, must be accomplished every 1500+/-250 operating hours, after module overtemperature, and in accordance with GROOM inspection prior to a deployment of 90 days or longer.

Always refer to and follow the MRC requirements when performing inspection. The following is general overview for performing VSV inspection (Ref S9234-AD-MMO-060/LM2500 and MRC 2340, R18).

NOTE

Report any VSV system discrepancies detected by this inspection to the Work Center Supervisor. If an out of limit condition is found, contact local Marine Gas Turbine Inspector (MGTI) or Fleet Technical Support Center (FTSC) gas turbine representative for further evaluation.

NOTE

The presence of dirt, oil and residual waterwash solution in VSV bushings and spacers will accelerate wear. Ensure periodicity of MRCs for internal and external waterwash and rinse procedures are strictly followed to reduce wear.

a. Inspect VSV actuator lever guides and spherical or slot loaded bearings for loose fit, wear, raised or displaced metal, scoring and binding.

b. Inspect VSV actuator and bracket for loose, damaged, or missing bolts and nuts. Inspect for any fuel leaks on VSV actuator, actuator rod end seals and all supply and return lines to and from the MFC.

NOTE

Bent VSV lever arms require inspection in accordance with NSTM S9234-AD-MMO-060/LM2500. Corrective action is accomplished by an IMA.

c. Inspect VSV lever arms for bending, loose or missing locknuts and inspect alignment sleeves for cracks.

NOTE

Ensure dial indicator mount/base and rig is secure to enable accurate measurements. Use attached Drawing to locally manufacture dial indicator mounting adapter for universal dial indicator set. Use of other mounting methods or dial indicator sets is authorized. Ensure dial indicator mounting method does not bend, scratch or damage VSV system.

d. By hand, try to move all accessible VSVs from side to side to evaluate degree of bushing and spacer wear. Pay particular attention to stages 3, 4 and 5. If any VSVs can be moved, a dial indicator shall be used where possible to read side-to-side movement.

(1) Inspect each loose vane.

(2) Ensure dial indicator is securely mounted.

(3) Ensure dial indicator is mounted in the direction of VSV movement.

(4) Ensure dial indicator is preloaded and reset to zero while VSV is pushed and held away from the dial indicator in the arc of movement. Move VSV back towards dial indicator until it stops and take reading. Repeat this twice to ensure the maximum amount of movement of the VSV is measured accurately.

(5) Record each VSV that shows signs of wear (can be moved) on MRC VSV Inspection Log. Ensure VSV specific location is annotated on the MRC VSV Inspection Log. This will aid in concurrent inspections.

(6) VSVs that can be moved side to side and are not accessible to be checked with a dial indicator can be compared with accessible VSVs that can be checked with a dial indicator to gage the wear by hand. If not sure of inaccessible VSV wear, contact Work Center Supervisor.

e. Inspect VSV actuation lever, VSV actuation rings and adjustable links, VSV feedback bellcrank and bellcrank bracket for loose, missing and/or damaged pins, fasteners, distorted linkage and wear.

(1) Check for any missing or broken safetywire on VSV actuation lever/actuation link jam nuts (14 on each side), actuation rings, VSV bellcrank link jam nut, VSV feedback cable rod end bearings, VSV feedback cable swivel support tube jam nuts and the MFC VSV trimmer bracket and lockscrew.

Table 2-8. VSV Inspection Criteria

CONDITION CATEGORY	SERVICEABLE LIMITS	CORRECTIVE ACTION
1. None to moderate movement of any number of VSVs	Serviceable 0.000” - 0.015” side to side movement	No corrective action required until next 1500 hour insp. Engine operation is authorized.
2.Moderate movement of any number of VSVs	Serviceable 0.016” − 0.019” side to side	No corrective action required until next 1500 hour insp. unless directed by MGTI or FTSC during pre-deployment Groom insp. Engine operation is auth.
3.Excessive movement of one or more VSVs	Not Serviceable 0.020” or more side to side movement	Schedule IMA to replace bushings/washers within 50 hours of engine operation, contact FTSC.

Table 2-9. General VSV Inspection Notes

1. Recommend checking VSVs by hand during each GTMI to determine wear trend. If VSV side to side movement appears to have increased, recheck with dial indicator.
2. VSV in and out movement is no longer required to be measured. Excessive in and out movement is normally associated with excessive side to side movement of greater than 0.020. If VSV in and out movement is excessive (> 0.010”) without excessive side to side movement (< 0.019”), contact MGTI or FTSC.
3. VSV stages 3 − 6 use a harder bushing which can produce an audible sound when moved side to side with clearance normally less than 0.020”. This condition is acceptable.
4. Condition Category 1. Inspection results shall be documented in MRC VSV Inspection Log only.
5. Condition Category 2. Inspection results shall be documented in MGTESRs MGTE Miscellaneous History Form 9400/7, and MRC VSV Inspection Log. PMS inspections are not recorded on MGTE Forms 9400/4 or 9400/6.
6. Condition Category 3. Inspection results shall be documented in MGTESRs MGTE Miscellaneous History Form 9400/7 in and MRC VSV Inspection Log. Repairs only shall be documented in MGTE Form 9400/11.
7. Repairs shall be reported IAW GGTB 4.

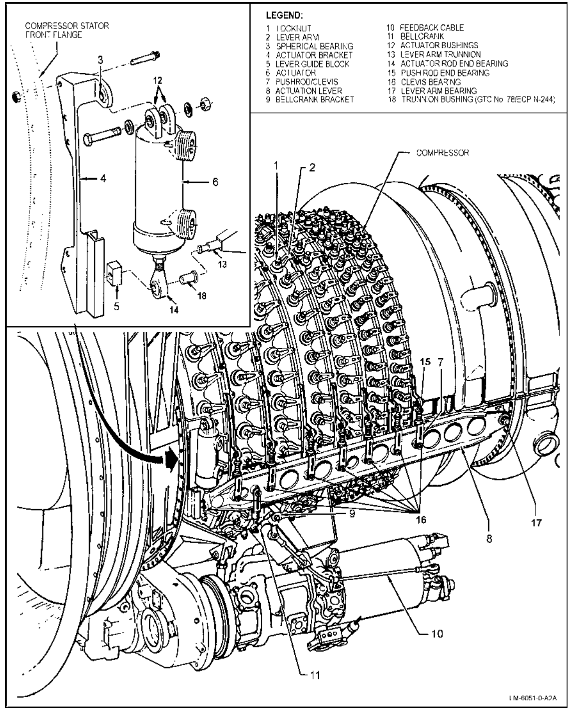


Figure 2-45. Variable Stator Vane System Components

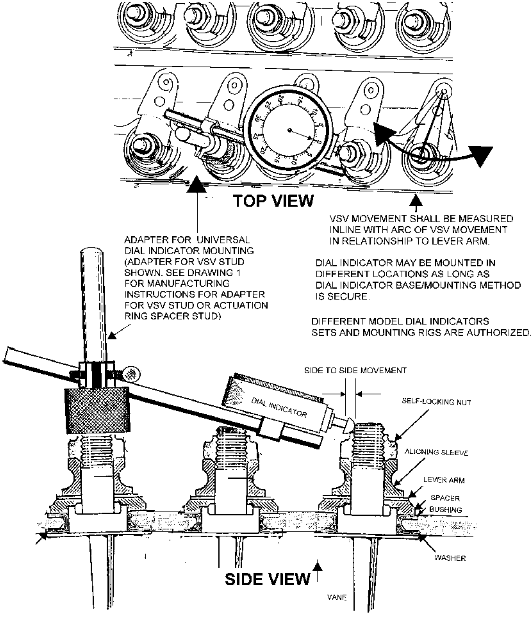


FIGURE 2

Figure 2-46. Dial Indicator Position

Figure 2-47. Typical Dial Indicator Set up

Table 2-10. Dimensions for Manufacturing Mounting Adapter

A	Overall Length − 3 Inches
B	Upper Shank − 2 Inches (Indicator Mount area)
C	Lower Shank − 1 Inch (Knurl Surface)
D	Outside Diameter (Lower) − 0.750 Inches
E	Outside Diameter (Upper) − 0.300 Inches
F	5/16 − 24 Hole/Threads with 0.750 Bore Depth − Mounts on VSV Stud Shank
G	¼ - 28 Hole/Threads with 0.750 Bore Depth - Mounts on VSV Actuation Ring Spacer Stud
Material: Stainless Steel (Recommended)	

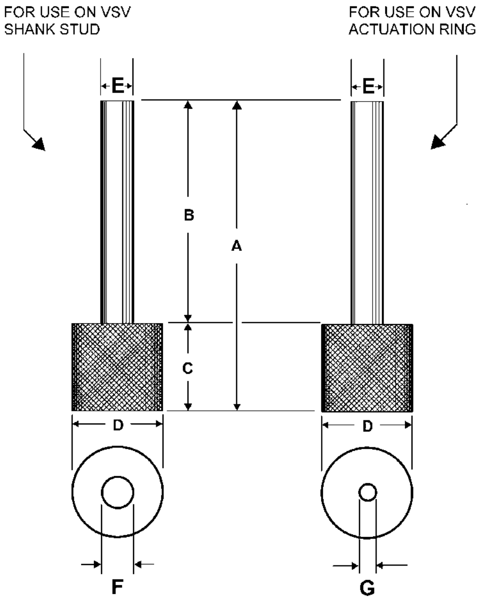


Figure 2-48. Mounting Adapter

Table 2-11. Compressor Stator Case and Variable Stator Vane Components (See Figure 2-45)

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
VARIABLE STATOR VANE (VSV) SYSTEM (See Figure 2-45)			
NOTE See Figure 2-45 - LM2500 GTC No. 78/ECP-244-R1 incorporates the following changes: replaces lever arm (8) clevis' (16) push-rod ends (15), lever arm pivot (17) and actuator (6) rod end (14) and bracket (3) bearings with slot-loaded bearings, replaces bushings (12) in actuator (6) attachment ears, rubber boots/dust covers are incorporated at locations (16) in OEM new production engines only, replaces thin clevis with thick clevis (7). See MMO-060, Figure 7-571 - replaces IGV through Stage 2 flanged bushings (7) and washers (6) with new Q8050A washers and bushings with flanged bushing being installed on outside of compressor case (same as in Stage 3-6 (GTC No. 26)), replaces hollow aluminum actuation ring segments (9) with solid aluminum actuation ring segments. See MMO-060, Figure7-571 - GTC No. 75 incorporates a new vane arm, alignment sleeve and adds an additional nut on stages 5 and 6.			
1. Locknut (1) for:			
a. Looseness	Nut must be tight with at least three vane stud threads showing as determined visually.	Any amount	Contact FTSC/MGTI Investigate for stall Replace by IMA *
2. Vane Lever Arm (2) for:			
a. Security	Lever arm must be in place and secure.	Any amount if nut in place and lever arm is engaged with vane trunnion.	Contact FTSC/MGTI Investigate for stall Replace by IMA *
b. Bent	Lever arm must not be bent more than 4°.	Not repairable	Contact FTSC/MGTI Investigate for stall Replace by IMA *
NOTE There is no limit for looseness in the axial direction, but axial looseness is controlled by vertical looseness.			
3. Slot-Loaded (ECP N-244/GTC No. 78) or Self-Aligning Bearing (Before ECP N-244/GTC No. 78) (3), (14), (15), (16) and (17) for: (see Figure 2-45):			
a. Seized or locked	All clevis' (7) should swivel/move using finger pressure. (Clevis and push-rod rod end bearing shall be aligned to allow maximum swivel.)	Not repairable	Contact FTSC/MGTI

Table 2-11. Compressor Stator Case and Variable Stator Vane Components (See Figure 2-45) - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
b. Looseness of outer race in lever	Not serviceable (for GTC No. 78 rubber boots/dust covers, do not pry back to inspect unless clevis (7) is excessively loose)	Any amount	Contact FTSC/MGTI
c. Looseness of ball to outer race	Slight looseness (0.020 inch max) of bearing ball is serviceable (for lever arms with rubber boots, do not pry back to inspect unless clevis (7) is excessively loose)	Any amount	Contact FTSC/MGTI (for slot-loaded bearings, replace bearing ball)
4. Actuator Bracket (4) for:			
a. Loose attaching fasteners	Not serviceable	Any amount	Retorque mounting bolts/nuts.
5. Actuation Bracket Lever Guide (4), Guide Block (5) for:			
a. Binding, excessive looseness	.054 inch max movement side to side of lever arm. (.054 inch includes max wear of guide block (internal and external), actuator bracket guide side walls and max lever arm trunnion wear)	Not repairable	Contact FTSC/MGTI. IMA replace guide block
6. Actuator (6) for:			
a. External leakage	Not serviceable	Any amount correctable by replacing attaching fitting O-rings or retorquing of fittings.	Refer to MMO-050, para. 7.75.1 and replace O-rings, or replace actuator.
b. Leakage from attaching drain manifold fitting	2 cm^3/min each actuator. (This limit is for trouble-shooting, not routine inspection.)	Any amount correctable by replacing attaching filling O-rings or retorquing of fittings.	Refer to MMO-050, para. 7.75.1 and replace O-rings, or replace actuator.
7. Pushrod Assembly (7) for:			
a. Missing safety-wire	Not serviceable	Any amount	Replace safety-wire.
8. Vane Actuation Lever (8) for:			
a. Loose attaching fasteners	Not serviceable	Any amount	Contact FTSC/MGTI.

Table 2-11. Compressor Stator Case and Variable Stator Vane Components (See Figure 2-45) - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
9. Feedback Bellcrank Bracket (9) and Bellcrank (11) for:			
a. Loose attaching fasteners	Not serviceable	Any amount	Retorque
b. Wear	Not serviceable	Any amount	Contact FTSC/MGTI.
10. Feedback Cable (10) for:			
a. Missing safety-wire on rod-end bearings or attaching fasteners	Not serviceable	Any amount	Safety-wire
b. Bent or binding cable	Not serviceable	Any amount	Refer to MMO-050, para. 7.62 and replace cable.
11. Sleeve, Alignment (See Figure 2-49)			
a. Cracks	Hairline cracks - any amount is serviceable as long as crack does not connect to another edge or enter vertical area. Single crack less than ¼ inch in bottom flat area is serviceable. More than one crack, any crack in radius of vertical section and missing piece is Not Serviceable. (See Figure 2-50)	Not repairable	Hairline cracks with no separation or edge noticeable - any amount. or Single crack less than ¼ inch in length. Replace sleeve at next opportunity by IMA. Full and unrestricted operation is allowed until next opportunity to replace by IMA. (See Figure 2-50)

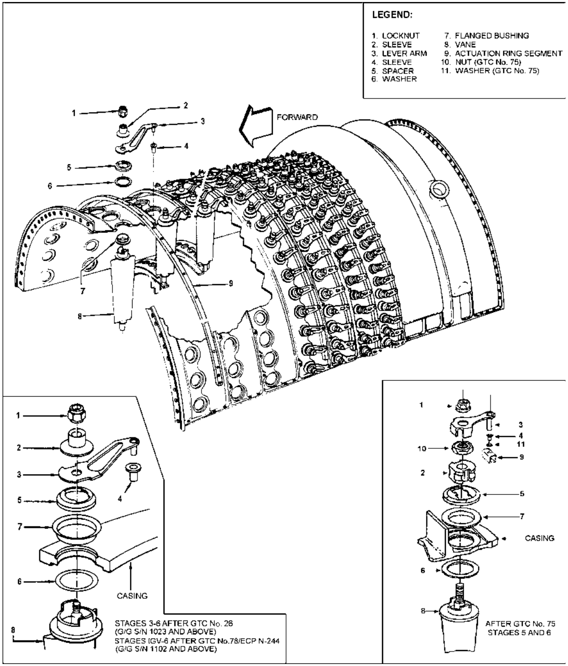


Figure 2-49. IGV through Stage 6 Variable Vane Assembly

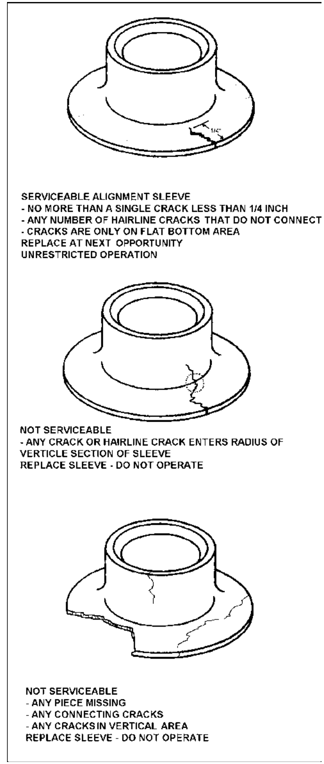


Figure 2-50. IGV through Stage 2 Alignment Sleeve Crack Criteria

2.5.1 <u>Inspect VSV Feedback Cable</u> When conducting the following checks, if a bent VSV feedback cable is found, a borescope inspection shall be conducted to determine if a stall condition has occurred.

a. Inspect VSV feedback cable and cable rod end bearings for looseness, damage or distortion.

(1) Inspect VSV feed back cable for kinks or sharp bends.

(2) Ensure that VSV feedback cable rod-end bearing attaching bolts have boltheads toward gas turbine and nuts are tight.

(3) Check VSV feedback cable upper and lower swivel support tube outer conduits to ensure they can be rotated by hand.

(4) If upper and lower swivel support tube outer conduits cannot be turned by hand, the tubes may be bent or may have internal interference, debris and/or corrosion. Contact Work Center Supervisor and replace VSV feedback cable in accordance with VSV feedback cable replacement procedure in S9234-AD-MMO-050/LM2500.

b. Visually check VSV feedback cable trimmer bracket. Neither end of the slot in the trimmer bracket shall touch the lockscrew. There must be some clearance.

(1) If there is no clearance between the trimmer bracket and the lockscrew (lockscrew is touching trimmer bracket), and/or if there are any safetywire discrepancies proceed to Inspect Feedback Cable Rig procedure.

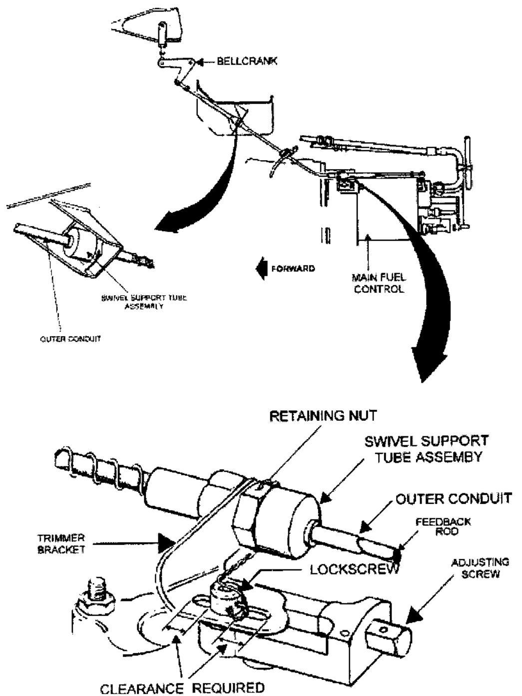


Figure 2-51. VSV Feedback Cable

2.5.2 Inspect VSV Feedback Cable Rig

WARNING

Fuel will drain from MFC flex hoses and piping when disconnected. Ensure face shield, gloves and apron are worn when disconnecting VSV flex hoses and connecting pressurizing pump to VSV actuator hard lines.

CAUTION

Incorrect rigging of VSV feedback cable can cause a compressor stall and can result in severe engine damage. Ensure the following procedure is thoroughly understood and followed. If any questions arise, contact Work Center Supervisor, MGTI or FTSC for assistance.

a. Place container under MFC to catch fuel and disconnect variable stator actuator head-end and rod-end flex hoses from hard lines at connection just above fuel pump. Use care not to scratch polished sealing surfaces of fittings.

WARNING

MIL-L-23669 Lube oil in this system contains tricresylphosphate compounds. Exposure to this lube oil may produce, on personal contact, paralysis, dermatitis or nausea. If taken internally it may cause death. Wear face shield, rubber gloves and apron while working with MIL-L-23699 lube oil. If contact with skin occurs, wash skin thoroughly. If oil saturates clothing, remove immediately. If spill occurs with large surface area, contact Work Center Supervisor. Do not attempt to clean without proper ventilation and respiratory equipment.

b. Ensure pressurizing unit P/N 1C3569 is full of gas turbine lube oil MIL-L-23699 and connect pressurizing unit to the rod-end and head-end tubes.

CAUTION

Ensure dial indicator rig mount is removed. To avoid damaging the equipment, check the VSV feedback system carefully to ensure there is no interference before applying pressure.

CAUTION

Pressurizing unit P/N 1C3569 can produce 400 psig before unit's internal relief valve lifts. Do not over pressurize VSVs system. Maximum working pressure is 300 psig. If a pressure greater than 200 psig is needed to actuate the VSVs, recheck for interference and position of pressurizing unit's directional valve.

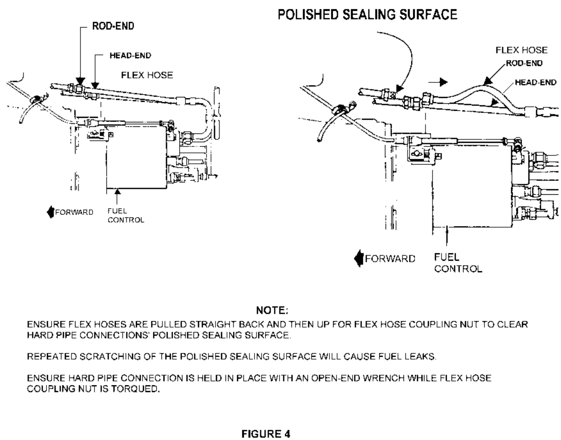


Figure 2-52. Variable Stator Actuator Head and Rod End Flex Hoses

NOTE

Due to bleed hole in actuator, pressure will drop slowly. Ensure 200-250 psig (read at gage on pressurizing unit) is maintained on the VSV system while checking feedback cable rig marks.

c. Slowly actuate VSVs to full open position (VSV actuator rod fully extended) by applying 200-250 psig pressure to the head-end of actuators.

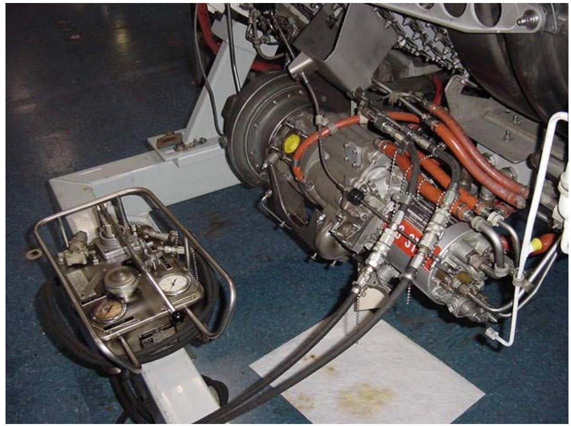


Figure 2-53. Pressurizing Unit P/N 1C3569 Set Up On Training Engine

NOTE

When checking rig marks, the rig marks must be viewed directly behind the MFC. Viewing rig marks on an angle will not allow an accurate reading.

NOTE

Two maintenance personnel are needed, one person to maintain pressure and one person to view the rig marks.

d. With the VSVs at the full open position and pressurizing unit pressure maintained at 200-250 psig, check alignment of rig marks.

(1) If rig marks are aligned, proceed to Inspect MFC/Feedback Cable Lever Rig Marks and VSV Actuation System Operation.

(2) If rig mark on the feedback lever is above or below the stationary rig mark on MFC, report discrepancy to Work Center Supervisor and perform VSV feedback cable rig procedure in S9234-AD-MMO-050/LM2500.

(3) If rig procedure in S9234-AD-MMO-050/LM2500, is performed with satisfactory results, skip Inspect MFC/Feedback Cable Lever Rig Marks and VSV Actuation System Operation and proceed with Check Side to Side Play of MFC Feedback Lever.

2.5.3 <u>Inspect MFC/Feedback Cable Lever Rig Marks And VSV Actuation System Operation</u>

a. Using pressurizing unit P/N 1C3569, cycle the VSVs closed and open three times while checking alignment of rig marks at the full open position each time. Check entire VSV actuation system for evidence of wear, leaks, binding, bending of any VSV lever arms and/or actuation rings and for any interference of rig marks.

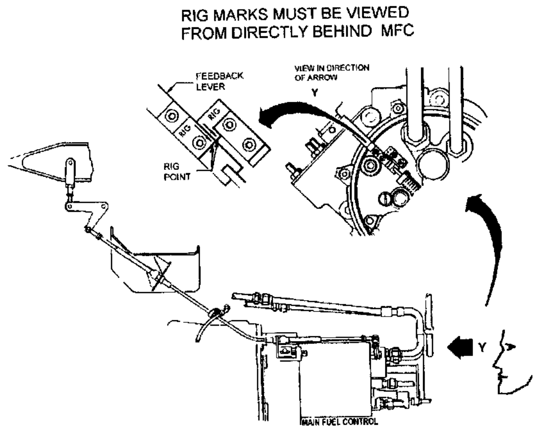


Figure 2-54. MFC/Feedback Cable Lever Rig Marks

b. If rig marks line up each time that VSVs are cycled to the full open position (with 200-250 psig maintained) and there is no evidence of wear, leaks, binding, and bending of any VSV lever arms and/or actuation rings, proceed to Check Side to Side Play of MFC Feedback Lever.

c. If alignment of rig marks are not the same each time the VSVs are cycled to the full open position (200-250 psig), thoroughly reinspect the VSV actuation/feedback system again for interference, wear, leaks, binding, and bending of any VSV lever arms and/or actuation rings. Cycle VSVs open/closed two additional times, if rig marks still do not line up at the same position each time and/or there is any VSV actuation component discrepancies, report to Work Center Supervisor and contact MGTI or FTSC for further evaluation.

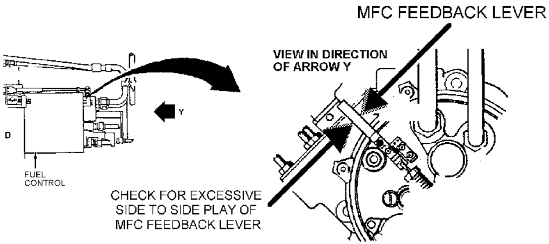


Figure 2-55. Checking Side to Side Play of MFC Feedback Lever

2.5.4 <u>Check Side to Side Play of MFC Feedback Lever</u>

a. With VSV at the full open position, use only thumb and forefinger to lightly check for side to side play of MFC feedback lever and any interference with rig plates.

(1) Acceptable: Side to side play does not allow MFC feedback lever or its rig plate to interfere with MFC housing or MFC stationary rig plate.

(2) Unacceptable: Side to side play that permits contact of lever or lever rig plate against MFC housing and MFC stationary rig plate. If MFC has unacceptable side to side play contact Work Center Supervisor and MGTI or FTSC for further evaluation.

2.5.5 <u>Return Equipment to Operational Readiness</u>

a. Disconnect pressurizing unit from the VSV actuator pressure tubes. Connect VSV actuator rod-end and head-end flex hoses to hard lines. Use care not to scratch polished sealing surfaces of fittings.

(1) Torque rod-end (1/2 inch) tube to 450-550 in-lb.

(2) Torque head-end (3/8 inch) tube to 270-300 in-lb.

NOTE

Ensure all VSV system discrepancies are corrected before continued engine operation unless otherwise directed by an MGTI or FTSC.

b. Remove all tools and materials from the module.

c. Close module doors.

2.6 <u>DETERGENT WASH GAS TURBINE; INTERNAL</u>

(Ref: MRC 2340, R-1 Detergent Wash Gas Turbine; Internal).

MRC check 2340, R-1, must be accomplished when turbine has been operated in excess of 48 operating hours, but not more than 100 hours, or if gas generator vibration level increases by more than 1 mil since last waterwash, or as soon as practical after activation of countermeasure washdown system.

NOTE

Ensure MRC checks 2340, R-2, Clean and Inspect waterwash module and GTRB waterwash "Y" Strainer is performed every eighth detergent wash and MRC check 2340, R-11, Inspect Gas Turbine Bellmouth Spray Pattern is performed every 750 +/- 125 operating hours, when directed as a result of excessive time (5.5 minutes) to empty water wash tank. Failure to accomplish these checks will diminish the effectiveness of gas turbine wash and can adversely affect engine performance.

The following is general overview for performing Detergent wash; Internal (Ref: MRC 2340, R-1). Always refer to and follow the MRC requirements when performing Internal waterwash.

NOTE

The preferred method of cooling is to allow normal air draft to cool engine. Approximately 2-3 hours is required to cool engine. Motoring on starter should only be done when absolutely necessary.

CAUTION

Do not waterwash when gas turbine is in operation or when T5.4 is above 200 degrees F. Damage to the gas turbine hot section parts may occur. If operational commitments require water washing immediately after operation, perform steps a-d. If T5.4 is below 200 degrees F. omit steps a-d.

a. Operate Gas Turbine at idle power for 8 minutes.

b. Shutdown gas turbine.

c. Ensure fuel system is aligned to gas turbine.

CAUTION

Failure to open fuel supply cutout valve may result in damage to either main fuel control or fuel pump.

d. Motor gas generator to cool gas turbine. Stay within starter duty cycle when motoring.

CAUTION

Always use 2 wrenches when loosening swivel coupling nuts, hoses, tubes, or fittings. Hold stationary part with one wrench while applying torque with second wrench.

e. Disconnect instrumentation lines PS3, PT2 and PT5.4. Disconnect the PS3 line at the union at compressor rear frame (CRF), the PT2 line from probe on compressor front frame at 12 o'clock position and the PT5.4 line at 10-11 o'clock position at PT5.4 probe. Install a small plastic bag over each open line.

f. Waterwash gas turbine IAW MRC card. Ensure when detergent wash is performed, soak for 10 minutes prior to rinse.

CAUTION

Always use 2 wrenches when tightening swivel coupling nuts, hoses, tubes, or fittings. Hold stationary part with on wrench while applying torque with second wrench.

g. Remove plastic bag from PS3 line and blow out line and reconnect line to the gas turbine. Remove plastic bag from PT2 and PT5.4 lines and reconnect lines. Torque lines fittings to 270-300 in-lbs.

h. Start Gas Turbine IAW EOSS for 5 minutes to dry, shutdown gas turbine if not needed for service.

NOTE

If engine performance or parameters are out of limits, shut gas turbine down and troubleshoot for possible water in instrumentation lines.

CAUTION

Ensure internal and external waterwash is completed at the proper periodicities Lack of proper waterwash will lead to poor engine performance, degradation of the VSV Actuator System and possible engine stall.

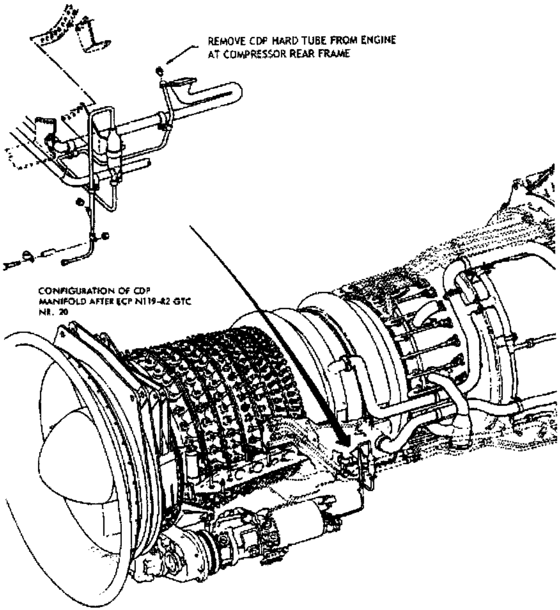


Figure 2-56. PS3 Connection

Figure 2-57. Proper Removal of PS3 Connection

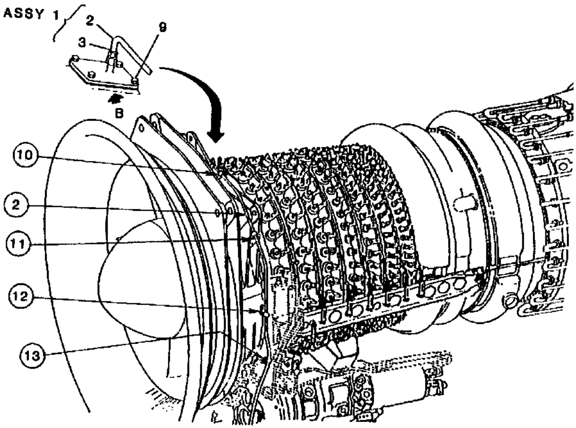


Figure 2-58. PT2 Connection

Figure 2-59. Proper Removal of PT2 Connection

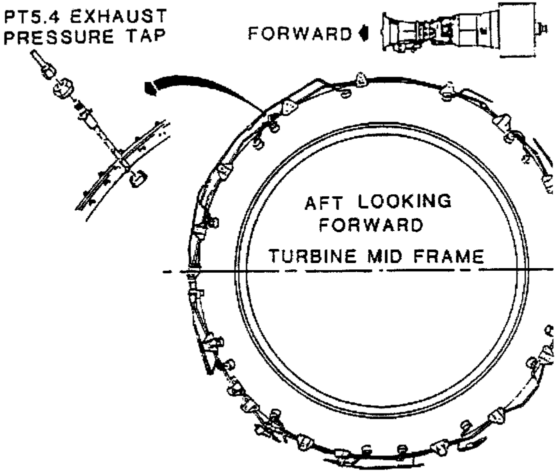


Figure 2-60. PT5.4 Connection

Figure 2-61. Proper Removal of PT5.4 Connection

Figure 2-62. Salt Buildup Due To Lack Of Proper Waterwash

Figure 2-63. Salt and Rust Buildup Due To Lack Of Proper Waterwash

2.7 DETERGENT WASH GAS TURBINE; EXTERNAL

(Ref: MRC 2340, R-27 Detergent Wash Gas Turbine; External).

MRC check 2340, R-27, must be accomplished every 750 +/-125 operating hours or every 3 months which ever occurs first, and in accordance with GROOM INSPECTION prior to a deployment of 90 days or longer.

The following is general overview for performing External waterwash (Ref: MRC 2340, R-27). Always refer to and follow the MRC requirements when performing External waterwash.

CAUTION

Do not waterwash when gas turbine is in operation of when T5.4 is above 200 degrees F. Damage to gas turbine hot section parts may occur.

NOTE

The preferred method of cooling is to allow normal air draft to cool engine. Approximately 2-3 hours is required to cool engine. Motoring on starter should only be done when absolutely necessary.

WARNING

Avoid use of concentrated MIL-C-85704 type II detergent near heat or open flame and provide adequate ventilation. Concentrated MIL-C-85704 type II detergent is flammable.

WARNING

Wear faceshield, rubber gloves, and apron when handling concentrated MIL-C-85704 type II detergent and while cleaning engine.

a. Mix 25% MIL-C-85704 type II detergent solution (51oz) in a 2-gallon pail of hot potable water.

Figure 2-64. Lack of Proper External Waterwash

Figure 2-65. Broken VSV caused by Compressor Stall (Stall contributed to lack of proper external waterwash)

b. Use detergent solution; brush and /or rags to scrub away salt deposits, grease, and grime from compressor case and VSV lever arms using up-down and side-side strokes. Work detergent onto bushing and spacer and under each VSV lever arm. Take care to clean the bottom of the compressor case as well as other hard-to-reach areas.

c. To clean areas inaccessible by brush or rag, pour detergent into spray bottle and douse areas with detergent solution.

d. Allow detergent lather to sit on compressor for 10 minutes to loosen dirt.

e. Rinse soapy solution from engine using hot potable water.

f. Allow engine to air dry or use cooling fan to dry engine more quickly.

g. Visually verify all salt and dirt deposits are cleaned from bushing and spacer around each VSV lever arm. Use flashlight to verify cleanliness of inaccessible places and, if needed, repeat step c.

h. Wipe up water from deck beneath engine and visually check drain ports forward or aft as water and debris exit.

i. Remove all tools and materials from the module.

CAUTION

Ensure external waterwash is completed at the proper periodicity. Lack of proper external waterwash will lead to degradation of the VSV Actuator System and possible engine stall.

2.8 INTAKE/UPTAKE INSPECTION

(Ref: MRC 2513, S-11 CG-47 and DD-963, MRC 2315, S-7 DDG, MRC 2315, and S-5 FFG, Inspect Propulsion Air Inlet System).

The following is general overview of Inspect Propulsion Air Inlet System (Ref: MRC 2513 S-11, S-7 and S-5). Always refer to and follow the MRC requirements when performing Inspection. MIP 2513 includes associated MRCs for the Combustion Air System ensure they are scheduled and completed.

MGTI inspections have revealed numerous ships are not performing proper intake maintenance. This is causing premature failures in the intakes and gas turbines. Ensure intakes are thoroughly inspected at every opportunity. Intake maintenance has changed from hours based to calendar based as recommended by MGTIs. If intakes are not thoroughly inspected and maintained IAW current guidelines inspectors will down the associated gas turbine until discrepancies are corrected.

It is vital that all discrepancies are corrected or documented onto the Ship's Force Work List or CSMP. Ensure that the chain of command is aware of discrepancies. Many ships have had to undergo extensive repairs to the inlet plenums during SRA. It is very important to ensure discrepancies are documented early prior to shipyard availabilities. The cost of adding work in the shipyard is high.

NOTE

If flaking, chipping or peeling paint is found during inspection, refer to MRC U-2, Preserve Corroded Areas of Combustion Air Intakes and Repair Paint.

NOTE

No amount of debris, sand, salt or foreign matter in the clean side and down stream of the filters or in the immediate area around the blow in door on the dirty side is permitted. The intakes are to be maintained and kept clean.

This inspection requires planning. It is very time consuming and may take an entire day or longer to accomplish. It requires inspection for corrosion, rust, failed or missing fasteners, weld failures, clogged drains, damaged ground straps, etc. In addition it requires a thorough cleaning of the entire Air Inlet System. Follow your applicable MRC to the letter. NSWCCD recently developed new intake coating policies and have updated applicable MRCs.

NOTE

A caution tag must be attached to throttle while nylon screen is installed. Tag should state nylon screen is attached. Anti-icing systems must be used if icing conditions are present.

When the inspection and cleaning is complete install a nylon screen over the engine bellmouth screen and operate gas turbine a minimum of 30 minutes. Secure engine and inspect nylon screen for any collected debris; ensure screen still meets serviceability limits. If no debris is collected on the screen, remove screen and store in a carton. If screen has collected debris, remove debris, reinspect nylon screen and repeat engine run; repeat until nylon screen collects no debris.

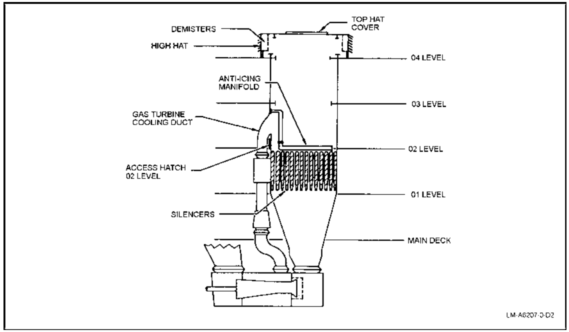


Figure 2-66. Ship's Intake Duct, DD-963/CG-47

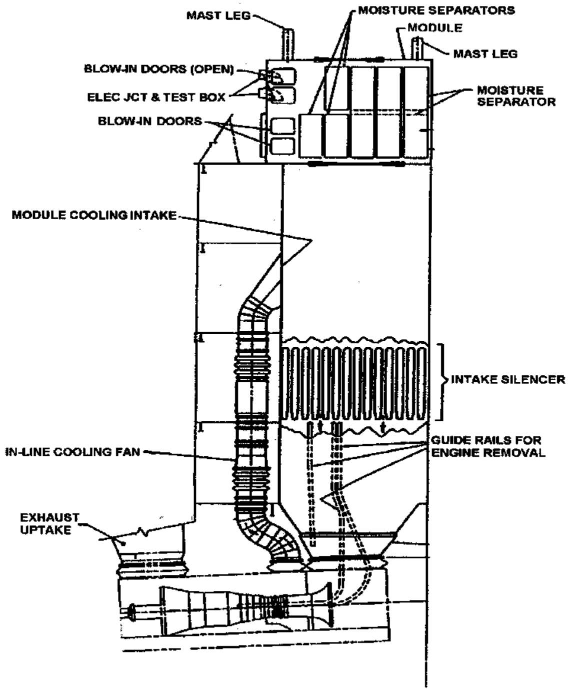


Figure 2-67. CG-47 Class Gas Turbine Module Engine Intake

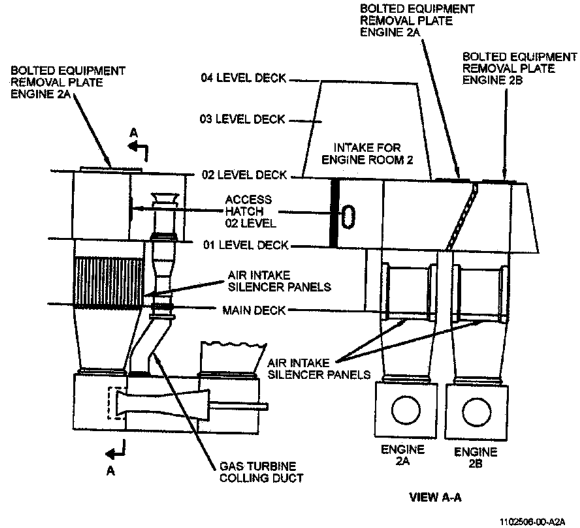


Figure 2-68. Ship's Intake Duct, DDG-51 Engine 2A/2B

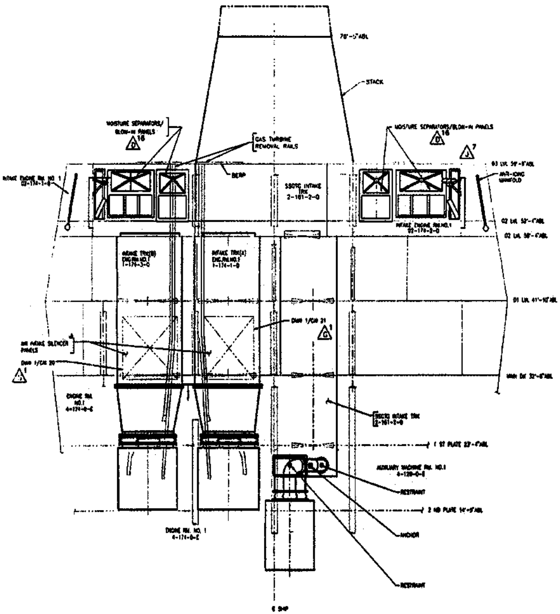


Figure 2-69. DDG-51 Engine 1A/1B Intake System

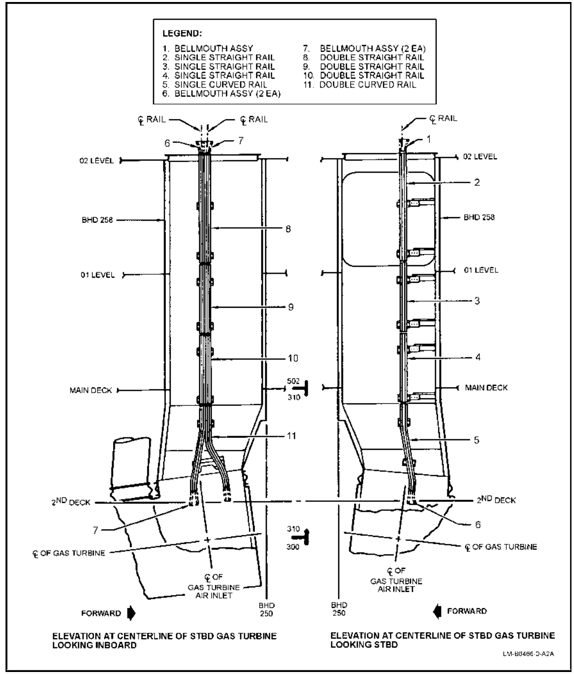


Figure 2-70. Ship's Intake Duct Rail System, Starboard Side, FFG-7

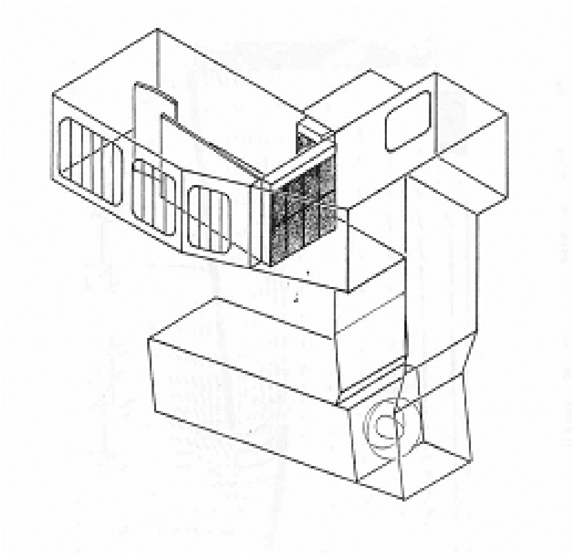


Figure 2-71. FFG-7 Intake System

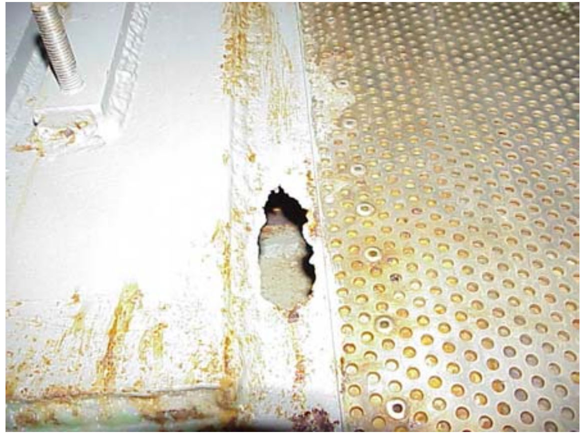


Figure 2-72. Rusted FFG Intake

Figure 2-73. Rusted FFG Intake

Figure 2-74. Dirty Inlet Plenum

Figure 2-75. Clean Inlet Plenum

2.9 SEAL GAS TURBINE AND MODULE

(Ref: MRC 2340, LU-1 Seal Gas Turbine and Module, Install Dehumidifier or Desiccant Bags).

MRC check 2340, LU-1, must be accomplished when turbine will be secured in excess of 90 days and when in an industrial environment and equipment will be subjected to chipping, sandblasting, or spray painting dust.

Several gas turbine ships have failed to properly lay-up their gas turbine engines during maintenance availabilities and have subsequently caused serious damage to the internal components of the engine.

NOTE

The Dehumidifier should be capable of removing a minimum of 40 pints in a 24-hour period and maintain humidity levels below 40%.

2.9.1 Seal Gas Turbine and Module

a. Gain access to and cover all openings to gas turbine and module including inlet plenum with at least 2 layers of fire retardant paper. Seal paper openings to provide a sealed unit of module interior free from air circulation.

b. Drape engine from deck to deck with fire retardant paper.

c. Shut module overhead doors and tag “Do Not Open”, if applicable.

2.9.2 Install Dehumidifier or Desiccant Bags

a. Install dehumidifier or desiccant bags; if desiccant bags are used, 150-16 unit bags are required.

b. Tie bags in pairs and hang over safety chains.

c. Install humidity indicator to inside of access door.

d. Exit module and shut enclosure doors. Remove tags and activate Fire Detection System.

e. If desiccant bags are used, inspect indicator weekly and replace desiccant bags when humidity indicator indicates 40%.

f. If dehumidifier is used, inspect indicator and drain holding tank every 24 hours. If humidity indicator reads 40% or more, check dehumidifier for proper operation and replace humidity indicator.

g. When required remove protective covering and sealing material installed during lay-up IAW 2340 SU-1.

2.10 MODULE INSPECTION

(Ref: MRC 2340, R-20 Inspect Gas Turbine, Base Enclosure Interior and Base Enclosure Exterior and S9234-AD-MMO-060/LM2500).

MRC check 2340, R-20, must be accomplished every 1500 +/-250 operating hours and in accordance with GROOM INSPECTION prior to a deployment of 90 days or longer.

The following is general overview for performing Gas Turbine and Base Enclosure Inspection (Ref: MRC 2340, R-20). Always refer to and follow the MRC requirements when performing Inspection.

2.10.1 Inspect Gas Turbine and Base Enclosure Interior

a. Inspect compressor front frame for cracks, loose bolts and nuts, and leakage.

b. Inspect transfer gearbox for security of mounting bolts, oil leakage, and cracks.

c. Inspect transfer gearbox support link spherical bearings for looseness. If looseness (play in bearing) exceeds 0.005” radial and 0.010” axially, rod end or link assembly should be replaced at next availability.

d. Inspect compressor casing for warping, cracks, security of attaching hardware, and leakage.

e. Inspect piping, electrical leads, and brackets for cracks, dents, chafing or rubbing.

f. Inspect all fuel, oil, and air piping for leakage and tightness of connections.

g. Inspect electrical connectors for tightness and electrical harness for damage.

h. Inspect compressor rear frame, attaching hardware, and brackets for cracks.

i. Inspect turbine midframe and attaching hardware for cracks.

j. Inspect power turbine for cracks and burned spots.

k. Inspect exhaust ducts for cracks and burns.

CAUTION

All corrective maintenance required for explosion-proof light fixtures is to be accomplished by qualified electrical work center personnel only.

l. Inspect module for burned out light bulbs; replace as necessary.

m. Inspect cooling fan vent damper.

n. Inspect module floor drains to ensure they are open.

NOTE

For ships with SHIPALT DD963-0240K installed, loop seals must be filled with water to keep oil mist from being drawn into module.

o. Pour approximately ½ gallon water into module drain, as applicable.

2.10.2 Inspect Base Enclosure Exterior

a. Inspect piping, electrical leads, and brackets for cracks, dents, chafing or rubbing.

b. Inspect fuel, oil and air piping for tightness of connections.

c. Inspect electrical connectors for tightness and electrical harness for damage.

d. Inspect transducers, gages, signal conditioners for security of mounts, tightness of tubing and electrical connections.

e. Inspect all instrumentation valves (9 per enclosure) and confirm that they are fully open and show no signs of leakage. If leakage occurs, replace the internal stem-mounted O-ring by removing stem-adapter assembly.

f. Inspect shaft shroud, located on enclosure rear panel, flexible cover for rips, separation of bonded joints, cracks and discoloration.

g. Inspect primary and secondary inlet and exhaust flexible joints, mounted on top of the enclosure, for rips, separation of bonded surfaces at corners and overlaps, surface cracks, discoloration and hard spots due to high temperatures.

h. Inspect enclosure structure exterior walls and panels for tears, broken or discolored windows, damaged or loose gaskets, and scratched, missing or chipped painted surfaces.

i. Inspect enclosure door seals and gaskets for missing or loose sections.

j. Check top hatch torsion bar for proper operation. Torsion bar should relieve weight of top hatch when unlatched in closed or open position.

k. Inspect LOSCA oil tank and frame for cracks and splits. Inspect instrumentation valves for leakage. If leakage occurs, replace the internal stem-mounted o-ring by removing stem-adapter assembly.

Table 2-12. Compressor Front Frame

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
1. All Surfaces (except forward mounts) for:			
a. Dents	Any number smooth contour dents 1/8-inch deep with a minimum separation of two inches.	Not repairable	Replace gas generator (GG).
b. Nicks, scratches and gouges	Contact local Fleet Technical Support Center (FTSC) for authorization for limited service.	Any number 1/32-inch deep, with a min separation of one inch after removal of high metal.	Remove high metal.
2. Threaded Pads, Ports and Bosses for:			
a. Damaged threads	Not serviceable	One full thread cumulative or continuous may be removed or Any amount thread damage.	Chase threads Install helical coil insert per MMO-060, para. 7.286.
b. Leaks around joint of press-fitted insert, if present	Not serviceable	Any amount, if insert not loose	Using etching tool (Vibra peen or equivalent), groove joint to a depth of 0.015 to 0.020 inch, and fill groove with heat/oil resistant silicon sealant.

Table 2-12. Compressor Front Frame - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
3. Mounts for:			
a. Cracks	Not serviceable	Not repairable	Replace GG.

Table 2-13. Transfer Gearbox

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
1. Transfer Gearbox and Air-Oil Separator for:			
a. Cracks	Not serviceable	Not repairable	Replace gearbox or replace air-oil separator.
b. Nicks, scores, scratches on non-machined surfaced	Any number, any length 1/32-inch deep.		
c. Leaking plugs or fittings	Not serviceable	Any amount	Retorque loose fittings or replace damaged O-ring.
d. Missing or broken safety-wire	Not serviceable	Any amount	Replace safety-wire.
NOTE Accessory Gearbox (AGB) mounting links may or may not be able to swivel depending on adjustment/loading of links. Links that may be moved by hand and swivel easily are serviceable unless actual play or slack is found (0.005” radial and 0.010” axial allowable play within the bearing).			
e. Mounting links’ (34, 49, 55) spherical bearings	0.005” radial and 0.010” axial allowable play.	Not repairable	Contact FTSC.
2. Studs for:			
a. Thread damage	Not serviceable	Total of 3/4 of one full thread may be removed.	Remove damage with fine file.
b. Looseness	Not serviceable	See Corrective Action column.	Torque stud one turn. If still not tight, replace gearbox.

Table 2-14. Compressor Stator Case and Variable Stator Vane Components

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
FRONT COMPRESSOR CASE			
NOTE Hot spots and bulges indicate internal damage in that area. Assess condition by borescope inspection.			
1. Casing for:			
a. Cracks (except in flange boltholes)	Not serviceable	Not repairable	Replace GG.
b. Cracks emanating from horizontal and vertical flange boltholes	Max of three per flange per casing half.	Not repairable	Replace GG.
c. Grooves worn by actuation ring spacers	Any number 0.015-inch deep after removal of high metal.	Not repairable	Replace GG.
d. Hot spots (discoloration)	Serviceable if metal is not granular and cracks are not present.	Not repairable	Replace GG.
e. Bulges	Not serviceable when associated with heat discoloration.	Not repairable	Replace GG if bulges and heat discoloration both are noted or serviceable limits are exceeded.
f. Nicks, gouges and scratches in:			
(1) Casing skin and manifolds	One per each four square inch area 0.015-inch deep, one inch long after removal of high metal, provided no sharp areas appear.	Not repairable	Replace GG if sharp areas are noted or serviceable limits are exceeded.
(2) Flanges and ribs	Any number 1/16-inch deep, 0.5-inch long with a min. separation of two inches after removal of high metal.	Not repairable	Replace GG.
REAR COMPRESSOR CASE			
NOTE Hot spots and bulges indicate internal damage in that area. Assess condition by borescope inspection.			

Table 2-14. Compressor Stator Case and Variable Stator Vane Components - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
1. Casing for:			
a. Cracks			
(1) Casing skin and manifold	Not serviceable	Not repairable	Replace GG.
(2) Casing ribs	One crack 1/4-inch long, and two weld cracks 1/16-inch long per rib in weld or heat affected zone that will not allow air leakage.	Not repairable	Replace GG.
(3) Cracks emanating from horizontal and vertical flange boltholes	Max of three per vertical flange and one per horizontal flange per casing half.	Not repairable	Replace GG.
b. Hot spots (discoloration)	Serviceable if metal is not granular and cracks are not present.	Not repairable	Replace GG if metal is granular or cracked or serviceable limits are exceeded.
c. Bulges	Not serviceable when associated with heat discoloration.	Not repairable	Replace GG if bulges and heat discoloration both are noted or serviceable limits are exceeded.
d. Nicks, dents, scratches and gouges in:			
e. Casing skin	Any number 0.015-inch deep, 1/2-inch long after removal of high metal.	Not repairable	Replace GG.
f. Flanges and ribs	Any number 1/32-inch deep, 1/2-inch long with min. separation of two inches after removal of high metal.	Not repairable	Replace GG.

Table 2-15. Propulsion Gas Turbine Module Tubes, Hoses, Tube/Hose Fittings, Electrical Cable Assemblies, and Electrical Connectors

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
TUBE ASSEMBLIES (ALL ASSEMBLIES UNLESS OTHERWISE SPECIFIED)			
1. Tubing for:			
a. Cracks, splits	Not serviceable	Not repairable	Replace assembly
b. Wrinkles, kinks in bend ID	Two percent of tube OD	Not repairable	Replace assembly
c. Dents, flat areas	Any amount of deviation from contour within 20 percent of original tube OD.	Not repairable	Replace assembly
d. Nicks, scores	Limited Service-Any amount to 0.005 inch deep.	Any amount to 0.010 inch deep	Blend to remove damage but not beyond depth of damage. Contour must be smooth and polished.
e. Chafing	Not serviceable	Any amount	Install chafing shield per MMO-060, para. 7.234.
2. Fittings and Connectors for:			
a. Leakage	Not serviceable	Light polishing of entire sealing (mating) surfaces to remove scratches is allowed.	Polish sealing surface and retorque or replace tube assembly. Refer to MMO-050, para. 7.4.5.
b. Looseness	Not serviceable	Any amount	Retorque. Refer to para. MMO-050, 7.4.5.
HOSE ASSEMBLIES (ALL ASSEMBLIES UNLESS OTHERWISE SPECIFIED)			
NOTE See MMO-060, para. 7.233.1 for method of identification of asbestos fire sleeves.			
1. Hose for:			

Table 2-15. Propulsion Gas Turbine Module Tubes, Hoses, Tube/Hose Fittings, Electrical Cable Assemblies, and Electrical Connectors - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
a. Broken braid wires	Three wires per plait (a band of interwoven wires) and no more than six broken wires per assembly.	15 wires in one 1/2-inch square area per hose assy.	Repair per MMO-060, para. 7.233.3.
b. Crimps	Any amount of deviation from contour within 10 percent of original hose OD.	Not repairable	Replace hose assembly. (If crimp does not affect engine operation, unrestricted operation of the gas turbine is authorized until ship's schedule will allow accomplishment of corrective action)
c. Chafing	Not serviceable	Any amount	Install chafing shield per MMO-060, para. 7.234.
2. Fire Sleeves for:			
a. Cuts and chafing	Any amount, repair/replace per corrective action column at earliest opportunity.	Any amount	Coat damaged area with RTV-106 Silicone Sealant. (If ship's operating schedule prevents this corrective action, an alternative action is to cut remaining fire sleeve away between clamps at both ends of hose ensuring no loose fire sleeve material. Hose and clamps at each end of hose do not have to be removed. Inspect hose assembly in accordance with Table 2-15.)

Table 2-15. Propulsion Gas Turbine Module Tubes, Hoses, Tube/Hose Fittings, Electrical Cable Assemblies, and Electrical Connectors - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
b. Tears	Any amount, repair/replace per corrective action column at earliest opportunity.	Not repairable	Replace sleeve per MMO-060, para. 7.233.4. (If ship's operating schedule prevents this corrective action, an alternative action is to cut remaining fire sleeve away between clamps at both ends of hose ensuring no loose fire sleeve material. Hose and clamps at each end of hose do not have to be removed. Inspect hose assembly in accordance with Table 2-15.)
3. Fittings and Connectors for:			
a. Damage	See TUBE ASSEMBLIES, this table		
BLEED AIR MANIFOLD AND DUCTING (BASE ENCLOSURE ASSEMBLY)			
1. Metal Hose Manifold for:			
a. Broken braid wires	In any radial plane all wires of one plait (a band of interwoven wires) per 45° segment may be broken and three broken wires per plait for consecutive plaits provided no more than 100 broken wires per manifold assembly.	Any amount	Repair per MMO-060, para. 7.233.3.
b. Cracks, splits, crimps	Not serviceable	Not repairable	Replace assembly
c. Dents/flat areas	Any amount, except in hose sections, provided deviation from contour does not exceed 25 percent of original tube OD.	Not repairable	Replace assembly

Table 2-15. Propulsion Gas Turbine Module Tubes, Hoses, Tube/Hose Fittings, Electrical Cable Assemblies, and Electrical Connectors - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
d. Nicks, scratches	Any amount, repair/replace per corrective action column at earliest opportunity.	Any amount 0.01-inch deep except on metal hose.	Blend to remove damage but not beyond bottom of damage. Contour of blend must be smooth.
e. Chafing	Not serviceable	Any amount	Install chafing shield per MMO-060, para. 7.234.
2. V-Band Clamp for:			
a. Cracks	Not serviceable	Not repairable	Replace clamp
b. Looseness	Not serviceable	Any amount	Torque to 80-90 inlb
c. Distortion	Must align and assemble to mating flanges		
d. Incorrect installations	Not serviceable	Any amount. Piping flanges must be diametrically aligned and clamps symmetrically engaged with GG and manifold flanges	Loosen clamp, realign manifold and re-install clamp
3. Assembly Fasteners for:			
a. Looseness	Not serviceable	Any amount	Torque to 70-110 inlb
ELECTRICAL CABLE ASSEMBLIES (ALL ASSEMBLIES UNLESS OTHERWISE SPECIFIED)			
1. Cable for:			
a. Broken braid	50 percent of exterior braid wires may be broken provided circuit continuity is maintained.	Not repairable	Replace assembly
b. Kinks/crimps	Any amount provided circuit continuity is maintained. Insulation resistance pin to pin and pin to case shall be 1 megohm minimum.	Not repairable	Replace assembly

Table 2-15. Propulsion Gas Turbine Module Tubes, Hoses, Tube/Hose Fittings, Electrical Cable Assemblies, and Electrical Connectors - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
c. Security/installation	Supported at maximum of 12 inch intervals. No relative motion between cable and contacted hardware.	Any amount	Re-clamp cable
d. Chafing	Not serviceable	Any amount	Install chafing shield per MMO-060, para. 7.234. For ignitor high tension lead chafing, see MMO-050, para. 7.78.1.
2. Connectors for:			
a. Pin, insert and shell damage	See ELECTRICAL CONNECTORS, this table		
b. Back shell potting separation, tears/cracks	Not serviceable	Not repairable	Replace assembly
c. Loose nut	Not serviceable	Any amount	Torque hand-tight
d. Seal	Each connector joint must have seal installed	Any number	Replace seal if damaged or missing
e. Braid/connector separation	50 percent of wires must be secure and circuit continuity maintained	Not repairable	Replace assembly
ELECTRICAL CONNECTORS			
1. Pins for:			
a. Distortion	Must assemble to mating connector	Any amount correctable by straightening pins	Straighten pins or replace assembly
b. Fracture	Not serviceable	Not repairable	Replace assembly
c. Corrosion	No visible corrosion permitted	Not repairable	Replace assembly
2. Insert for:			

Table 2-15. Propulsion Gas Turbine Module Tubes, Hoses, Tube/Hose Fittings, Electrical Cable Assemblies, and Electrical Connectors - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
a. Cracks	Any amount provided circuit continuity is maintained. Insulation resistance pin to pin and pin to case shall be one megohm minimum	Not repairable	Replace assembly
3. Shell for:			
a. Distortion	Must assemble to mating connector and seal	Not repairable	Replace assembly
b. Cracks	Not serviceable	Not repairable	Replace assembly

Table 2-16. Turbine Mid-Frame

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
1. Casing for:			
a. Cracks	Any number 1/8-inch long that will not permit air or fluid leakage, one inch min separation between cracks.	Not repairable	Replace GG.
b. Nicks, dents, gouges, etc.	Any number 1/16-inch deep, one inch long, provided metal is not thinned to less than 75 percent of original thickness.	Not repairable	Replace GG.
c. Distortion	Acceptable if proper assembly can be made.	Not repairable	Replace GG.
d. Hot spots (discoloration)	Serviceable if metal is not crazed and cracks are not present. Perform a borescope inspection of immediate area if hot spots are noted.	Not repairable	Replace GG.

Table 2-16. Turbine Mid-Frame - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
e. Bulges	Not serviceable when associated with heat discoloration. Perform a borescope inspection of immediate area if bulges are noted.	Not repairable	Replace GG.
2. Service Tube Pads and Instrumentation Bosses for:			
a. Nicks, gouges etc., on flange mating surface	1/32-inch deep extending across not more than 1/2-the sealing surface after removal of high metal.	Not repairable	Replace GG.
3. All Threaded Ports and Bosses for:			
a. Damaged threads	Not serviceable	One complete thread may be removed or Any amount of damage.	Chase threads Install helical coil wire insert per MMO-060, para. 7.286.
4. Tubes for:			
a. Cracks	Not serviceable	Not repairable	Replace GG.
b. Nicks, scores and scratches	0.010 inch deep after removal of high metal.	Not repairable	Replace GG.
c. Dents	Any number smooth contour dents 1/8-inch deep.	Not repairable	Replace GG.
5. Liner for cracks	Any number		
6. Liner for buckling or distortion	Any amount 1/4-inch from original contour.	Not repairable	Replace GG.
TURBINE MID-FRAME LINER			
1. TMF Liner			
a. Chafed	Serviceable if chafing does not reach the deflector.		IMA grind TMF liner in accordance with Gas Turbine Bulletin (GTB) No.24.

Table 2-16. Turbine Mid-Frame - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
2. TMF Liner Deflector			
a. Chafed	Not serviceable		Condition requires I-Level repair or GG replacement coordinate with local FTSC.
THERMOCOUPLE AND TOTAL PRESSURE PROBES			
1. $T_{5.4}$ $P_{t5.4}$ Probes			
a. Cuts/chafing	Cuts and chafing serviceable up to 0.025 inch deep. Record depth on clocking map and file in the brown envelope in the back of the engine logbook.		IMA install anti-rotation pins in accordance with GTB No. 24.

Table 2-17. Power Turbine Stator Case

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
CASE			
1. Front Flanges Mating Face for:			
a. Nicks, scores, scratches	Any amount after re-moval of high metal.		
2. Casing Body for:			
a. Cracks	Not serviceable	Not repairable	Replace PT.
b. Dents	Any number, 1/8-inch deep.	Not repairable	Replace PT.

Table 2-18. Power Turbine Nozzles

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
1. Outer and Inner Platforms for:			
a. Cracks not in fillets	Any number 3/16-inch long.	Not repairable	Replace damaged nozzle segment.
b. Nicks, dents and scratches	Any number 1/16-inch deep.	Not repairable	Replace damaged nozzle segment.
2. Airfoil Leading Edge for:			
a. Cracks	Not serviceable	Not repairable	Replace damaged nozzle segment.
b. Nicks, dents and scratches	1/16-inch deep provided no torn metal.	Not repairable	Replace damaged nozzle segment.
c. Corrosion, erosion	Any amount		
3. Airfoil Concave and Convex Surfaces Other than Edges for:			
a. Cracks	Any number, 1/8-inch long.	Not repairable	Replace damaged nozzle segment.

Table 2-18. Power Turbine Nozzles - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
b. Nicks, dents and scratches	Any number, 1/32-inch deep provided no torn metal.	Not repairable	Replace damaged nozzle segment.
c. Corrosion, erosion	Any amount		

Table 2-19. Power Turbine Rotor Blades

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
STAGES 1 AND 6			
1. All Areas for:			
a. Cracks	Not repairable	Not repairable	Replace PT.
2. Leading and Trailing Edges for:			
a. Nicks	None within 1/2-inch of inner platform or within 1/4-inch of shroud. Balance of blade any number 1/32-inch on opposite side.	Not repairable	Replace Stage 1 blades. Stages 3-6 may be blended as determined by FTSC
b. Dents	Any number with no protrusions on opposite side and five per blade with protrusion not to exceed 1/32-inch on opposite side.	Not repairable	Replace Stage 1 blades. Stages 3-6 may be blended as determined by FTSC
c. Corrosion, erosion	Any amount		
3. Concave and Convex Surfaces for:			
a. Nicks	Any number 1/32-inch deep; min separation 1/4-inch.	Not repairable	Replace Stage 1 blades. Stages 3-6 may be blended as determined by FTSC

Table 2-19. Power Turbine Rotor Blades - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
b. Dents	Stage 1 – any number with no protrusions on opposite side. Stage 2 through 6 any number with no protrusions on opposite side and five per blade with protrusion not to exceed 1/32-inch on opposite side.	Not repairable	Replace Stage 1 blades. Stages 3-6 may be blended as determined by FTSC
c. Corrosion, erosion	Any amount		
4. Stage 6 Shroud Circumferential Mate Faces for: (See Figure 2-76)			
a. Wear (irregular or smooth)	Any amount provided there is no associated interlock wear.		Repair by IMA*
5. Stage 6 Shroud Interlocks for: (See Figure 2-76)			
a. Shingled or unlatched interlocks	Not serviceable. If interlocks can be unshingled or relatched with axial pre-load present, then blades are serviceable.		Repair by IMA*
b. Wear (axial pre-load present)	0.020 inch offset	0.125 inch offset	Repair by IMA*
c. Worn surface having step or out of square with top of interlock	0.003 inch offset	Any amount providing max. limit is not exceeded after repair.	Repair by IMA*
* See GTB No. 12 for inspection of stage 6 PT blades and Gas Turbine Change (GTC) No. 65 for installation of stage 6 wear inserts.			

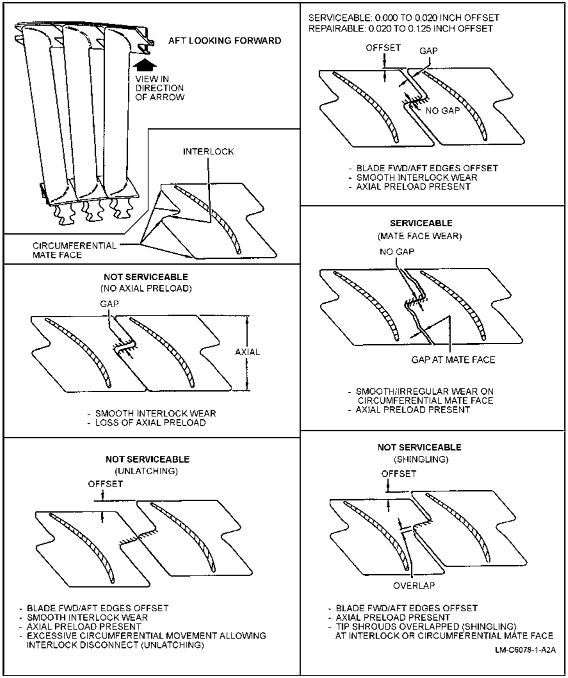


Figure 2-76. Shroud Circumferential Mate Face and Interlock Wear

Table 2-20. Exhaust Duct Assembly

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
1. Assembly for:			
a. Exhaust Collector support lug weld cracks	Total length of crack around lug not to exceed four inches.	Any amount	Weld repair per MMO-060, para. 7.298.
b. Exhaust Collector side stiffener (horizontal channel between support lugs) weld cracks	Not acceptable within four inches of support lugs.	Any amount	Weld repair per MMO-060, para. 7.298 as far along crack as can be reached.
c. Exhaust Collector vent/drain hole weld cracks	Cracks in straight line, between holes, acceptable (see MMO-060, Figure 7-646, detail E).	Any amount	Weld repair per MMO-060, para. 7.298.
d. Outer exhaust collector cracks	Below shaft, any number less than two inches long but no wider than 1/64-inch. Above shaft, any number less than six inches long but no wider than 1/32-inch. In top flange any amount.	Any amount	Weld repair per MMO-060, para. 7.298.
e. Loose threaded fasteners	Not serviceable	Any amount	Retorque fastener.
f. Missing or loose rivets	One per anchor nut plate.	Any amount	Replace rivet.
2. Insulation Blankets (including TRF) for:			
a. Tears	Any number 10 inches long, Minimum distance between tears shall not be less than eight inches.	Not repairable	Replace blanket at next availability

Table 2-20. Exhaust Duct Assembly - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
b. Loose fasteners	Not serviceable	Any number	Retighten or replace safety-wire.
c. Reflective material or insulation material burnt away or missing	Any amount missing is serviceable as long as insulation blanket has no tears as per 2a.	Not repairable	During next availability inspect for cracks in exhaust duct/TRF area if signs of burning/soot carbon deposits are present, contact FTSC. If cracks are found Contact FTSC, see crack criteria in this table for serviceable limits. Replace blanket at next opportunity. Unrestricted engine operation allowed until opportunity to replace.

Table 2-21. Inlet Duct And Centerbody

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
INLET DUCT			
1. Assembly (Unless otherwise specified) for:			
a. Cracks	Not serviceable	Any amount	Weld repair per MMO-060, para. 7.241.1, step c.
b. Nicks, scores (except on water inlet fitting)	Any number, any length 1/32-inch deep after removal of high metal.		
c. Dents	Any number, 1/4-inch deep, 0.1 inch min bend radius except on mating surfaces.	Any amount	Repair per MMO-060, para. 7.241.1, step b.
d. Missing/loose paint	Any amount provided no parent metal exposed.	Any amount	(1) When discovered remove loose/non-adhering paint per MMO-060, para. 7.241.2, step b. Full and unrestricted operation is allowed until next minor maintenance availability.

Table 2-21. Inlet Duct And Centerbody - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
			(2) Next minor maintenance availability touch up per MMO-060, para. 7.292. Full and unrestricted operation is allowed until next major maintenance availability. (3) Next major maintenance availability repair per MMO-060, para. 7.241.2.
e. Plugged waterwash discharge holes	Not serviceable	Any amount	Remove contamination using a small wire or No. 57 (0.043 inch) drill bit.
f. Dirty airflow path surfaces	Serviceable. Wipe clean if inlet screen has been removed for other maintenance actions.		
g. Loose installation fasteners	Not serviceable	Any amount	Retorque fasteners
h. Leakage at water inlet connection	Not serviceable	Any amount	Retorque fasteners
CENTERBODY			
1. Assembly for:			
a. Cracks	Not serviceable	Not repairable	Replace centerbody.
b. Nicks, scratches	Any number, any length 1/32-inch deep, 1/32-inch wide with min separation of one inch.	Any number, 1/16-inch deep, 1/16-inch wide and 1/2-inch long, provided none extend into boltholes.	Blend to remove damage but not beyond depth of damage. Contour of blend must be smooth.
c. Missing/loose paint:	Any amount provided no parent metal exposed.	Any amount	(1) When discovered remove loose/non-adhering paint per MMO-060, para.7.241.2, step b.(1). Full and unrestricted operation is allowed until next minor maintenance availability.

Table 2-21. Inlet Duct And Centerbody - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
			(2) Next minor maintenance availability touch up per MMO-060, para. 7.292. Full and unrestricted operation is allowed until next major maintenance availability. (3) Next major maintenance availability repair per MMO-060, para.7.241.2.
d. Dirty airflow path surface	Serviceable.		Wipe clean if inlet screen has been removed for other maintenance actions.
e. Loose installation fasteners	Not serviceable	Any amount	Retorque fasteners and safety-wire. Apply adhesive, RTV-102, white or RTV-106, red, as an alternate (GE Co., Silicone Products Dept., Waterford, NY) to cover safety-wire.
f. Dents	Any number, 1/4-inch deep, 0.1 inch min bend radius.	Any amount	Repair per MMO-060, para. 7.241.1, step b.
COMPOSITE CENTERBODY (PN L31411P01)			
1. Inspect Assembly for:			
a. Cracks	Not serviceable	Not repairable	Replace centerbody
b. Dirty airflow path surface	Serviceable		Wipe clean, if inlet screen has been removed for other maintenance action

WARNING

Vapor from uncured sealant is flammable and toxic to skin, eyes, and respiratory tract. Avoid contact with skin and eyes. Use in a well ventilated area.

Table 2-21. Inlet Duct And Centerbody - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
c. Loose bolts	Not serviceable	Any amount	Retighten and safety-wire. Apply adhesive RTV-103

NOTE

The recommended RTV listed for use with the composite centerbody (RTV-103) is black in color and is required only if esthetics is desired (black RTV with a black centerbody). Either RTV-102 (white) or RTV-106 (red) may be used if RTV-103 is not available.

Table 2-22. Pneumatic Starter

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
1. Starter Stator Vanes:			
a. Holes in stator vane	One hole per stator vane or a total of five holes or less per stator. No limit on hole size provided it does not remove more than 1/8-inch of trailing edge.	Not repairable	Replace stator
b. Stator vane trailing edge erosion	No more than 1/8-inch of trailing edge removed.	Not repairable	Replace stator
2. Starter turbine:			
a. Notches in turbine blade	Not serviceable	Notches with radii 3/64-inch or greater and 1/16-inch or less deep.	Blend
3. Threaded inserts for starter housing:			
a. Looseness, damage or missing	Not serviceable	Any amount	Replace insert per MMO-060, para. 7.286.5.
*Intermediate Maintenance Activity - Special Shipboard Maintenance Manual, S9234-BF-MMI-010/LM2500			

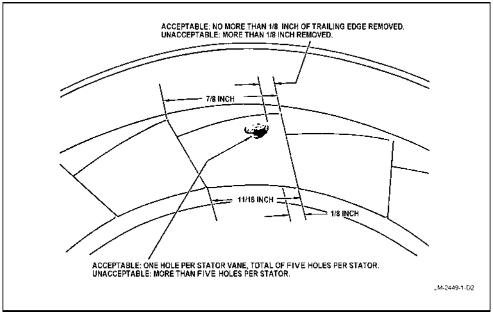


Figure 2-77. Pneumatic Starter Stator (Acceptable Vane Erosion)

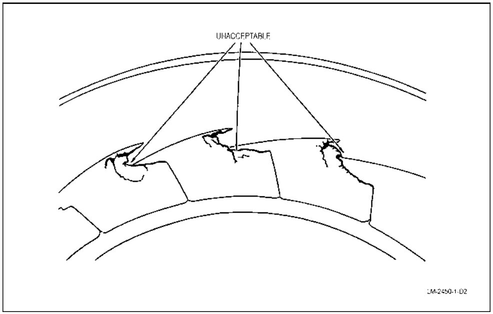


Figure 2-78. Pneumatic Starter Stator (Unacceptable Vane Erosion)

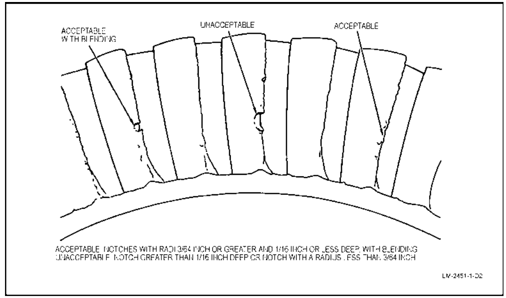


Figure 2-79. Pneumatic Starter Turbine Blades

Table 2-23. Base Enclosure Assembly - External Items

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
SHAFT SHROUD (Mounted on Enclosure Rear Panel)			
1. Metal parts for:			
a. Parent metal cracks	Contact Fleet Technical Support Center (FTSC) for authorization for limited service.	Any number, any length	Weld repair.
b. Weld cracks	Contact FTSC for authorization for limited service.	Any number, any length	Weld repair.
c. Flange distortion	1/8-inch per foot	(1) 1/2-inch per foot.	Mechanically straighten using hand tools.
		(2) Greater than 1/2-inch per foot.	
d. Nicks, scratches and gouges	Any number, any length, any depth		
e. Discoloration	Any amount		

Table 2-23. Base Enclosure Assembly - External Items - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
2. Flexible Member for:			
a. Rips	Contact FTSC for authorization for limited service.	Any amount, 12 inches long	Repair per MMO-060, para. 7.269.
b. Separation of bonded joints (overlap)	Any number local separations provided joint remains bonded.	Any amount	Clean and re-cement joint using cement specified in MMO-060, para. 7.269, step c.
c. Surface cracks, discoloration	Any amount		
EXPANSION JOINTS - PRIMARY AND SECONDARY INLET, AND EXHAUST (Mounted on Top of Enclosure)			
1. Metal Parts (Flanged, Baffles) for:			
a. Parent metal cracks	Contact FTSC for authorization for limited service.		
b. Weld cracks	Contact FTSC for authorization for limited service.		
c. Dents	Any number within 1/8-inch per foot flatness.	Any number within one inch per foot flatness.	Mechanically straighten, using hand tools.
d. Nicks, scratches and gouges	Any number, any length, any depth		
e. Corrosion (discoloration)	Any amount		
2. Flexible Members (outside surface) for:			
a. Rips	Contact FTSC for authorization for limited service.	Any amount	Repair per MMO-060, para. 7.270.
WARNING Exhaust gases may enter ship's machinery space.			
b. Separation of bonded joints (corners and overlaps)	Any number local separations four inches long with a minimum spacing of two inches.	Any amount	Clean and re-cement joint using cement specified in MMO-060, para. 7.270.

Table 2-23. Base Enclosure Assembly - External Items - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
c. Surface cracks, discoloration	Any amount		
3. Acoustical Coating (Secondary Inlet Joint Only) for:			
a. Damage	Contact FTSC for authorization for limited service.	Any amount	Repair per MMO-060, para. 7.270, step h.
4. Acoustical Coating (Primary Inlet Joint Only) for:			
a. Surface cracks and scratches	Any amount		
b. Holes, missing coating	Contact FTSC for authorization for limited service.		
5. Gaskets for:			
a. Deterioration	Contact FTSC for authorization for limited service.	Not repairable	Replace gasket or seal leakage.
WARNING Exhaust gases may enter ship's machinery space.			
6. Studs for:			
a. Thread damage	Contact FTSC for authorization for limited service.	Two threads may be removed.	Remove damage with fine file or replace stud.
ENCLOSURE STRUCTURE			
1. Exterior Walls and Panels for:			
a. Tears	Any number, two inches long		
2. Interior Walls for:			
a. Tears	Any number, two inches long		

Table 2-23. Base Enclosure Assembly - External Items - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
b. Loose CRES perforated interior sheets or corrosion within module walls	One or more separated plug-welds	Any number	As per MMO-060, para. 7.271.
c. Module door corrosion, loose interior sheathing	One or more separated plug-welds	Any number	As per MMO-060, para. 7.271.
3. Windows for:			
a. Broken or leaking	Contact FTSC for authorization for limited service.	Any number	Replace window per MMO-060, para. 7.273.
b. Permanently discolored	Contact FTSC for authorization for limited service.	Any amount	Replace window per MMO-060, para. 7.273.
c. Moisture collected behind windows	Contact FTSC for authorization for limited service.	Any amount	Replace gaskets per MMO-060, para. 7.273.
d. Loose window gaskets	Contact FTSC for authorization for limited service.	Any amount	Replace gaskets per MMO-060, para. 7.273.
4. Module top hatch			
a. Torsion bar for operation by opening hatch to 90°, then slowly close while observing end of torsion bar. Bar should rotate 90°.	None	None	Replace torsion bar per MMO-060, para. 7.298.
5. Seals and Gaskets for:			
a. Deterioration or seal leakage	Not serviceable	Any amount	Replace gasket section or entire gasket as applicable.
6. Painted Surface for:			
a. Scratch marks, missing or chipped paint beneath fastener heads	Serviceable. Touch-up is optional.		Touch-up paint on exterior surfaces use epoxy paint per MIL-P-24441 Formula F-151 (haze gray).

Table 2-23. Base Enclosure Assembly - External Items - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
NOTE For all purpose interior/exterior primer, use MIL-P-24441/1 Formula F-150 (green) Class “C” chromate, Class “N” non chromate. Exterior or interior top coat paint to be used everywhere except on module floor or box beams is MIL-P-24441, Formula F- 151 (haze gray). For module floor and box beams, use MIL-C-22750 epoxy polyamide finish PN 101-10A (clear) with 10l-250B catalyst with extra fine aluminum paste TT-P-320, Type II, Class “C” (obtained separately) and mixed locally into the above epoxy polyamide finish. Or use epoxy mastic PN 113-145 (aluminum) system which contains the catalyst and mixed-in fine aluminum paste. When applying, follow manufacturers instructions. Both paint systems are available from Coronado Paint Co., 308 Old County Rd., Edgewater, FL 32132-0308. Commercial (904) 428-6461.			
SHOCK MOUNTS			
1. Tie Bolt for:			
a. Cracks, pitting and damage	Contact FTSC for authorization for limited service.	Not repairable	Replace bolt and torque per MMO-060, para. 7.131.
b. Self locking quality (inspect per MMO-060, para. 7-264)	Tie bolt/nut is not loose using hand pressure.	Not repairable	Replace bolt and nut and torque per MMO-060, para. 7.131.
2. Rubber Boots for:			
a. Cuts, holes, or other damage	Contact FTSC for authorization for limited service.	Any amount	Repair per MMO-060, para. 7.275.
3. Resilient Mount for:			
a. Deterioration and cracks	Two surface cracks 0.030 inch deep, 1.00 inch long, per 90° segment.	Not repairable	Replace resilient mount per para. 7.131.
b. Swelling due to oil effects	Contact FTSC for authorization for limited service.	Not repairable	Replace resilient mount per MMO-060, para. 7.131.
c. Separation of rubber to metal bond	Not serviceable	Not repairable	Replace resilient mount per MMO-060, para. 7.131.
d. Other visible damage	Contact FTSC for authorization for limited service.	Not repairable	Replace resilient mount per MMO-060, para. 7.131.
4. Housing and Resilient Mount Flange for:			
a. Cracks	Contact FTSC for authorization for limited service.	Not repairable	Contact FTSC for part disposition.

Table 2-23. Base Enclosure Assembly - External Items - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
b. Corrosion, nicks scratches, and defective paint	Contact FTSC for authorization for limited service.	Any amount	Remove corrosion and high metal; touch-up paint.
BOLTS AND NUTS			
1. HSCS to Ship's Reduction Gear Input Shaft Bolts for:			
a. Cracks, (inspect per MMO-060, para. 7.263)	Not serviceable	Not repairable	Replace bolt.
b. Damaged threads	Not serviceable	Not repairable	Replace bolt.
2. Other Bolts for:			
a. Cracks	Not serviceable	Not repairable	Replace bolt.
b. Pitting	Contact FTSC for authorization for limited service.	Not repairable	Replace bolt.
c. Damaged threads	Not serviceable	Not repairable	Replace bolt.
d. Discoloration	Serviceable		
e. Self locking quality (A locking insert not incorporated on all bolts)	Serviceable provided no loss in self locking quality.	Not repairable	Replace bolt.
3. Nuts for:			
a. Cracks	Not serviceable	Not repairable	Replace nut.
b. Damaged threads	Not serviceable	Not repairable	Replace nut.
c. Discoloration	Serviceable		
d. Self locking quality (Locking feature not incorporated on all nuts)	Serviceable provided minimum breakaway torque is met, refer to Table 7-6, MMO-050.	Not repairable	Replace nut.
SWITCHES - LIGHT, FIRE ALARM, AND FIRE EXTINGUISHER INHIBIT (Mounted on Side of Enclosure). See MMO-060, Figure 7-213			

Table 2-23. Base Enclosure Assembly - External Items - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
1. Housing for:			
a. Cracks	Contact FTSC for authorization for limited service.	Not repairable	Replace switch.
b. Dents	Any amount within 3/16-inch of original contour.	Not repairable	Replace switch.
2. Cover for:			
a. Cracks, dents	Contact FTSC for authorization for limited service.	Not repairable	Replace assembly.
b. Handle fastener looseness	Not serviceable	Any amount	Torque to 10-12 inlb.
c. Fastener looseness	Not serviceable	Any amount	Torque to 20-30 inlb.
3. Electrical Connectors for:			
a. Fastener looseness	Not serviceable	Any amount	Torque to 10-13 inlb.
b. Distortion	Pins and connector must assemble with mating connector.	Any amount correctable by straightening pin.	Straighten pin or replace switch.
4. Mounting Brackets for:			
a. Cracks	Contact FTSC for authorization for limited service.	Not repairable	Replace assembly.
b. Distortion	Any amount provided bracket holes align with mating part.	Any amount	Straighten using hand tools or replace switch.
NOTE Disconnect electrical lead before testing.			
5. Switch Assembly for:			
a. Electrical short/open	Not serviceable	Not repairable	Replace switch.
b. Mechanical operation	Switch must open/close when actuated.	Not repairable	Replace switch.

Table 2-23. Base Enclosure Assembly - External Items - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
PRESSURE TRANSDUCERS (Mounted on Bottom of Base). See MMO-060, Figure 7-194			
1. Housing/Cover for:			
a. Cracks	Contact FTSC for authorization for limited service.	Not repairable	Replace transducer.
b. Nicks, scratches	Any amount 1/16-inch deep	Not repairable	Replace transducer.
2. Electrical Connector for:			
a. Distortion	Connector and pin must assemble with mating connector.	Any amount correctable by straightening pin.	Straighten pin or replace transducer.
3. Assembly for:			
a. Loose mounting bolts	Not serviceable	Any amount	Torque to 40-60 inlb.
b. Loose assembly bolts	Not serviceable	Any amount	Torque 1/4-20 size bolts to 40-60 inlb and No. 6 size bolt to 10 inlb.
SIGNAL CONDITIONER, FIRE DETECT/EXTINGUISH (Mounted on Bottom of Base). See MMO-060, Figure 7-211			
1. Housing for:			
a. Cracks	Contact FTSC for authorization for limited service.	Not repairable	Replace assembly.
a. Dents, distortion	Any amount within 5/32-inch from original contour.	Not repairable	Replace assembly.
b. Nicks, scratches	Any number, 1/32-inch deep.	Not repairable	Replace assembly.
2. Cover for:			
a. Loose fasteners	Not serviceable	Any amount	Torque to 20-23 inlb.

Table 2-23. Base Enclosure Assembly - External Items - Continued

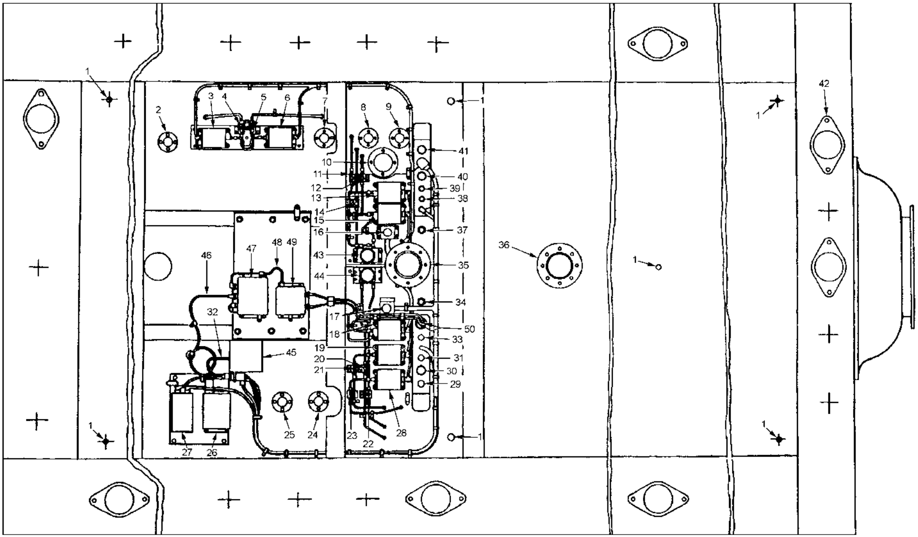
Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
b. Looseness	Must be tight when locking bolts and cover latch are installed.	See Corrective Action column.	Open cover and replace gasket if missing or damaged. Re-contour latching tab, or replace assembly.
3. Mounting Feet for:			
a. Cracks	Contact FTSC for authorization for limited service.	Not repairable	Replace assembly.
b. Distortion	Must mate and assemble to mounting plate.	Not repairable	Replace assembly.
4. Electrical Connector for:			
a. Distortion	Pins and connector must assemble with mating connector.	Not repairable	Replace assembly.
a. Loose fastener	Not serviceable	Any amount	Torque to 10-13 inlb.
5. Bonding Strap for:			
a. Loose fastener	Not serviceable	Any amount	Torque to 70-100 inlb.
b. Cracks	Contact FTSC for authorization for limited service.	Not repairable	Replace strap.
6. Mounting Fasteners for:			
a. Looseness	Not serviceable	Any amount	Torque to 70-110 inlb.
SIGNAL CONDITIONER, ICE DETECTOR (Mounted on Bottom of Base). See MMO-060, Figure 7-211			
1. Housing for:			
a. Cracks, dents distortion	Contact FTSC for authorization for limited service.	Not repairable	Replace assembly.
b. Nicks, scratches	Any amount 0.02 inches deep.	Not repairable	Replace assembly.
2. Electrical Connector for:			

Table 2-23. Base Enclosure Assembly - External Items - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
a. Distortion	Pins and connector must assemble with mating connector.	Not repairable	Replace assembly.
b. Looseness	Not serviceable	Any amount	Torque to 10-13 inlb.
3. Bonding Strap for:			
a. Loose fastener	Not serviceable	Any amount	Torque to 70-110 inlb.
b. Cracks	Contact FTSC for authorization for limited service. No through cracks.	Not repairable	Replace strap.
4. Mounting Fasteners for:			
a. Looseness	Not serviceable	Any amount	Torque to 70-110 inlb.
INSTRUMENTATION VALVES (Mounted on Bottom of Base). See MMO-060, Figure 7-199 and 7-249			
1. Assembly for:			
a. Distortion	Valve must rotate from open to closed positions.	Not repairable	Replace valve.
b. Handle position	Valve must be open (Handle to full counterclockwise (CCW) position).	Any amount	Rotate valve to open position.
c. Loose nuts, test cap	Not serviceable	Any amount	Torque mounting nut to 30-40 inlb; handle nut 30-40 inlb; test cap 135-150 inlb.
d. Leakage around stems	Not serviceable	Any amount	Repair per MMO-060, para. 7.268.
DIFFERENTIAL PRESSURE GAGES (Mounted on Bottom of Base)			
1. Gages for:			
Refer to Table 2-26, item 10.			

Table 2-23. Base Enclosure Assembly - External Items - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
VIBRATION DAMPING TILES (Underside of Base)			
1. Tiles for:			
a. Looseness	Not serviceable	Any amount	Cut away loose tile. Repair per MMO-060, para. 7.276.
b. Damage, missing, or missing pieces	Serviceable. Repair is optional.	Any amount	Repair per MMO-060, para. 7.276.
ROOF MOUNTED HATCH			
1. Torsion Bar for:			
a. Cracks	Not serviceable	Not repairable	Replace torsion bar per MMO-060, para. 7.277.
MODULE FLOOR			
a. Cracks	Not serviceable	Less than two in. long, less than 1/64 in. wide	Stop drill per MMO-060, para 7.279.
		Greater than 2 in. but less than 6 in. long and no wider than 1/16 in.	Weld repair per MMO-060, para. 7.279.
		Greater than 6 in. long, wider than 1/16 in.	Refer to Special Shipboard Maintenance Manual S9234-BF-MMI-010/LM2500.
b. Corrosion	Not serviceable	Less than 16 sq. in.	Repair per MMO-060, para. 7.279.
		Greater than 16 sq. in.	Refer to Special Shipboard Maintenance Manual S9234-BF-MMI-010/LM2500.



LEGEND:

1. Floor Drains - D3, D4, D8, D9, D10, D11, D14
2. Water Wash Inlet Port - W1
3. $P_{S}3$ Transducer
4. P_{T2} Transducer Calibration Port - HC1
5. $P_{S}3$ Transducer Calibration Port - HC2
6. P_{T2} Transducer
7. Fuel Drain - D1
8. Vent Damper ACT Air Supply Port - A3
9. Fuel Manifold Shroud Drain - D5
10. Fuel Supply Port - F1
11. Fuel Filter Inlet Pressure Calibration Port - HC6
12. Fuel Manifold Pressure Transducer Calibration Port - HC8
13. Fuel Manifold Pressure Transducer
14. Fuel Filter Discharge Pressure Calibration Port - HC7
15. Fuel Filter ΔP Transducer
16. Electrical Receptacle - E10
17. Electrical Receptacle - E8
18. Lube Oil Supply Filter ΔP Transducer
19. Lube Oil Supply Pressure Transducer
20. Lube Oil Supply Filter Discharge Pressure Calibration Port - HC4
21. Lube Oil Supply Pressure Calibration Port - HC5
22. Lube Oil Supply Filter Inlet Pressure Calibration Port - HC3
23. $P_{t5.4}$ Transducer Calibration Port - HC9
24. Lube Oil Supply Port - L1
25. Lube Oil Scavenge Port - L2
26. Flame Detector Signal Conditioner
27. Ice Detector Signal Conditioner
28. $P_{t5.4}$ Transducer
29. Electrical Receptacle - E1
30. Electrical Receptacle - E2
31. Electrical Receptacle - E3
32. Electrical Receptacle - E4
33. Electrical Receptacle - E9
34. Co_2 Extended Port - C2
35. Starter Air Inlet Port - A1
36. Bleed Air Outlet Port - A2
37. Co_2 Initial Port - C1
38. Electrical Receptacle - E7
39. Electrical Receptacle - E5
40. Electrical Receptacle - E6
41. Electrical Receptacle - E11
42. Shock Mount - P1
43. Fuel Filter ΔP Gage
44. Lube Oil Supply Filter ΔP Gage
45. $T_{5.4}$ Signal Conditioner
46. Accelerometer Power Supply Lead
47. Accelerometer Power Supply
48. Accelerometer Signal Conditioner Power Supply Lead
49. Accelerometer Signal Conditioner
50. Accelerometer Leads

NOTE:

CG-47 class smart ships delete accelerometer power supply and signal conditioner with power supply lead items 47, 48, and 49. An RSI vibration monitor is used in place of accelerometer signal conditioner and uses power supply lead 46 and input lead 50.

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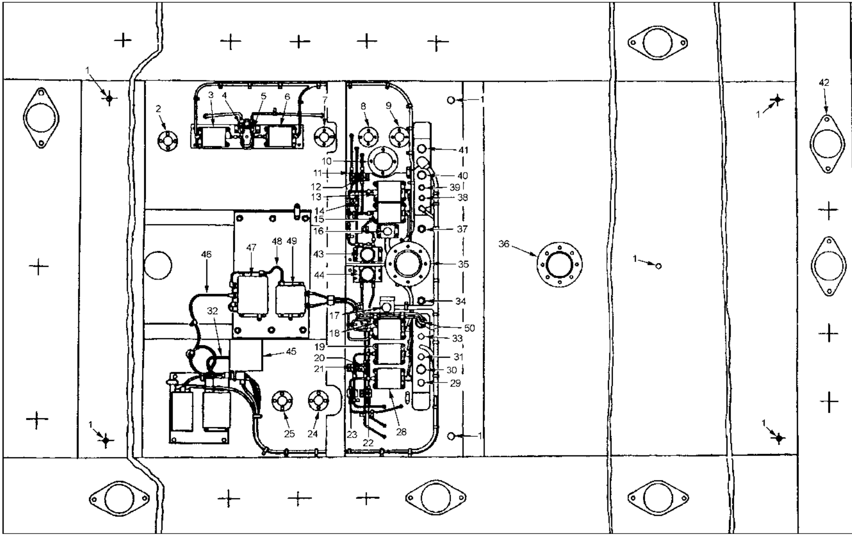
Figure 2-80. Base Enclosure Interface, DD-963 and CG-47



LEGEND:

1. Floor Drains - D3, D4, D8, D9, D10, D11, D14
2. Water Wash Inlet Port - W1
3. P_S3 Transducer
4. P_{T2} Transducer Calibration Port - HC1
5. P_S3 Transducer Calibration Port - HC2
6. P_{T2} Transducer
7. Fuel Drain - D1
8. Vent Damper ACT Air Supply Port - A3
9. Fuel Manifold Shroud Drain - D5
10. Fuel Supply Port - F1
11. Fuel Filter Inlet Pressure Calibration Port - HC6
12. Fuel Manifold Pressure Transducer Calibration Port - HC8
13. Fuel Manifold Pressure Transducer
14. Fuel Filter Discharge Pressure Calibration Port - HC7
15. Fuel Filter ΔP Transducer
16. Electrical Receptacle - E10
17. Electrical Receptacle - E8
18. Lube Oil Supply Filter ΔP Transducer
19. Lube Oil Supply Pressure Transducer
20. Lube Oil Supply Filter Discharge Pressure Calibration Port - HC4
21. Lube Oil Supply Pressure Calibration Port - HC5
22. Lube Oil Supply Filter Inlet Pressure Calibration Port - HC3
23. $P_{t5.4}$ Transducer Calibration Port - HC9
24. Lube Oil Supply Port - L1
25. Lube Oil Scavenge Port - L2
26. Flame Detector Signal Conditioner
27. Ice Detector Signal Conditioner
28. $P_{t5.4}$ Transducer
29. Electrical Receptacle - E1
30. Electrical Receptacle - E2
31. Electrical Receptacle - E3
32. Electrical Receptacle - E4
33. Electrical Receptacle - E9
34. Not Used Capped - C2
35. Starter Air Inlet Port - A1
36. Bleed Air Outlet Port - A2
37. Halon Supply - C1
38. Electrical Receptacle - E7
39. Electrical Receptacle - E5
40. Electrical Receptacle - E6
41. Electrical Receptacle - E11
42. Shock Mount - P1
43. Fuel Filter ΔP Gage
44. Lube Oil Supply Filter ΔP Gage
45. $T_{5.4}$ Signal Conditioner
46. Accelerometer Power Supply Lead
47. Accelerometer Power Supply
48. Accelerometer Signal Conditioner Power Supply Lead
49. Accelerometer Signal Conditioner
50. Accelerometer Leads

Note:

DDG-51 Class ships delete the power supply and input leads items 47, 46 and 48, with ECP N-304 incorporation. 28VDC is input from the IIEC directly to the signal conditioner.

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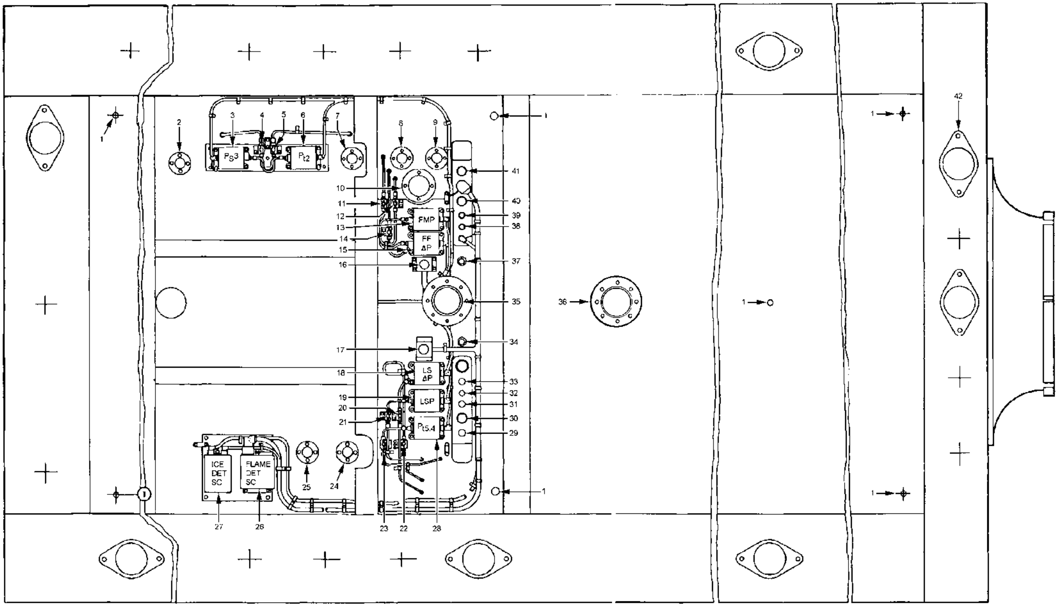
Figure 2-81. Base Enclosure Interface, DDG-51



LEGEND:
1. Floor Drains - D3, D4, D8, D9, D11, D14
2. Water Wash Inlet Port - W1
3. P_S3 Transducer
4. P_{t2} Transducer Calibration Port - HC1
5. P_S3 Transducer Calibration Port - HC2
6. P_{t2} Transducer
7. Fuel Drain - D1
8. Vent Damper Act Air Supply Port - A3
9. Fuel Manifold Shroud Drain - D5
10. Fuel Supply Port - F1
11. Fuel Filter Inlet Pressure Transducer Calibration Port - HC6
13. Fuel Manifold Pressure Transducer
14. Fuel Filter Discharge Pressure Calibration Port - HC7
15. Fuel Filter ΔP Transdcuer
16. Electrical Receptacle - E10
17. Electrical Receptacle - E8
18. Lube Oil Supply ΔP Transducer
19. Lube Oil Supply Pressure Transducer
20. Lube Oil Supply Filter Discharge Pressure Calibration Port - HC4
21. Lube Oil Supply Pressure Calibration Port - HC5
22. Lube Oil Supply Filter Inlet Pressure Calibration Port - HC3
23. $P_{t5.4}$ Transducer Calibration Port - HC9
24. Lube Oil Supply Port - L1
25. Lube Oil Scavenge Port - L2
26. Flame Detector Signal Conditioner
27. Ice Detector Signal Conditioner
28. $P_{t5.4}$ Transducer
29. Electrical Receptacle - E1
30. Electrical Receptacle - E2
31. Electrical Receptacle - E3
32. Electrical Receptacle - E4
33. Electrical Receptacle - E9
34. Not Used Capped - C2
35. Starter Air Inlet Port - A1
36. Bleed Air Outlet Port - A2
37. Halon Supply - C1
38. Electrical Receptacle - E7
39. Electrical Receptacle - E5
40. Electrical Receptacle - E6
41. Electrical Receptacle - E11
42. Shock Mount - P1

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Figure 2-82. Base Enclosure Interface, FFG-7

Table 2-24. Base Enclosure Assembly - Internal Items

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
INLET SCREEN. See MMO-050, Figure 7-104, Figure 7-105 and Figure 7-106*			
NOTE Replaced inlet screen shall be shipped to designated repair point. (Repair procedure may be accomplished by Intermediate Maintenance Activity, Special Shipboard Maintenance Manual, S9234-BF-MMI-010/LM2500.)			
1. Frame for:			
a. Parent metal cracks	Not serviceable	None	Replace inlet screen.
b. Weld cracks	Not serviceable	None	Replace inlet screen.
2. Wire Mesh for:			
a. Separated/broken wires along the seam at entrance to epoxy	Not serviceable	Seven separated and/or broken wires in a row or in a group of 12. No more than 20 percent of the wires along the seam.	(1) Trim broken wire back to where it overlaps the next crossing wire. Re-inspect within 100 hours, then inspect per routine thereafter if damage does not progress.
			(2) Replace screen if limits are exceeded.
b. Broken wires in mesh all other areas	Not serviceable	No more than seven broken wires on a side.	(1) Replace screen if limits are exceeded.
			(2) Trim broken wire back to where it overlaps the next crossing wire. Re-inspect within 100 hours then per routine thereafter if damage does not progress.
3. Epoxy Bonds for:			
a. Pieces surrounded by cracks			

Table 2-24. Base Enclosure Assembly - Internal Items - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
(1) Pieces not loose	*Limited service if piece measures 3/8-inch or larger for any dimension. Contact FTSC for authorization for limited service.	Any number	Repair per MMO-060, para. 7.295 for out of limit conditions.
(2) Loose pieces	Not serviceable	Any number	Remove pieces immediately. Repair per MMO-060, para. 7.295.
b. Missing pieces	*Limited service is missing pieces surface area is 25 percent or less of any 12 inches of channel length. Contact FTSC for authorization for limited service.	Any number	Remove any pieces from inlet area immediately. Repair per MMO-060, para. 7.295 for out of limit conditions.
c. Epoxy separation from strut/ring or wire mesh (bare mesh metal or bare strut/ring metal visible in separation)	*Contact FTSC for authorization for limited service if separation is 1/8-inch wide or less and 50 percent or less of each bonded wire mesh section. Serviceable for 0.010 max width and any length.	Any number	Repair per MMO-060, para. 7.295 for out of limit conditions.
d. Surface cracks and crazing	*Serviceable for 1/8-inch width or less and any length.	Any number	Repair per MMO-060, para. 7.295 for out of limit conditions.
4. Metallic Surfaces for:			
a. Discoloration	Any amount		
INLET PLENUM SEAL			
1. Neoprene Material:			
a. Rips	Not serviceable	Any amount	Repair per MMO-060, para. 7.270.
BARRIER WALL			
1. Metal Frame and Panels for:			
a. Parent metal cracks	Contact FTSC for authorization for limited service.	Any number, any length	Repair

Table 2-24. Base Enclosure Assembly - Internal Items - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
b. Weld cracks	Contact FTSC for authorization for limited service.	Any number, any length	Repair
c. Dents	Any amount provided part can be installed.	Any number within two inches per foot flatness.	Mechanically straighten using hand tools, or replace panel.
d. Scale	Contact FTSC for authorization for limited service.	Any amount	Remove scale. Vacuum work area after repair to prevent entry of material into Gas Turbine (GT).
e. Discoloration	Any amount		
f. Nicks, scratches, gouges	Any amount		
FORWARD MOUNTING HARDWARE (Attaches to GT Front Frame)			
Mounting Hardware for Forward (B), Aft (C, D, F) and Exhaust Duct (E, G) (Attaching links: CFF to yoke & TRF and Exhaust Duct to BEA) (See MMO-060, Figure 7-624 and Figure 7-625)			
1. Yoke for:			
a. Parent metal cracks	Not serviceable		
b. Weld cracks	Not serviceable		
c. Corrosion, nicks scratches and gouges	Contact FTSC for authorization for limited service.	Any amount	Remove corrosion. Blend to remove damage but not beyond bottom of damage. Contour of blend must be smooth.
2. Clevis and Links for:			
a. Cracks	Not serviceable	Not repairable	Replace clevis or link.
b. Corrosion	Contact FTSC for authorization for limited service.	Any amount	Remove corrosion and high metal; touch up paint or repaint.
3. Pins for:			
a. Cracks	Not serviceable	Not repairable	Replace pin.
b. Thread damage	Not serviceable	Two threads may be removed.	Remove damage with fine file or replace pin.

Table 2-24. Base Enclosure Assembly - Internal Items - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
c. Discoloration	Any amount		
d. Pitting	Not serviceable	Not repairable	Replace pin.
4. Spherical Bearing for:			
NOTE It is assumed the GG has been removed when checking CFF to yolk mounting links. With engine installed, the weight of the engine will prevent inspecting the CFF to yoke links. With PT installed, TRF to BEA mount links may be able to be swiveled/turned by hand. As long as there is no noticeable end-play in bearing, link is serviceable.			
a. Radial play	Not serviceable if end play is detectable using hand pressure.	Not repairable	Contact FTSC.
b. Discoloration	Any amount		
c. Pitting	Any amount provided no detectable radial play.	Not repairable	Replace bearing per MMO-060, para. 7.297.
d. Protrusion of spherical bearing outer race from forward mount links	Less than 0.125 inches and no cracks in present stakes (viewed with 10X magnification).	0.125 inches or more or cracks in present stakes (viewed with 10X magnification).	Repair and re-stake per MMO-060, para. 7.297.
5. Bolts for:			
a. Cracks, pitting and thread damage	Not serviceable	Not repairable	Replace bolt.
b. Discoloration	Any amount		
c. Self-locking quality	Bolt is serviceable provided no loss in self-locking quality.	Not repairable	Replace bolt.
6. Nuts for:			
a. Cracks, thread damage	Not serviceable	Not repairable	Replace nut.
b. Discoloration	Any amount		
TURBINE REAR FRAME (TRF) AND EXHAUST DUCT MOUNTING HARDWARE (Attaches to TRF and Exhaust Duct)			
1. Links, Spherical Bearings, Clevis, Pins, Bolts, and Nuts for:			

Table 2-24. Base Enclosure Assembly - Internal Items - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
a. Damage	Same as GT forward mounting hardware.	Same as GT forward mounting hardware.	Same as GT forward mounting hardware.
EXHAUST EXTENSION (Mounted on Top of Exhaust Duct)			
1. Assembly for:			
a. Parent metal cracks	Contact FTSC for authorization of limited service.	Any amount	Weld repair per MMO-060, para. 7.298.
b. Pitting	Any amount provided depth is less than 1/2-metal thickness and no more than 1/2 the cumulative surface area of the part is affected.	Not repairable	Replace exhaust extension.
c. Discoloration	Any amount		
d. Flange warpage	1/4-inch per foot	Any amount which can be re-formed to serviceable limits.	Mechanically straighten using common tools.
e. Missing rivets	Contact FTSC for authorization of limited service.	Any number	Replace rivet.
f. Weld Cracks	Contact FTSC for authorization of limited service.	Any amount	Weld repair per MMO-060, para. 7.298.
2. Bolts, Nuts for:			
a. Missing, loose	Not serviceable	Any number	Replace missing; retorque loose bolts, nuts.
b. Thread damage	Not serviceable	Not repairable	Replace bolt or nut.
c. Pitting	Not serviceable	Not repairable	Replace nut or bolt.
d. Discoloration	Any amount		
VENT DAMPER (Mounted on Ceiling of Enclosure). See MMO-060, Figure 7-222 or 7-223			
1. Metal Frame for:			
a. Parent metal cracks	4 cracks, each 1/2-inch long.		

Table 2-24. Base Enclosure Assembly - Internal Items - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
b. Weld cracks	4 cracks, each 1/2-inch long with two inch min. spacing between cracks.		
c. Pitting	Any amount provided depth is less than 1/2 metal thickness and no more than 1/2 the frame cumulative surface area is affected.	Not repairable	Replace frame per MMO-060, para. 7.126.
d. Discoloration, nicks, scores	Any amount		
e. Dents	Any amount provided no affect on operation and/or air leakage.	Not repairable	Replace frame per MMO-060, para. 7.126.
2. Vanes for:			
a. Cracks	Any amount provided no affect on operation and/or air leakage.	Not repairable	Replace vane/shaft assembly per MMO-060, para. 7.126.
b. Vane seal deformation	Not serviceable	Any amount provided no rip or tears.	Straighten mechanically using hand tools.
c. Vane shaft deformation	Any amount provided no affect on operation.	Not repairable	Replace vane/shaft assembly per MMO-060, para. 7.126.
d. Pitting, nicks dents, scores	Any amount provided no affect on operation.	Not repairable	Replace vane/shaft assembly per MMO-060, para. 7.126.
e. Discoloration	Any amount		
f. Air leakage between vanes and between vanes and frame	Total area of leakage may not exceed 4.9 square inches, as measured by MMO-060, para. 7.267.2.	Not repairable	Remove/replace vent damper assembly per MMO-060, para. 7.126.
3. Actuator for:			
a. Adequate spring force (spring internal to actuator)	Not serviceable if vent damper can be opened easily by pushing on shaft cranks or, if secondary air pressure (static) opens vent damper vanes.	Not repairable	Replace actuator per MMO-060, para. 7.128.

Table 2-24. Base Enclosure Assembly - Internal Items - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
	Not serviceable if vent damper vanes will not close at GT shutdown.	See Corrective Action column.	Using hand pressure, adjust side seals to eliminate binding of vanes. Replace actuator if side seal adjustment is not effective and the solenoid circuit and solenoid have been determined to be serviceable. (See item 3.b. which follows:)
b. Solenoid (Item 3.a. has been determined to be serviceable	Not serviceable if vent damper will not close at air dump (electrical power off dumps air and allows vent damper to close).	See Corrective Action column.	Clean and repair per MMO-060, para. 7.267.1.
	Not serviceable if vent damper will not close (electrical power on opens vent damper).	See Corrective Action column.	If power supply to solenoid is 28 VDC and inlet air supply is 80-100 PSIG, the solenoid is defective; replace solenoid. Also refer to MMO-060, para. 7.267.1, step p.
4. Limit Switch for:			
a. Malfunction	Not serviceable	Not repairable	Replace per MMO-060, para. 7.129.
HEATER - FUEL/ENCLOSURE (Mounted on Ceiling of Enclosure). See MMO-060, Figure 7-203			
1. Enclosure for:			
a. Cracks	Contact FTSC for authorization for limited service.	Any amount	Stop - drill crack.
b. Louver distortion	Any amount within 1/2-inch from original contour.	Any amount	Straighten
c. Inlet screen distortion	Any amount within 1/4-inch from original contour.	Any amount	Straighten
d. Dents	Any number within 1/4-inch from original contour.	Any amount	Straighten or replace assembly.
e. Assembly fastener looseness	Not serviceable	Any amount	Torque to 20-30 inlb.
2. Electrical Connectors for:			

Table 2-24. Base Enclosure Assembly - Internal Items - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
a. Distortion	Pins and connector must assemble with mating connector.	Any amount correctable by straightening pins.	Straighten pins.
b. Mounting bolt looseness	Not serviceable	Any amount	Torque to 10-20 inlb.
3. Reset Switch for:			
c. Installation nut looseness	Not serviceable	Any amount	Torque to 50-70 inlb.
4. Bonding Strap for:			
a. Installation nut looseness	Not serviceable	Any amount	Torque to 70-110 inlb.
b. Cracks	Contact FTSC for authorization for limited service. No through cracks.		
5. Installation Fastener for:			
a. Looseness	Not serviceable	Any amount	Torque to 160-210 inlb.
6. Installation Bracket for:			
a. Fastener looseness	Not serviceable	Any amount	Torque to 160-210 inlb.
TEMPERATURE SWITCH - FIRE DETECT (Mounted on Ceiling of Enclosure). See MMO-060, Figure 7-205			
1. Housing for:			
a. Cracks, dents	Not serviceable	Not repairable	Replace switch.
2. Mounting Flange for:			
a. Cracks	Not serviceable	Not repairable	Replace switch.
b. Distortion	Switch must assemble to mounting bracket without causing physical interference of either the switch or the mating electrical cable.	Any amount which can be straightened.	Straighten to serviceable limits.
3. Connector for:			

Table 2-24. Base Enclosure Assembly - Internal Items - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
a. Distortion	Pins and connector must assemble with mating connector.	Any amount correctable by straightening pins.	Straighten pins.
TEMPERATURE SENSORS See MMO-060, Figure 7-204			
1. Housing for:			
a. Cracks, splits	Not serviceable	Not repairable	Replace sensor.
b. Assembly looseness	Not serviceable	Any amount	Torque cover and housing hand-tight.
2. Sensor Well for:			
a. Installation looseness	Not serviceable	Any amount	Torque bolt to 135-150 inlb, and -20 size B nut to 100-200 FTLB.
3. Electrical Connector for:			
a. Installation looseness	Not serviceable	Not repairable	Replace sensor.
b. Distortion	Connector and pins must assemble with mating connector.	Any amount correctable by straightening pins.	Straighten pins or replace sensor.
LIGHT FIXTURES See MMO-060, Figure 7-218			
1. Globe for:			
a. Cleanliness	Serviceable if adequate illumination is provided by light fixture.	Any amount of contamination.	Clean
b. Cracks, chips	Not serviceable	Not repairable	Replace globe.
c. Security	Not rotatable by hand. Wire and lead seal must be assembled.	Any amount	Torque to align wire holes. Install wire and lead seal.
2. Housing Assembly for:			
a. Loose electrical connector screws	Not serviceable	Any amount	Torque to 13-16 inlb.
b. Distorted connector pins	All pins must assemble and mate with mating connector.	Any amount correctable by straightening.	Straighten pins.

Table 2-24. Base Enclosure Assembly - Internal Items - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
c. Loose shock mount (bracket) fasteners	Not serviceable	Any amount	Torque bracket to fixture bolts (1/4-inch OD) 40-60 inlb. Torque bracket to BEA bolts (3/8-inch OD) to 160-210 inlb.
d. Shock mount (bracket)			
(1) Cracked, broken	Contact FTSC for authorization for limited service.	Not repairable	Replace assembly.
(2) Bent	Any amount provided no physical interference with surrounding hardware.	Any amount	Mechanically re-form to original contour. Use undamaged part as a pattern.
e. Burned out lamp	Contact FTSC for authorization for limited service.	Not repairable	Replace lamp.
FLAME ARRESTOR (Located in Air Line Between GG Air-Oil Separator and Exhaust Duct)			
1. Assembly for:			
a. Contamination	Not serviceable	Any amount	Clean
b. Loose mounting fasteners	Not serviceable	Any amount	Torque to 70-110 inlb.
FLAME DETECTOR (Two Mounted on Floor of Base and One Mounted on Ceiling of Enclosure). See MMO-060, Figure 7-209			
1. Sensor Viewing Glass for:			
a. Surface contamination	Not serviceable	Any amount	Wipe clean.
b. Cracks, chipped	Not serviceable	Not repairable	Replace cover assembly.
c. Looseness	Not serviceable	Any amount	Torque hand-tight.
2. Cover Assembly for:			
a. Cracks	Not serviceable	Not repairable	Replace cover assembly.
b. Nicks, scores	Any amount 1/16-inch deep	Not repairable	Replace cover assembly.
c. Looseness	Not serviceable	Any amount	Torque to 30-50 FTLB.

Table 2-24. Base Enclosure Assembly - Internal Items - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
3. Housing for:			
a. Cracks	Not serviceable	Not repairable	Replace assembly.
b. Nicks, scores	Any amount 1/8-inch deep	Not repairable	Replace assembly.
c. Loose mounting of electrical connector	Not serviceable	Any amount	Torque to 10-13 inlb.
d. Electrical connector distortion	Pins and connector must assemble with mating connector.	Not repairable	Replace assembly.
4. Bonding Strap for:			
a. Loose fastener	Not serviceable	Any amount	Torque to 70-110 inlb.
b. Cracks	Contact FTSC for authorization for limited service. No through cracks.	Not repairable	Replace strap.
5. Mounting Fasteners for:			
a. Looseness	Not serviceable	Any amount	Torque to 40-60 inlb.
ICE DETECTOR SENSOR (Mounted on Floor of Base in Wet Plenum). See MMO-060, Figure 7-219			
1. Assembly for:			
a. Housing cracks, dents, distortion	Contact FTSC for authorization for limited service.	Not repairable	Replace assembly.
b. Electrical connector distortion	Pins and connector must assemble with mating connector.	Not repairable	Replace assembly.
c. Loose mounting fasteners	Not serviceable	Any amount	Torque to 40-60 inlb.
VALVES, PNEUMATIC-STARTER AND BLEED AIR (Mounted on Floor of Base). See MMO-060, Figure 7-192 and Figure 7-202			
1. Housing for:			
a. Cracks	Not serviceable	Not repairable	Replace assembly.

Table 2-24. Base Enclosure Assembly - Internal Items - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
b. Nicks, scores	Not serviceable	Any amount, 0.02 inch deep	Blend to remove damage but not beyond bottom of damage. Contour of blend must be smooth.
2. Bleed Valve Actuator and Starter Valve Solenoid for:			
a. Cracks, dents distortion	Not serviceable	Not repairable	Replace assembly.
b. Electrical connector distortion	Pins and connector must assemble with mating connector.	Not repairable	Replace assembly.
3. Mounting Fastener for:			
a. Looseness	Not serviceable	Any amount	Torque to 70-110 inlb.
VALVE, FUEL PURGE (Mounted on Floor of Base). See MMO-060, Figure 7-191			
1. Actuator for:			
a. Cracks, distortion, dents	Not serviceable	Not repairable	Replace assembly.
b. Nicks, scores	Not serviceable	Any amount to 0.02 inch deep	Blend to remove damage but not beyond bottom of damage. Contour of blend must be smooth.
2. Electrical Connector for:			
a. Distortion	Pins and connector must assemble with mating connector.	Not repairable	Replace assembly.
3. Mounting and Assembly Fasteners for:			
a. Looseness	Not serviceable	Any amount	Torque mounting fasteners to 20-30 inlb and assembly fasteners to 20-23 inlb.
DUPLEX LUBE OIL FILTER. See MMO-060, Figure 7-193 and Figure 7-244			
1. Filter Element/Bowl for:			

Table 2-24. Base Enclosure Assembly - Internal Items - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
a. Differential pressure	15 psid	See Corrective Action column.	Switch clean filter element into oil circuit. Clean high differential pressure element per Planned Maintenance System (PMS).
b. Bowl/housing leakage	Not serviceable	Any amount	Replace seal.
c. Bowl distortion (bent or twisted)	Any amount provided no leakage, parts assemble correctly and differential pressure is within serviceable limits.	Not repairable	Replace assembly.
d. Bowl looseness	Not serviceable	Any amount	Torque nut to 250-275 inlb.
2. Filter Housing for:			
a. Cracks	Not serviceable	Not repairable	Replace assembly.
b. Mounting fastener looseness	Not serviceable	Any amount	Torque 7/16-14 thread fasteners to 250-320 inlb, 1/2-13 threaded fasteners to 420-510 inlb.
3. Selector Valve for:			
a. Selector operation	Selector valve handle, when operated, to rotate 90° from one element detent lock position to second element detent lock position.	See Corrective Action column.	Disassemble selector valve from housing and remove any noted chips or foreign particles between housing and valve. Reassemble and check for proper operation.
b. Position detent operation	Position detent lock must engage and disengage the selector valve shaft in each selected position.	See Corrective Action column.	Torque detent handle set screw to 20-23 inlb. or Disassemble detent lock assembly by removing handle and snap ring. Correct condition by freeing or replacing parts/valve assembly. Reassemble and check for proper operation.
BLEED AIR MANIFOLD AND DUCTING			

Table 2-24. Base Enclosure Assembly - Internal Items - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
1. Parts for:			
a. Damage	Refer to Table 2-15		
ENCLOSURE INTERIOR SURFACES			
1. Rust on surfaces between and around perforated stainless steel panels (pay particular attention to spot weld locations)	Contact FTSC for authorization for limited service.	Any amount	Clean and paint per MMO-060, para. 7.294, step a.
2. Rust at stainless steel inlet flange (inlet plenum area)	Contact FTSC for authorization for limited service.	Any amount	Clean and paint per MMO-060, para. 7.294, step b.
3. Rust at the recess area at the enclosure roof/front wall intersection	Contact FTSC for authorization for limited service.	Any amount	Clean and paint per MMO-060, para. 7.294, step c.
4. Rust at electrical bonding boss locations (on base exterior)	Contact FTSC for authorization for limited service.	Any amount	Clean and paint per MMO-060, para. 7.294, step d.

NOTE

LM2500 Module Seal Kits can be procured from San Diego Seal, Inc., 7635 Ronison Rd., San Diego, CA. 92111. Tel: 619-278-3270, FAX: 619-278-2950. CAGE: 22, CODE: 3R262.

Kit Description	Kit Number
Module Door Seal Replacement(Contains seals for one door and its module recess, includes adhesives)	51893
Side Access Panel Seal Replacement(Contains seals for one panel and its module recess, includes adhesives)	12642
Rear Access Panel Seal Replacement(Contains seals for left and right panel and their module recess, includes adhesives)	10763

Forward Wall Cover Seal Replacement(Contains seals for one cover, includes adhesives)	30667
Top Hatch Seal Replacement(Contains seals for one hatch and its module recess, includes adhesives)	20234
Module Door Window Seal Replacement(Contains seals for replacement of all windows (four panes) in one module door, includes adhesives)	13134
Inlet Plenum Inspection Window Seal Replacement(Contains seals for replacement of the inlet plenum inspection window (one pane) in one module, includes adhesives)	149345

*Table 2-25. LM2500 Gas Turbine Resilient Mount Inspection Time**

SHIP CLASS	ENGINE ROOM	MODULE	APPROX. RAKE ANGLE	INSP. TIME
AOE-6	FWD/MER 1	2A/2B	0.5 Degrees	19 Years
AOE-6	AFT/MER 2	1A/1B	2.0 Degrees	16 Years
CG-47/DD-963	FWD/MER 1	2A/2B	2.5 Degrees	15 Years
CG-47/DD-963	AFT/MER 2	1A/1B	3.5 Degrees	13 Years
DDG-51	FWD/MER 1	1A/1B	3.0 Degrees	14 Years
DDG-51	AFT/MER 2	2A/2B	4.5 Degrees	11 Years
FFG-7	MER 1	1A/1B	7.0 Degrees	6 Years
* Inspection times are plus or minus 1 year; Calculate from commissioning date for ships with original mounts. For ships with mounts replaced, use date stamped on mounts and/or logged in Ancillary Equipmemt section of Marine Gas Turbine Equipment Service Record. Note: Rake angle is approximate.				

Table 2-26. Lube Oil Storage And Conditioning Assembly

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
1. Tank/Frame Assembly for:			
a. Cracks/splits in piping and tank	Not serviceable	See Corrective Actioncolumn.	Weld repair or replace assembly.

Table 2-26. Lube Oil Storage And Conditioning Assembly - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
b. Cracks	Contact Fleet Techincal Support Center (FTSC) for authorization for limited service.	See Corrective Action column.	Weld repair or replace assembly.
c. Dents/flat areas			
(1) Piping	Any number not to exceed 20 percent of piping OD.	See Corrective Action column.	Weld repair or replace assembly.
(2) Tank	Any amount		
d. Nicks, scratches			
(1) Piping	Limited Service - Any amount to 1/32-inch deep. Contact FTSC for authorization for limited service.	Any amount up to 0.050 inch deep or Over 0.050 inch deep.	Blend to remove damage but not beyond bottom of damage. Contour of blend must be smooth. Weld repair or replace.
(2) Tank shell	Limited Service - Any amount 1/8-inch deep. Contact FTSC for authorization for limited service.	Any amount	Weld repair.
(3) Frame	Not serviceable	Any amount up to 0.15 inch deep or Over 0.15 inch deep.	Blend to remove damage but not beyond bottom of damage. Contour of blend must be smooth. Weld repair or replace.
e. Nicks, scores in sealing surfaces	Not serviceable if over 0.020 inch deep.	Any amount over 0.020 inch deep.	Refinish sealing surface to remove high metal protruding above sealing surface.
f. Leakage from sight glass	Limited Service - Repair at first opportunity. Contact FTSC for authorization for limited service.	Any amount	Replace assembly.
g. Scratch marks, missing or chipped paint beneath fastener heads	Serviceable. Touch-up is optional.		Touch-up paint. On exterior surfaces use epoxy paint per MIL-C-22751D, color per Federal Standard 595, No. 26307.
2. Cover for:			

Table 2-26. Lube Oil Storage And Conditioning Assembly - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
a. Cracks	Contact FTSC for authorization for limited service.	See Corrective Action column.	Weld repair or replace.
b. Nicks, scores			
(1) Sealing surfaces	Same as 1.e.	Same as 1.e.	Same as 1.e.
(2) Casting surfaces	Limited Service - Any amount to 1/8-inch deep. Contact FTSC for authorization for limited service.	Any amount up to 0.10 inch deep or Over 0.10 inch deep.	Same as 1.d.(2) Weld repair or replace.
3. Tubing and Electrical Cable for:			
a. Damage	Refer to Table 2-15,Tube Assemblies, Electrical Cable Assemblies.		
b. Loose clamps		Any number	Adjust clamps and torque bolts to 40-60 inlb.
c. Loose electrical connector	Not serviceable	Any amount	Press back of connector and hand-tighten.
4. Fill Cap Assembly for:			
a. Cracks/ splits	Contact FTSC for authorization for limited service.	Not repairable	Replace assembly per MMO-060, para. 7.135.
b. Flange leaks	Not serviceable	Retorque bolts or replace seal if necessary.	Replace seal and torque bolts 40-60 inlb.
c. Loose mounting bolt	Not serviceable	Any amount	Torque bolts to 40-60 inlb.
d. Cap installation security and locking tank	Installation torque must increase during rotation of cap from removed position to installed position. Cap must lock in closed position.	Not repairable	Replace assembly per MMO-060, para. 7.135.
5. Lube Oil Switch for:			
a. Cracks/Splits	Contact FTSC for authorization for limited service.	Not repairable	Replace assembly per MMO-060, para. 7.136.

Table 2-26. Lube Oil Storage And Conditioning Assembly - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
b. Flange leaks, loose bolts	Not serviceable	Any amount	Torque to 40-60 inlb.
c. Connector distortion	Pins and shell must mate with cable assembly.	Not repairable	Replace assembly per MMO-060, para. 7.136.
d. Inoperative	Limited Service - Use sight glass to determine oil level until repair is accomplished. Contact FTSC for authorization for limited service	Not repairable	Replace assembly per MMO-060, para. 7.136.
e. Corrosion on solder joints	Not serviceable	Any amount	Clean per MMO-060, para. 7.281.
6. Heat Exchanger (Oil Cooler) for:			
a. Cracks, splits	Not serviceable	Damaged brackets only may be repaired.	Weld repair brackets. Replace cooler for other cracks/splits per MMO-060, para. 7.141.
b. Nicks, scores	Limited Service - Any amount to 1/32-inch deep. Contact FTSC for authorization for limited service.	Any amount up to 0.050 inch deep.	Blend to remove damage but not beyond bottom of damage. Contour of blend must be smooth.
c. Dents, flats	Any number within 3/16-inch from original contour provided none within 1.5 inches of flange or on domes.	Not repairable	Replace cooler per MMO-060, para. 7.141.
d. Flange joint leaks	Not serviceable	Any amount	Torque bolts to 250-320 inlb.
e. Mounting bolt looseness	Not serviceable	Any amount	Torque bolt to 135-150 inlb.
7. Duplex Lube Oil Filter for:			
f. Damage	Refer to Table 2-24		
8. Instrumentation Valve for:			
a. Damage and leakage	Refer to Table 2-23		
9. Differential Pressure Transducer for:			

Table 2-26. Lube Oil Storage And Conditioning Assembly - Continued

Observed Condition/Discrepancy	Max Serviceable Limits	Max Repairable Limits	Corrective Action
a. Damage	Refer to Table 2-23		
10. Differential Pressure Gage for:			
a. Inoperative or out of calibration	Contact FTSC for authorization for limited service.	Not repairable	Replace gage per MMO-060, para. 7.142.
b. Broken glass, or bent hand	Contact FTSC for authorization for limited service.	Not repairable	Replace gage per MMO-060, para. 7.142.
11. Temperature Sensor for:			
a. Damage	Refer to Table 2-24		

2.11 SAFETY-WIRING

(Ref: S9234-AD-MMO-050/LM2500)

Safety-wiring is the securing of two or more parts with a wire installed in such a manner that any tendency for a part to loosen will be counteracted by the wire. It is not a means of obtaining or maintaining torque, but rather a safety device used to prevent the disengagement of the safety-wired parts. See Safety-Wiring Practices Illustrations.

NOTE

Although not every possible combination of safety-wiring is shown in the illustrations, all safety-wiring must generally correspond to the examples shown.

a. Observe the following rules for safety-wiring, unless specific instructions to the contrary are given in the text:

(1) Safety-wiring shall consist of two strands of wire twisted together (double-twist method), where one twist is defined as being produced by twisting the strands through an arc of 180 degrees, equivalent to half a complete turn. Use the single strand method only when specified.

(2) Safety-wire shall not be installed in a manner to cause the wire to be subjected to chafing, fatigue through vibration, or additional tension other than the tension imposed on the wire to prevent loosening.

(3) In all cases, safety-wiring must bed one through the holes provided. If no wire hole is provided, safety-wiring shall be to a neighboring part in a manner not to interfere with the function of the parts and in accordance with the basic principles described.

(4) The maximum span of safety-wire between tension points shall be six inches unless otherwise specified. Where multiple groups are safety-wired either by the double-twist or the single-strand method, the maximum number in a series shall be determined by the number of units that can be safety-wired with a 24-inch length of wire. When safety-wiring widely spaced multiple groups with the double-twist method, three units shall be the maximum number in a series.

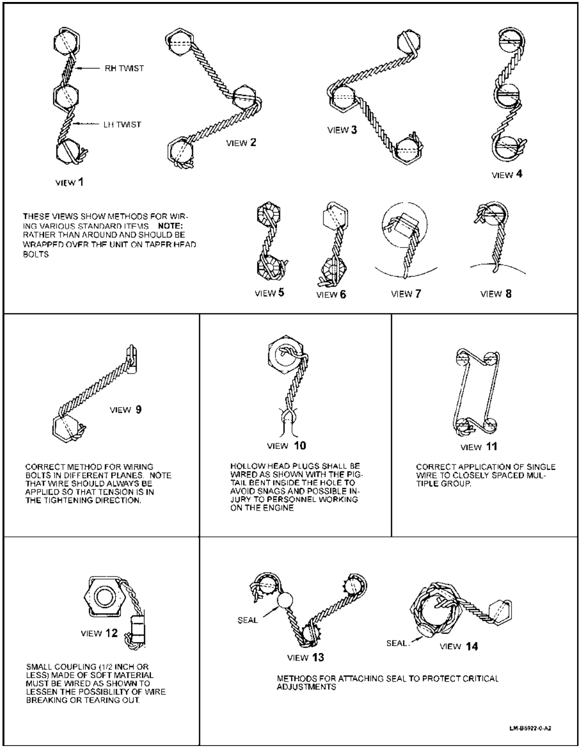


Figure 2-83. Safety-Wiring Practices

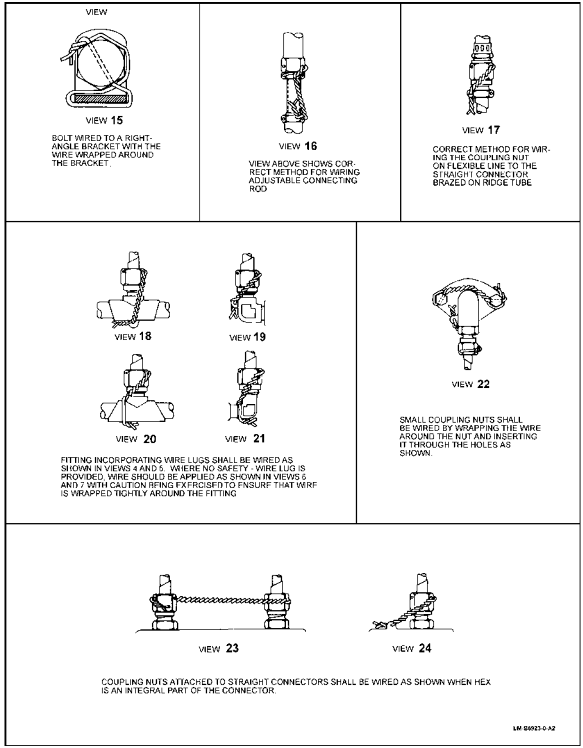


Figure 2-84. Safety-Wiring Practices (Cont.)

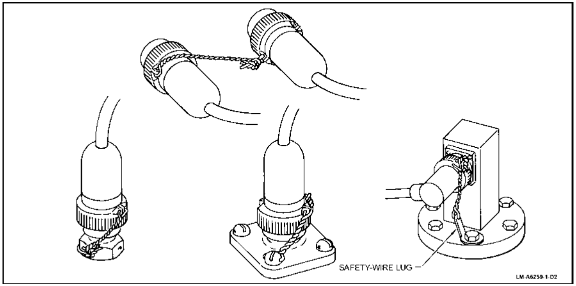


Figure 2-85. Safety-Wiring Electrical Connectors

(5) Both 0.020-inch diameter and 0.032-inch diameter safety-wire are used throughout the GT. Electrical connector back shells do not require safety-wire. However, connector-coupling nuts are provided with safety-wire holes that can accommodate 0.032-inch diameter safety-wire. Other applications are determined by the size of the hole in the unit to be safety-wired. Whenever possible, use the 0.032-inch diameter safety-wire. Only new safety-wire shall be used in each application.

(6) The safety-wire shall be pulled taut while being twisted and shall have 9-12 twists per inch for 0.020-inch diameter wire and 7-10 twists per inch for 0.032-inch diameter wire.

(7) Caution must be exercised during the twisting operation to keep the wire tight without overstressing or allowing it to become nicked, kinked, or otherwise mutilated.

b. The following safety-wiring procedures are to be used:

(1) Insert the safety-wire through the first part, and bend the upper end either over the head of the part or around it. If bent around it, the direction of wrap and twist of the strands shall be such that the loop around the part comes under the strand protruding from the hole. Done this way, the loop will not tend to slip up and leave a slack loop.

(2) Twist the strands while taut until the twisted part is just short of a hole in the next part. The twisted portion should be within 1/8-inch of the hole in either part.

(3) If the free strand is to be bent around the head of the second part, insert the upper strand through the hole in this part, and then repeat substep (2). If the free strand is to be bent over the unit, the direction of twist is unimportant. If there are more than two units in the series, repeat the preceding steps.

(4) After safety-wiring the last part, continue twisting the wires to form a pigtail of three to eight twists (1/4 to 1/2-inch long) and cut off the excess wire. Bend the pigtail in toward the part in a manner to prevent it from becoming a hazard to personnel.

NOTE

Apply light finger pressure at the midpoint of the safety-wire span and flex in both directions to check for tautness.

c. If the safety-wire is not taut after safety-wiring per the preceding instructions, use the following limits to determine its acceptability:

Length of safety-wire between parts (inches)	Total flexing at center (inches)
1/2	1/8
1	1/4
2	3/8
3	1/2
4	3/4
5	3/4
6	3/4

d. If the safety-wire fails to meet these limits, remove it and install new safety-wire.

e. Always cut, rather than break, safety-wire so that safety-wire holes are not torn or pulled out. The instructions for dismantling and disassembly do not include safety-wire removal because of its obvious necessity.

f. When removing safety-wire, ensure that all pieces are removed to prevent their entering GT parts or otherwise causing damage.

g. Safety-wire electrical connectors as follows:

WARNING

Electrical power shall be turned off to prevent possible injury to personnel or damage to equipment.

(1) Check each connector for cleanliness and possible corrosion. Clean, if necessary, using a soft bristle brush and alcohol.

(2) Verify that a seal ring is installed in each connector to be safety-wired. Replace damaged seal rings.

(3) Align connector pins and fully engage connectors.

(4) Tighten coupling nuts finger-tight while wiggling connectors.

(5) Repeat steps (3) and (4) until the connectors are fully engaged.

(6) Tighten coupling nuts 5-20 beyond the full engagement using connector pliers.

(7) On DD-963 and FFG-7 only, install safety-wire lug under nearby mounting bolt where required (25 locations on BEA and two places on LOSCA). See Figure 2-85.

h. For DD-963 and FFG-7, see Figure 2-86 through Figure 2-93 for safety-wire locations and refer to Table 2-27 through Table 2-32 for safety-wire checklists. It is recommended that Table 2-27 through Table 2-32 be locally reproduced and used for quality check table.

Table 2-27. Safety-Wire Checklist for Figure 2-86 through Figure 2-90

BEA, Figure 2-86					
Note: Tubes and hoses of BEA do not require safety-wire.					
1.		5.		9.	
2.		6.		10.	
3.		7.		11.	
4.		8.		12.	
BEA, Figure 2-87				The Following Do Not Require Safety-Wire:	
11.		27.		21.	
12.		28.		22.	
13.		29.		23.	
14.		30.		24.	
15.		35.		25.	
16.		36.		26.	
17.		37.		31.	
18.		38.		32.	
19.		39.		33.	
20.		40.		34.	
BEA, Figure 2-88					
41.		48.		55.	
42.		49.		56.	
43.		50.		57.	
44.		51.		58.	
45.		52.		59.	
46.		53.		60.	
47.		54.			
BEA, Figure 2-89					
61.		67.		73.	
62.		68.		74.	
63.		69.		75.	
64.		70.		76.	
65.		71.		77.	
66.		72.		78.	
LOSCA, Figure 2-90					
1.		2.		3.	

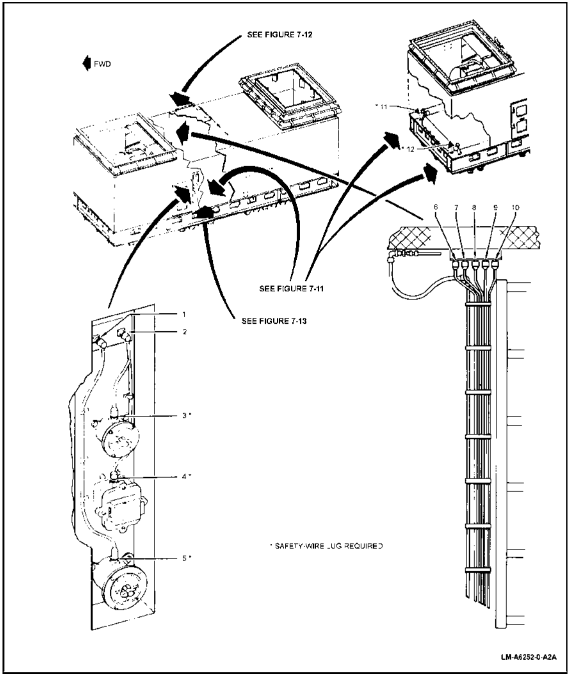


Figure 2-86. Safety-Wire Locations (Base Enclosure Assembly)

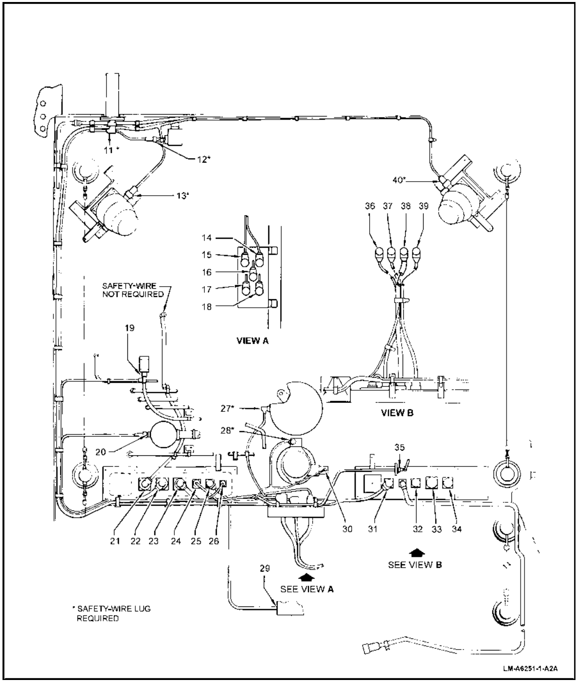


Figure 2-87. Safety-Wire Locations (Base Enclosure Assembly - Cont.)

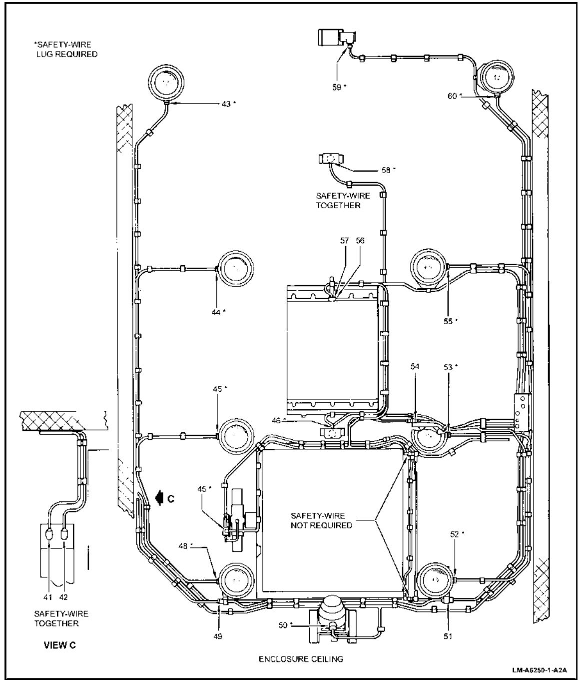


Figure 2-88. Safety-Wire Locations (Base Enclosure Assembly - Cont.)

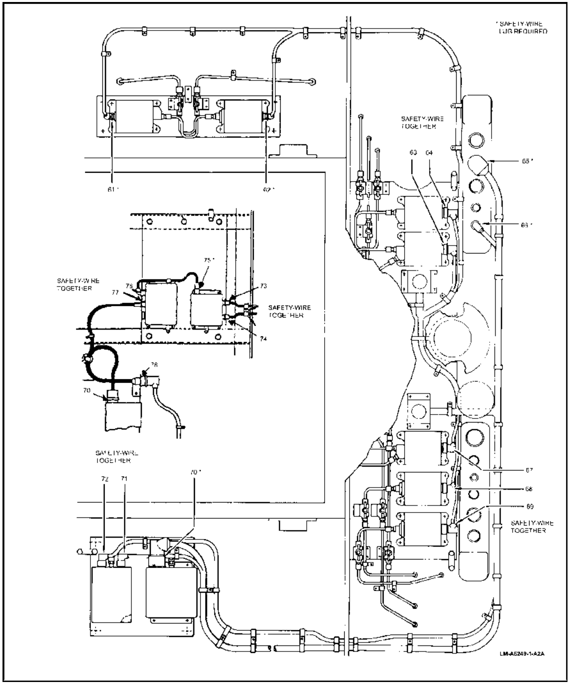


Figure 2-89. Safety-Wire Locations (Base Enclosure Assembly - Cont.)

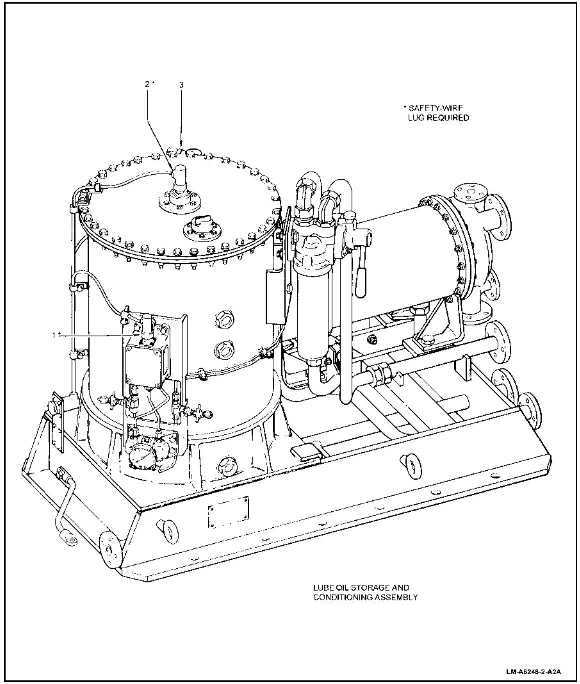


Figure 2-90. Safety-Wire Locations (Lube Oil Storage and Conditioning Assembly)

Table 2-28. Safety-Wire Checklist for Figure 2-91

Gas Turbine Paired Blade					
1.	Cover Plate, Turbine Rear Frame (TRF)		21.	A-Sump vent tube	
2.	Thermocouple probe nut (Qty 11)		22.	Centerbody	
3.	Thermocouple harness and lead connectors		23.	Cover plate, Compressor Front Frame (CFF)	
4.	Borescope plug, stg 2		24.	Cover plate, CFF	
5.	High Pressure Turbine (HPT) cooling tube, flexible coupling		25.	Bracket, compressor case	
6.	HPT cooling tube adapter		26.	Bracket, compressor case	
7.	Borescope plug, std 1		27.	HPT cooling tube, flexible coupling (Qty two each side)	
8.	Turbine Mid-Frame (TMF) cooling tube, flexible coupling (Qty 8)		28.	HPT cooling tube adapter	
9.	Borescope plugs, combustor (Qty 10)		29.	HPT cooling tube, flexible coupling	
10.	Combustor mounting pins (Qty 10)		30.	$P_{t5.4}$ probe nut (Qty 5)	
11.	Plug, Compressor Rear Frame (CRF)		39.	B-sump oil supply plug	
12.	Cover plate, CRF			The Following Do Not Require Safety-Wire:	
13.	Variable Stator Vane (VSV) actuation lever aft mount		31.	Overspeed electrical lead	
14.	VSV bridge connector bolts (Qty 28 on each side of GT)		32.	Vent tube coupling	
15.	VSV link jam nuts (Qty 14 on each side)		33.	Vent tube coupling	
16.	Bracket to compressor case		34.	Vent tube coupling	
17.	Borescope plugs, compressor stator (except Inlet Guide Vane (IGV)) (Qty 11)		35.	VSV actuator tubes	
18.	Bracket to compressor case		36.	Vent tube coupling	
19.	VSV actuator shroud		37.	A-sump oil supply hose	
20.	VSV actuator rod-end bearing and jam nut		38.	$P_{t5.4}$ tubes and manifold coupling (Qty 14)	

Table 2-29. Safety-Wire Checklist for Figure 2-92

Gas Turbine Single Shank					
1.	Cover Plate, TRF		21.	A-Sump vent tube	
2.	Thermocouple probe nut (Qty 11)		22.	Centerbody	
3.	Thermocouple harness and lead connectors		23.	Cover plate, CFF	
4.	Borescope plug, stg 2		24.	Cover plate, CFF	
5.	HPT cooling tube, flexible coupling		25.	Bracket, compressor case	
6.	HPT cooling tube adapter		26.	Bracket, compressor case	
7.	Borescope plug, std 1		27.	HPT cooling tube, flexible coupling (Qty two each side)	
8.	TMF cooling tube, flexible coupling (Qty 5)		28.	HPT cooling tube adapter	
9.	Borescope plugs, combustor (Qty 6)		29.	HPT cooling tube, flexible coupling	
10.	Combustor mounting pins (Qty 10)		30.	$P_{t5.4}$ probe nut (Qty 5)	
11.	Plug, CRF		39.	B-sump oil supply plug	
12.	Cover plate, CRF			The Following Do Not Require Safety-Wire:	
13.	VSV actuation lever aft mount		31.	Overspeed electrical lead	
14.	VSV bridge connector bolts (Qty 28 on each side of GT)		32.	Vent tube coupling	
15.	VSV link jam nuts (Qty 14 on each side)		33.	Vent tube coupling	
16.	Bracket to compressor case		34.	Vent tube coupling	
17.	Borescope plugs, compressor stator (except IGV) (Qty 11)		35.	VSV actuator tubes	
18.	Bracket to compressor case		36.	Vent tube coupling	
19.	VSV actuator shroud		37.	A-sump oil supply hose	
20.	VSV actuator rod-end bearing and jam nut		38.	$P_{t5.4}$ tubes and manifold coupling (Qty 14)	

Table 2-30. Safety-Wire Checklist for Figure 2-93

Gas Turbine Paired Blade					
1.	Cover Plate, TRF		29.	Power Lever Angle (PLA) actuator turnbuckle jam nuts	
2.	Inlet pressure probe		30.	VSV feedback cable jam nut	
3.	VSV actuator jam nut		31.	Compressor case bracket	
4.	VSV actuator shroud		32.	VSV feedback cable jam nut	
5.	VSV feedback link jam nuts		33.	Quick Assembly Disconnect (QAD) ring	
6.	VSV bridge connector bolts (Qty 28 on each side of gas turbine as required)		34.	Gearbox plug	
7.	VSV link jam nuts (Qty 14 on each side)		35.	Compressor Inlet Temperature (CIT) sensor nipples	
8.	Compressor case bracket		36.	CIT sensor to frame	
9.	Compressor case bracket			The Following Do Not Require Safety-Wire:	
10.	VSV actuation lever aft mount		18.	Nipple, D-sump scavenge	
11.	Combustor mounting pins (Qty 10)		37.	A-sump oil supply plug	
12.	Combustor boroscope plugs (Qty 6)		38.	Inlet pressure probe tube	
13.	CRF cover plate		39.	VSV tubes/couplings	
14.	HPT cooling tube adapter		40.	C-sump oil supply tube	
15.	HPT cooling tube, flexible coupling		41.	Overspeed electrical lead	
16.	PT vibration transducer (velocity PN)		42.	D-sump oil supply tube	
17.	D-sump vent manifold		43.	D-sump scavenge tube and plug	
19.	Cover plate, TRF		44.	D-sump oil supply and scavenge tubes	
20.	Thermocouple connectors, (Qty 5)		45.	C-sump drain tube	
21.	$P_{t5.4}$ probe nuts		46.	C-sump oil supply tube	
22.	Thermocouple probe nuts (Qty 11)		47.	C-sump scavenge tube	
23.	HPT cooling tube, flexible coupling		48.	C and D-sump check valve (before GTC 51) C and D lube supply tube connection (after GTC 51)	
24.	HPT cooling tube adapter		49.	C-sump scavenge tube	
25.	HPT cooling tube, flexible coupling (Qty 2)		50.	CDP bleed air tube	
26.	TMF cooling tube, flexible coupling (Qty 2)		51.	Tubes to Main Fuel Control (MFC)	
27.	VSV feedback cable jam nut		52.	VSV actuator tube/hose connections	
28.	VSV feedback cable and MFC adjustment		53.	Fuel supply hose	
			54.	VSV actuator tube/connections	

Table 2-31. Safety-Wire Checklist for Figure 2-94

Gas Turbine Single Shank					
1.	Cover Plate, CFF		29.	PLA actuator turnbuckle jam nuts	
2.	Inlet pressure probe		30.	VSV feedback cable jam nut	
3.	VSV actuator jam nut		31.	Compressor case bracket	
4.	VSV actuator shroud		32.	VSV feedback cable jam nut	
5.	VSV feedback link jam nuts		33.	QAD ring	
6.	VSV bridge connector bolts (Qty 28 on each side of gas turbine as required)		34.	Gearbox plug	
7.	VSV link jam nuts (Qty 14 on each side)		35.	CIT sensor nipples	
8.	Compressor case bracket		36.	CIT sensor to frame	
9.	Compressor case bracket			The Following Do Not Require Safety-Wire:	
10.	VSV actuation lever aft mount		18.	Nipple, D-sump scavenge	
11.	Combustor mounting pins (Qty 10)		37.	A-sump oil supply plug	
12.	Combustor boroscope plugs (Qty 6)		38.	Inlet pressure probe tube	
13.	CRF cover plate		39.	VSV tubes/couplings	
14.	HPT cooling tube adapter		40.	C-sump oil supply tube	
15.	HPT cooling tube, flexible coupling		41.	Overspeed electrical lead	
16.	PT vibration transducer (velocity PN)		42.	D-sump oil supply tube	
17.	D-sump vent manifold		43.	D-sump scavenge tube and plug	
19.	Cover plate, TRF		44.	D-sump oil supply and scavenge tubes	
20.	Thermocouple connectors, (Qty 5)		45.	C-sump drain tube	
21.	$P_{t5.4}$ probe nuts		46.	C-sump oil supply tube	
22.	Thermocouple probe nuts (Qty 11)		47.	C-sump scavenge tube	
23.	HPT cooling tube, flexible coupling		48.	C and D-sump check valve (before GTC 51) C and D lube supply tube connection (after GTC 51)	
24.	HPT cooling tube adapter		49.	C-sump scavenge tube	
25.	HPT cooling tube, flexible coupling (Qty 2)		50.	Compressor Discharge Pressure (CDP) bleed air tube	
26.	TMF cooling tube, flexible coupling (Qty 2)		51.	Tubes to MFC	
27.	VSV feedback cable jam nut		52.	VSV actuator tube/hose connections	
28.	VSV feedback cable and MFC adjustment		53.	Fuel supply hose	
			54.	VSV actuator tube/connections	

Table 2-32. Safety-Wire Checklist for Figure 2-95, Figure 2-96, Figure 2-97, and Figure 2-98

Gas Turbine Figure 2-95					
1.	Fuel nozzles (Qty 30)		12.	Electrical connector, scavenge oil	
4.	Electrical connectors (Qty 4)		13.	V-band clamp, lube and scavenge pump	
5.	Vibration pickup		14.	Electrical connector, scavenge oil	
6.	Compressor case bracket		15.	Electrical connectors (ref BEA)	
7.	Ignition exciter shock mount		16.	Spark ignitor leads and adapters (Qty 2)	
8.	Ignition input leads (Qty 2)		17.	GG accelerometer mount bolts	
9.	Ignition exciter shock mount		The Following Do Not Require Safety-Wire:		
10.	Gearbox link		2.	Fuel nozzle shroud/feeder tube (Qty 30)	
11.	Gearbox mount		3.	Fuel nozzle shroud/feeder tube	
Gas Turbine, Figure 2-96					
1.	Lube nozzle plug		10.	Lube oil supply	
2.	Gas Generator speed pickup		11.	Lube oil supply	
3.	Drain plug		12.	V-band clamp	
4.	Drain plug		13.	Inlet pressure probe tube	
5.	Air-oil separator drain tube		14.	Gearbox drain tube	
6.	Air-oil separator drain tube		15.	Gearbox drain tube	
7.	Sump vent tube		16.	Gearbox drain tube	
The Following Do Not Require Safety-Wire			17.	Gearbox drain tube	
8.	Air-Oil separator seal pressure		18.	Gearbox drain tube	
9.	Lube oil supply		19.	Gearbox drain tube	
			20.	A-sump scavenge line	
Gas Turbine, Figure 2-97 and Figure 2-98					
1.	Electrical connector, fuel shutdown valve		The Following Do Not Require Safety-Wire:		
2.	Fuel manifold shroud drain		12.	Scavenge oil tube/hose connectors	
3.	Electrical connector, fuel shutdown valve		13.	Scavenge pump tubes	
4.	Electrical connector, scavenge oil		14.	Oil supply tubes and caps	
5.	Electrical connector, scavenge oil		15.	A-sump scavenge hose/tube	
6.	Electrical connector, scavenge oil		16.	Lube and scavenge pump drain	

Table 2-32. Safety-Wire Checklist for Figure 2-95, Figure 2-96, Figure 2-97, and Figure 2-98 - Continued

7.	Starter drain plug		17.	Starter fill port (Qty 2)	
8.	Gearbox mount and link		18.	PLA actuator electrical connector	
9.	Electrical connector, starter		19.	Fuel pressurizing valve connectors	
10.	Starter vent plug		20.	Fuel pressurizing valve connectors	
11.	Fuel filter drain plug		21.	Fuel supply tube/hose connectors	
22.	Fuel manifold flex hose (2 places)		24.	Lube and scavenge pump plugs (6 places)	
23.	Fuel manifold fittings (2 places)				

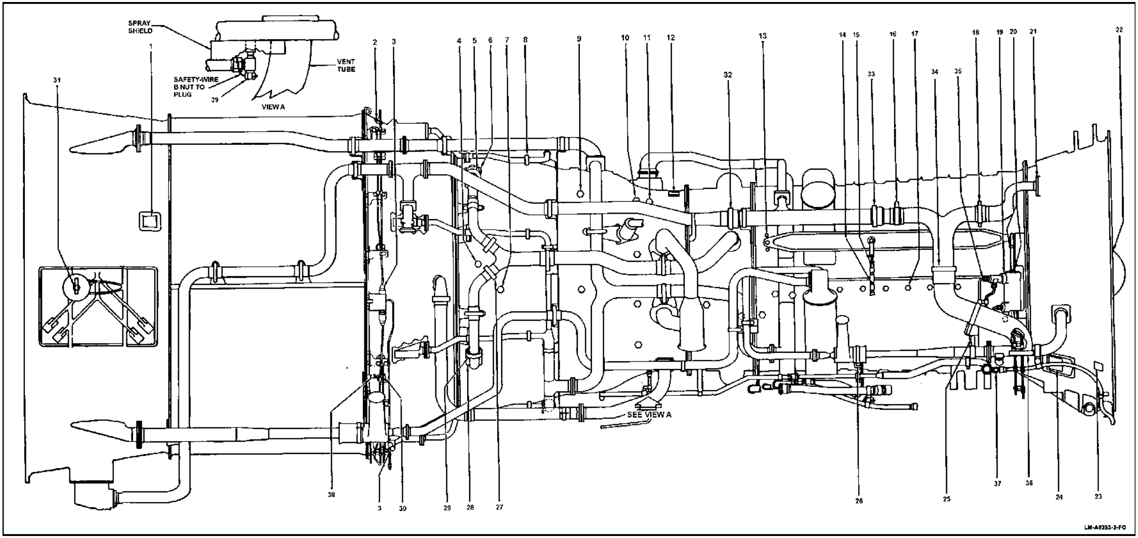


Figure 2-91. Safety-Wire Locations (Gas Turbine Paired Blade)

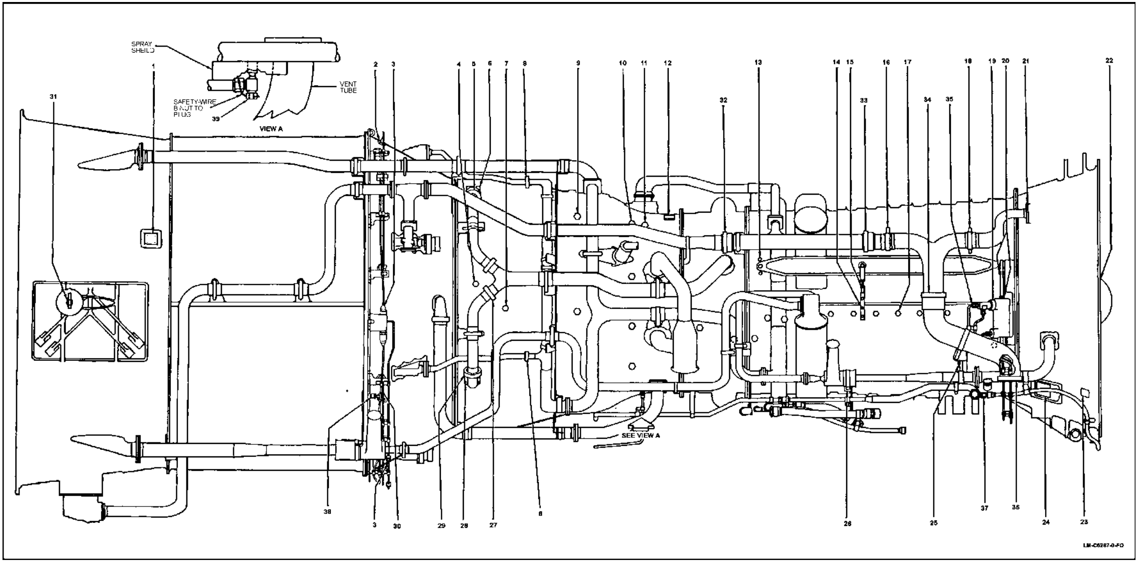


Figure 2-92. Safety-Wire Locations Single Shank/C-Sump Revent Configuration

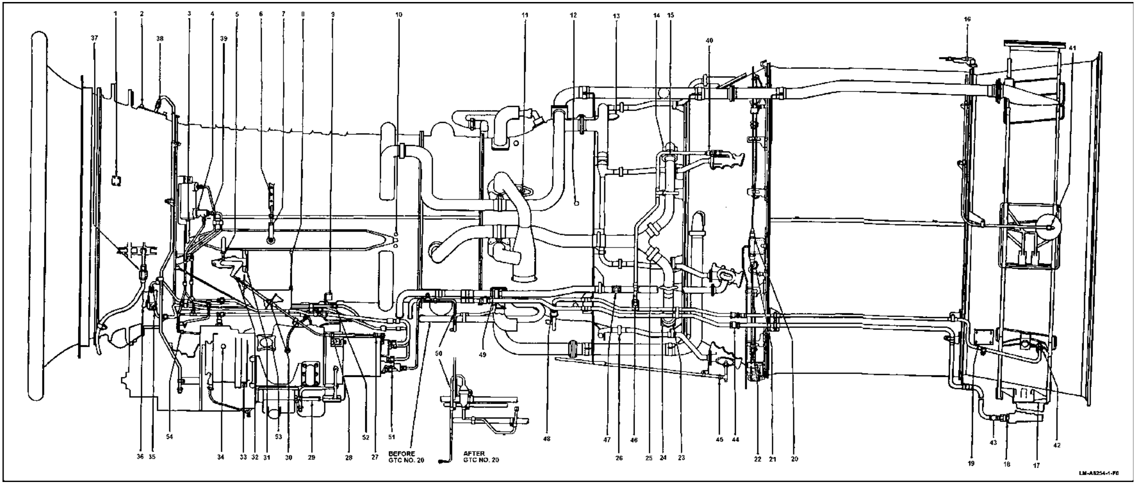


Figure 2-93. Safety-Wire Locations (Gas Turbine Paired Blade)

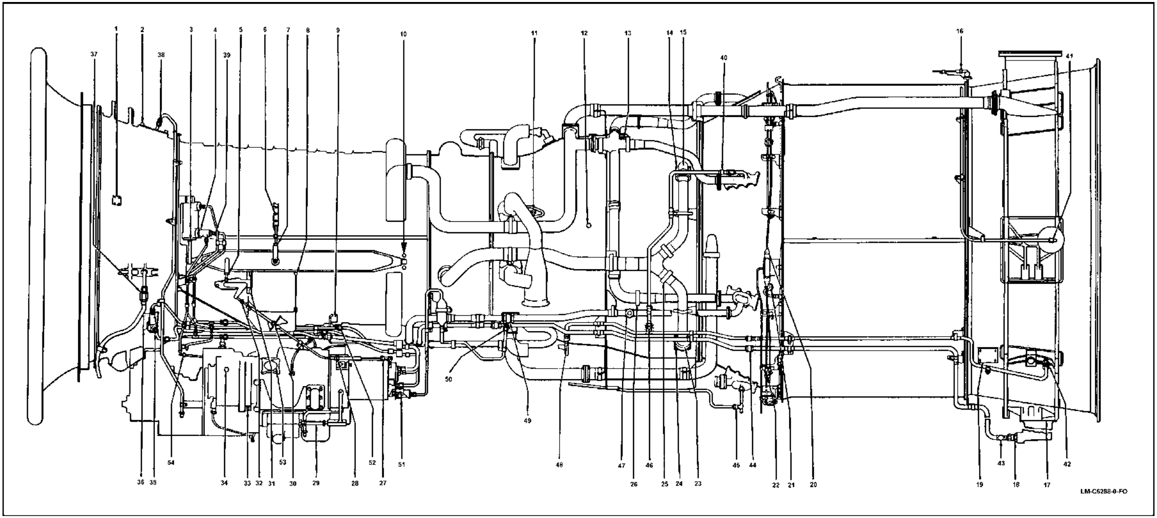
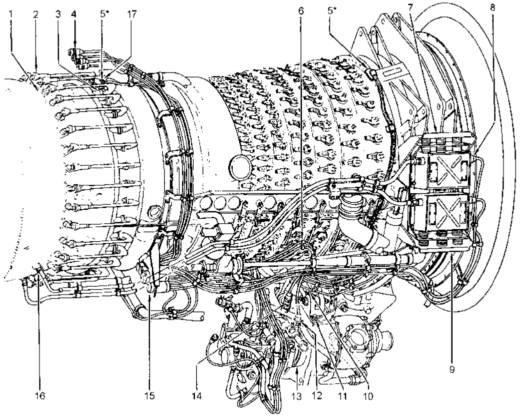


Figure 2-94. Safety-Wire Locations (Single Shank/C-Sump Revent Configuration)



LEGEND:

1. FUEL NOZZLES (QT7 30)
2. FUEL NOZZLE SHROUD (QTY 30)
3. FUEL NOZZLE SHROUD (QTY 30)
4. ELECTRICAL CONNECTORS (QTY 4)
*5. VIBRATION PICKUP
6. COMPRESSOR CASE BRACKET (AS REQUIRED)
7. IGNITION EXCITER SHOCK MOUNT
8. IGNITION INPUT LEADS (QTY 2)
9. IGNITION EXCITER SHOCK MOUNT
10. GEARBOX LINK
11. GEARBOX MOUNT
12. ELECTRICAL CONNECTOR, SCAVENGE OIL
13. V-BAND CLAMP, LUBE AND SCAVENGE PUMP
14. ELECTRICAL CONNECTOR, SCAVENGE OIL
15. ELECTRICAL CONNECTORS (REF BASE/ENCLOSURE)
16. SPARK IGNITER LEADS AND ADAPTERS (QTY 2)
17. ACCELEROMETER MOUNT BOLTS

* VIBRATION PICKUP (5) INSTALLED IN EITHER LOCATION

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Figure 2-95. Safety-Wire Locations

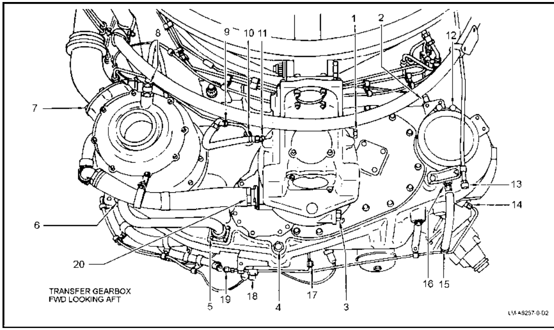


Figure 2-96. Safety-Wire Locations

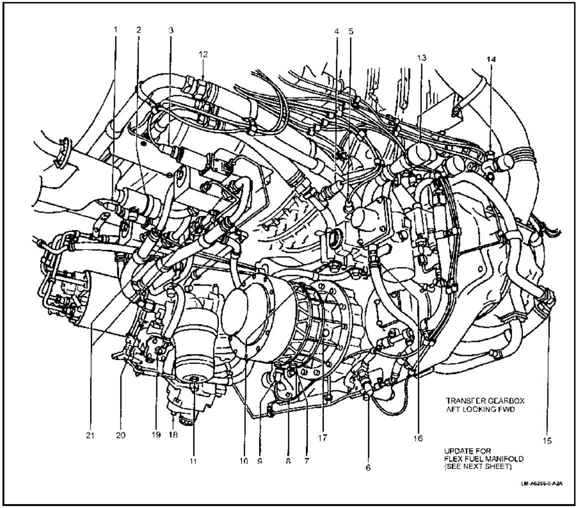


Figure 2-97. Safety-Wire Locations

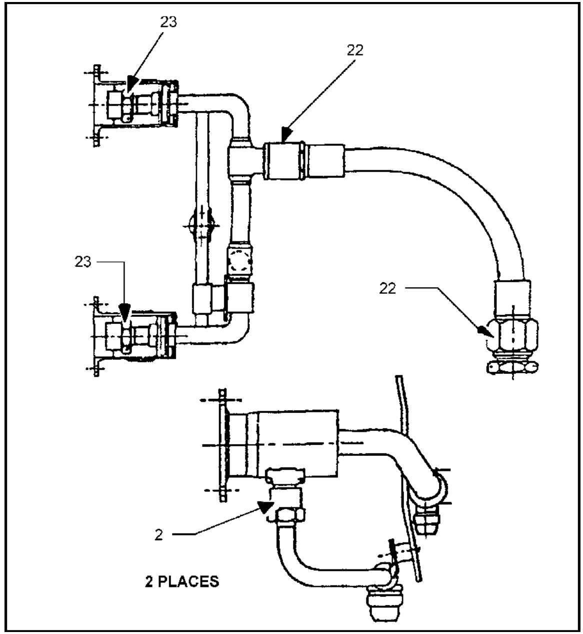


Figure 2-98. Safety-Wire Locations for LM2500 Flex Fuel Manifold

2.12 SAFETY CABLING

(Ref: S9234-AD-MMO-050/LM2500)

Safety cable is an alternative to safety-wire. Safety cable is installed through two or more parts in such a way that as the fastener or part loosens the safety cable will tighten. When the safety cable tightens it will not permit the fastener or part to turn. When installing safety cable, a basic pattern of procedures is followed. However, depending upon the specific tool being used, certain steps will vary.

NOTE

Safety cabling tools and equipment can be procured from either Bergen Cable Technologies, Inc., Gregg St., P.O. Box, 1300 Lodi, NJ 07644 or Snap-on Tool Co., 2801 - 80th St., Kenosha, WI 53141-1401.

a. The safety cable system has three components: The safety cable, ferrules and crimping tool. See Figure 2-99.

(1) The safety cable is available in one size, 0.032-inch (0.81-mm), and is made of AMS 5689 (321 stainless steel) material. One end of the cable will have a cable end fitting swaged to it. The cable end fitting is made of AMS 5674 (347 stainless steel) or AMS 5689 (321 stainless steel) material. The strands of the cable on the opposite end of the cable are fused together to prevent the cable from fraying.

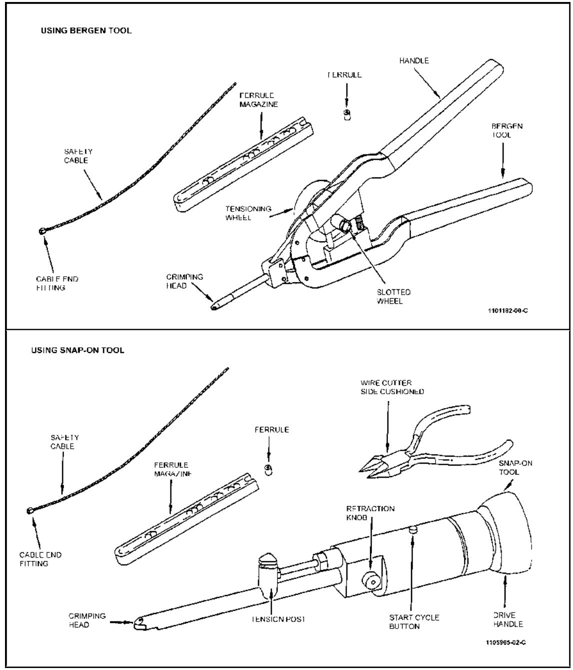


Figure 2-99. Safety Cable System Components

(2) The ferrules are made of AMS 5674 (347 stainless steel) or AMS 5689 (321 stainless steel) material and are purchased in a spring-loaded, disposable magazine. When the safety cable is installed the ferrule will be crimped on the open end of the cable.

(3) The crimping tool will differ depending on the manufacturer:

(a) Bergen Tool: The hand operated crimping tool comes in different lengths. The crimping pressure tool is set by the manufacturer. The primary parts of the crimping tool are the crimping head, tensioning wheel, slotted wheel and handles. This tool is used to crimp the ferrule on the end of the safety cable. The crimping tool will cut the safety cable even with the ferrule at the same time the ferrule is crimped.

(b) Snap-On Tool: The hand operated crimping tool operates in one direction only and has a cycle end dead stop to tell the operator when the ferrule is fully crimped. The crimping pressure of the tool is set by the manufacturer. If necessary, the crimping pressure can be adjusted with standard hand tools. The Snap-On tool has a spring-loaded crimp rod to hold the ferrule in place during the crimping procedure. Cable tension is done automatically by the internal retraction mechanism.

b. Observe the following rules for safety cabling:

(1) Where possible, install the safety cable so it does not touch other parts.

(2) Make sure the cable is not damaged or bent when you install the safety cable through the holes in the fastener or part. Frayed cable assemblies are not permitted.

(3) Install the safety cable through existing holes only.

(4) Unless specified differently in the engine manual:

(a) The maximum length of the safety cable between safety cabled parts is six inches (152.4 mm).

(b) Do not safety cable more than three bolts with one safety cable.

(c) Do not use safety cable on titanium fasteners.

c. Detailed Safety Cable procedures are located in S9234-AD-MM0-050/LM2500.

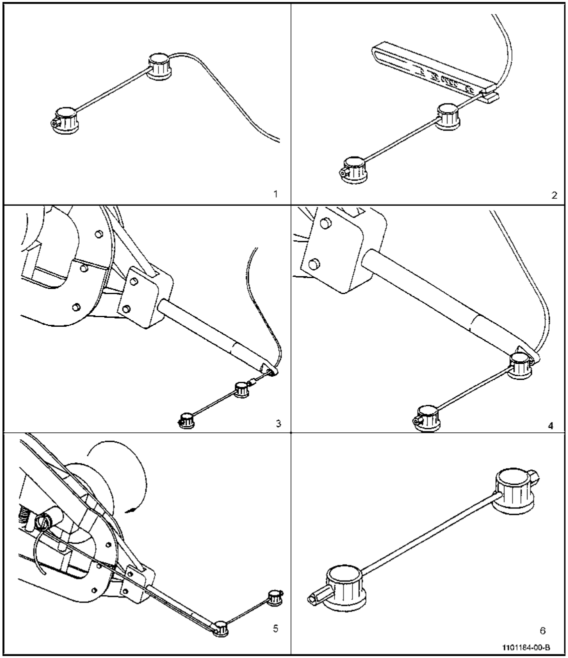


Figure 2-100. Safety Cable Procedure (Bergen Tool)

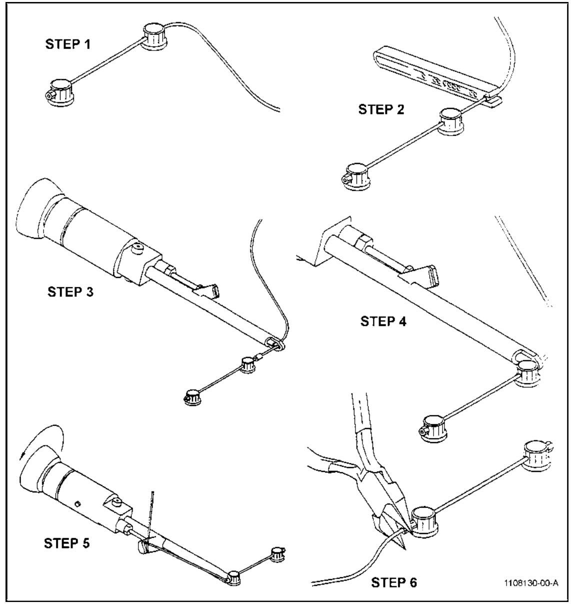


Figure 2-101. Safety Cable Procedure (Snap-On Tool)

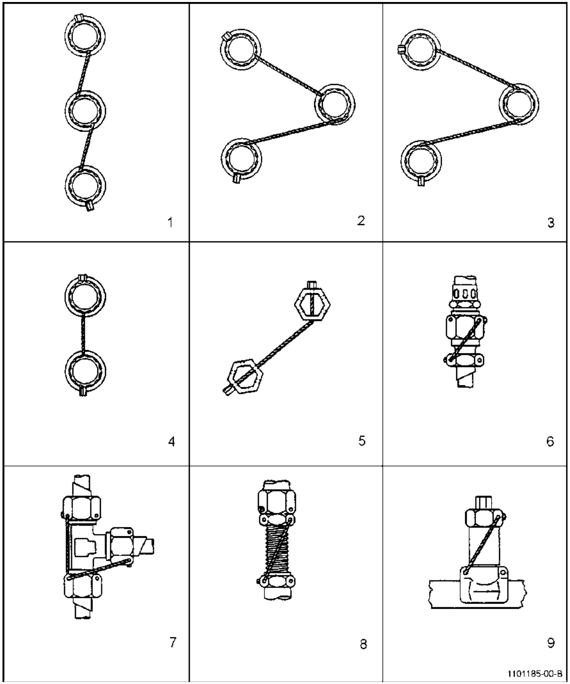


Figure 2-102. Safety Cable Patterns

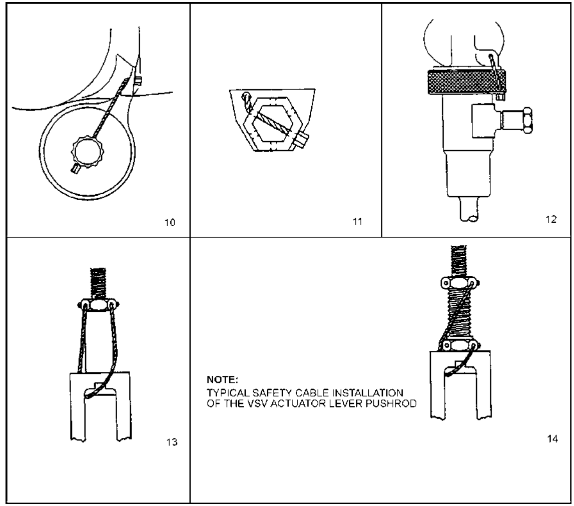
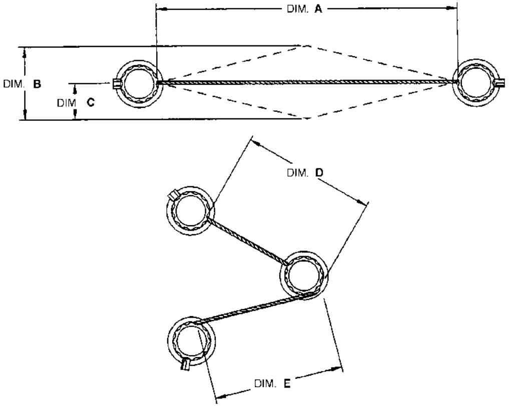


Figure 2-103. Safety Cable Patterns (Cont.)

NOTE

Although every possible combination of safety cabling is not shown in Figure 2-102 and Figure 2-103, all safety cabling must conform generally to the examples shown.



FOR THREE BOLT PATTERNS
DIM. A = DIM. D + DIM. E

DIM. A	DIM. B	DIM. C
0.5 IN. (13 MM)	0.125 IN. (3.18 MM)	0.062 IN. (1.57 MM)
1.0 IN. (25 MM)	0.250 IN. (6.35 MM)	0.125 IN. (3.18 MM)
2.0 IN. (51 MM)	0.375 IN. (9.53 MM)	0.188 IN. (4.78 MM)
3.0 IN. (76 MM)	0.375 IN. (9.53 MM)	0.188 IN. (4.78 MM)
4.0 IN. (102 MM)	0.500 IN. (12.70 MM)	0.250 IN. (6.35 MM)
5.0 IN. (127 MM)	0.500 IN. (12.70 MM)	0.250 IN. (6.35 MM)
6.0 IN. (152 MM)	0.625 IN. (15.88 MM)	0.312 IN. (7.92 MM)

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Figure 2-104. Safety Cable Flex Limits

2.13 TORQUE, V-BAND CLAMPS, HOSES, CLAMPS AND ELECTRICAL CABLES AND CONNECTORS

(Ref: S9234-AD-MMO-050/LM2500)

During maintenance procedures, all threaded parts on the GT will be tightened to specific torques. Special torque values, if required, will be stated in the text; otherwise, standard torque values should be used.

a. Torque values are expressed as inlb (inch-pound) or FTLB (foot-pound). One inch-pound (or one foot-pound) is the twisting force of one pound applied to a twist-type fastener (such as a bolt or nut) with one inch (or one foot) of leverage. This twisting force is applied to the fastener to secure the components.

b. Never over-tighten a fastener. Torque limits are provided in the text and in Table 2-33 through Table 2-36; these limits must be observed.

c. Do not use lubricant on bolt threads unless specified in assembly procedures. Start threads at least two turns by hand to ensure proper engagement.

CAUTION

If torque increases significantly before final seating of any threaded fastener, remove and inspect the fastener for cause of torque increase.

d. Tightening Procedures:

CAUTION

When chilling or heating GT parts during assembly, do not torque spanner nuts, locknuts, or retaining bolts until the parts have returned to room temperature. The fastener may loosen as the part cools. If the part has been chilled, the fastener may be over-stressed as the part warms and expands.

(1) If possible, tighten at a uniformly increasing rate until the desired torque is obtained. In cases where gaskets or other parts cause a slow permanent set, be sure to hold the torque at the desired value until the material is seated.

(2) Apply a uniform torque to a series of bolts that have different diameters and are installed on one flange or in one area. This torque shall be less than the required final torque for the smallest diameter bolt. This prevents shearing or breaking bolts because of force concentrations.

(3) It is not desirable to tighten to the final torque value during the first drawdown; uneven tension can cause distortion or overstressing of parts. Torque mating parts by drawing down the bolts or nuts gradually until the parts are firmly seated; then loosen each one separately, a quarter turn, and apply final tightening. Tightening in a diametrically opposite (staggered) sequence is desirable in most cases. (See Figure 2-105) Do not exceed listed maximum torque values.

e. Install all bolts with heads forward and up and with nuts aft and down, unless otherwise specified.

f. Washers are always installed beneath the part, which turns when tightening, unless otherwise specified.

g. The torque wrenches listed in Table 2-37 are recommended for use within the indicated ranges. Larger wrenches have too great a tolerance, and use of these wrenches can result in inaccuracies.

h. Torque values specified in this manual are actual values to be applied to fasteners. Whenever an adapter (crowfoot, spanner wrench, etc.) is used with a torque wrench, torque must be calculated per Figure 2-106.

i. Inspect all nuts and bolts after tightening to ensure they are seated. If nut/bolt is not seated after required torque has been applied, remove it and inspect for thread damage.

j. Lubricate tube/hose connector threads and between the B-nut and ferrule of a connector. Run B-nuts onto fittings with the fingers to ensure that tubes and holes are aligned and that threads are free of burrs. Two wrenches must be used when loosening or tightening B-nuts, one on the fitting to which the tube or hose is being connected to hold it stationary, and one on the B-nut for torquing. This not only prevents twisting the tube, but also prevents loosening or over-torquing the fitting. When using an extension on a torque wrench, calculate the correct torque input before applying torque.

k. Breakaway (Running) Torque. Refer to Table 2-38 for minimum breakaway torque on self-locking nuts. This table applies to silver-plated, lubricated, and non-lubricated self-locking nuts. Values given are for nuts with no axial load. To check minimum break-away torque, screw the nut onto a bolt until two to five threads are exposed beyond the nut. Measure the amount of torque required to turn the nut on or off the bolt. Nuts that do not meet these minimum frictional requirements should be replaced.

l. Standard Torque. Use the following standard torque tables, unless otherwise directed in the text.

(1) Use the torque values given in Table 2-33 for steel bolts and nuts (including self-locking nuts). Values given are for clean bolts and nuts that are free of nicks and burrs.

(2) Use half of the value given in Table 2-33 for the following applications:

(a) Thin steel hex nuts. (These nuts have a height of less than 0.6 of the inside diameter for plain nuts and less than 0.8 of the inside diameter for selflocking nuts.)

(b) Non-steel nuts and bolts except titanium.

(c) All bolts threaded directly into aluminum, magnesium or other non-steel parts.

(3) Use the torque values given in Table 2-34 and Table 2-36 for gasketed fittings. Install fittings as illustrated in Figure 2-107. Torque values given in Table 2-34 and Table 2-36 are for packings or O-rings made of synthetic material or asbestos compounds or soft metal (copper, aluminum, etc.). These values do not apply to steel gaskets or special boss seals.

(4) Use torque values given in Table 2-35 for tubing nuts and hose fittings.

m. Loose Fasteners. Prior to retorque, examine fastener for cause of looseness. If safety-wire is missing, tighten to required torque and safety-wire. If fastener has self-locking feature, check breakaway torque per step k. Replace defective fastener.

Table 2-33. Torque Values For Steel Bolts, Nuts, and Self-Locking Nuts

Size and Threads Per Inch	Torque Value
8-32	13-16 inlb
10-24	20-23 inlb
1/4-20	40-60 inlb
5/16-18	70-110 inlb
3/8-16	160-210 inlb
7/16-14	250-320 inlb
1/2-13	420-510 inlb
8-36	16-19 inlb
10-32	33-37 inlb
1/4-28	55-70 inlb
5/16-24	100-130 inlb
3/8-24	190-230 inlb
7/16-20	300-360 inlb
1/2-20	480-570 inlb

Table 2-34. Torque Values for Plugs and Unions

Tubing OD	Fitting Dash No.	Torque Value	Torque Units
1/8	2	40-50	inlb
3/16	3	90-100	inlb
1/4	4	135-150	inlb
5/16	5	155-175	inlb
3/8	6	180-200	inlb
1/2	8	270-300	inlb
5/8	10	360-400	inlb
3/4	12	45-50	FTLB
1	15	58-70	FTLB
1 1/4	20	75-87	FTLB
1 1/2	24	83-100	FTLB

Table 2-35. Torque Values for Tubing Nuts and Hose Fittings

Tube OD	Hose Dash No.	Aluminum Female Sealing Surfaces*	Steel Female Sealing Surfaces**	Torque Units
0.125 (1/8)	-2	-	40-50	inlb
0.1875 (3/16)	-3	30-50	90-100	inlb
0.250 (1/4)	-4	40-65	135-150	inlb
0.3125 (5/16)	-5	60-80	180-200	inlb
0.375 (3/8)	-6	75-125	270-300	inlb
0.500 (1/2)	-8	150-250	450-550	inlb
0.625 (5/8)	-10	200-350	650-770	inlb
0.750 (3/4)	-12	25-41	75-91	FTLB
1.000 (1)	-16	41-58	112-128	FTLB
1.250 (1 1/4)	-20	50-75	133-150	FTLB

Table 2-35. Torque Values for Tubing Nuts and Hose Fittings - Continued

Tube OD	Hose Dash No.	Aluminum Female Sealing Surfaces*	Steel Female Sealing Surfaces**	Torque Units
1.500 (1 1/2)	-24	50-75	158-183	FTLB
* These values apply when female sealing surface is aluminum. Male connector and nut may be either steel or aluminum.				
** These values apply when female sealing surface is steel. Male connector and nut may be either aluminum or steel.				

Table 2-36. Torque Values for Plugs and Unions Used In Bosses and for Universal Bulkhead Fitting Locknuts

Size	Thread Size	Torque (inlb)	Torque (FTLB)
-2	0.3125-24	40-50	-
-3	0.375-24	90-100	-
-4	0.4375-20	135-150	-
-5	0.500-20	155-175	-
-6	0.5625-18	180-200	-
-8	0.750-16	270-300	-
-10	0.875-14	360-400	-
-12	1.0625-12	540-600	45-50
-16	1.3125-12	700-850	58-70
-20	1.625-12	900-1050	75-87
-24	1.875-12	1000-1200	83-100

Table 2-37. Torque Wrench Size

Torque Between	Torque Wrench
0-25 inlb	30 inlb
25-140 inlb	150 inlb
140-550 inlb	600 inlb
30-140 FTLB	150 FTLB
140-240 FTLB	250 FTLB
240-1000 FTLB	1000 FTLB

Table 2-38. Minimum Breakaway Torque for Self-Locking Nuts

Thread Size	Threads/Inch	Minimum Breakaway Torque (inlb)
0.136 (6)	32/40	1.0
0.164 (8)	32/36	1.5
0.190 (10)	32	2.0
1/4	28	3.5
5/16	24	6.5
3/8	24	9.5
7/16	20	14.0
1/2	20	18.0
9/16	18	32.0
5/8	18	50.0
3/4	16	50.0

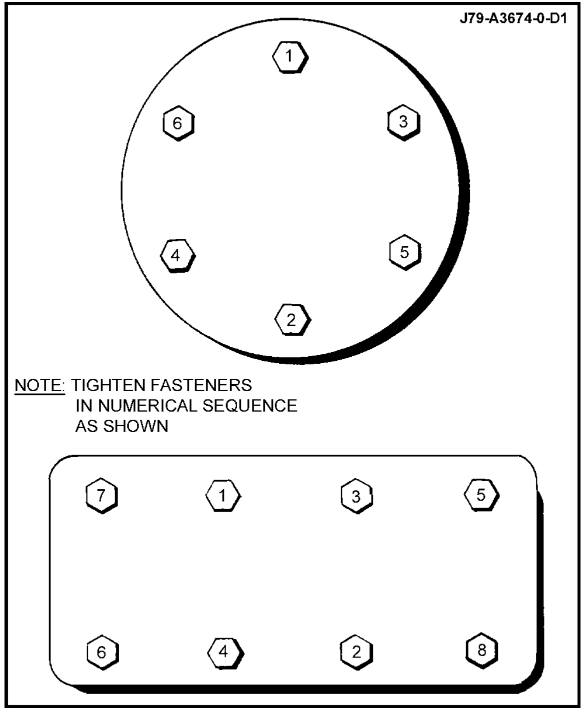


Figure 2-105. Sequence of Tightening Threaded Fasteners

1. WHEN AN ADAPTER IS BEING USED WITH A TORQUE WRENCH, THE EFFECTIVE LENGTH OF THE WRENCH IS CHANGED. WHEN USING AN ADAPTER, THE TORQUE WHICH APPEARS ON THE DIAL OR GAGE OF THE WRENCH WILL BE DIFFERENT FROM THE ACTUAL AMOUNT OF TORQUE APPLIED TO THE NUT OR BOLT. THEREFORE, THE WRENCH MUST BE SET TO COMPENSATE FOR THE INCREASE OR DECREASE IN ACTUAL TORQUE COMPARED TO THE INDICATED TORQUE

2. THE EFFECTIVE LENGTH OF THE ADAPTER MAY BE DETERMINED BY MEASURING FROM THE CENTER OF THE SOCKET OPENING TO THE CENTER OF THE WRENCH OPENING, PARALLEL TO THE CENTER-LINE OF THE TORQUE WRENCH.

3. THE EFFECTIVE LENGTH OF THE TORQUE WRENCH MAY BE DIFFERENT FOR EACH TYPE OF WRENCH. THE EFFECTIVE LENGTH IS THE DISTANCE BETWEEN THE CENTER-LINE OF THE DRIVE SQUARE AND THE CENTER-LINE OF THE FORCE APPLIED AT THE HANDLE (CENTER OF HAND HOLD).

4. THE ADDITION OF THE EFFECTIVE LENGTH OF THE ADAPTER (E) IS DETERMINED BY THE POSITIONING OF THE ADAPTER ON THE WRENCH. WHEN THE ANGLE BETWEEN THE TORQUE WRENCH AND ADAPTER IS 90°, THE EFFECTIVE LENGTH OF THE WRENCH IS UNCHANGED (SEE VIEW B). WHEN THE ANGLE IS GREATER THAN 90° (SEE VIEW A) THE EFFECTIVE LENGTH (E) OF THE ADAPTER WILL BE ADDED TO THE EFFECTIVE LENGTH (L) OF THE WRENCH. WHEN THE ANGLE IS LESS THAN 90° (SEE VIEW B) THE EFFECTIVE LENGTH (E) OF THE ADAPTER IS SUBTRACTED FROM THE EFFECTIVE LENGTH (L) OF THE WRENCH

5. WHEN USING AN ADAPTER, THE INDICATED TORQUE MAY BE COMPUTED BY USING THE FOLLOWING FORMULA

$$I = \frac{TL}{L \pm E}$$

T = DESIRED TORQUE
I = TORQUE INDICATED ON WRENCH
L = EFFECTIVE LENGTH OF TORQUE WRENCH
E = EFFECTIVE LENGTH OF ADAPTER

EXAMPLE OF VIEW A

I = ?
T = 265 INCHES - POUND
L = 8.5 INCHES
E = 1.5 INCHES

STEP 1 $I = \frac{TL}{L + E}$	STEP 2 $I = \frac{265 \times 8.5}{8.5 + 1.5}$
STEP 3 $I = \frac{2252.5}{10}$	STEP 4 I = 225 INCHES - POUND (APPROXIMATE)

EXAMPLE OF VIEW B

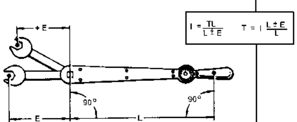
I = ?
T = 265 INCHES - POUND
L = 8.5 INCHES
E = 1.5 INCHES

STEP 1 $I = \frac{TL}{L - E}$	STEP 2 $I = \frac{265 \times 8.5}{8.5 - 1.5}$
STEP 3 $I = \frac{2252.5}{7}$	STEP 4 I = 322 INCHES - POUND (APPROXIMATE)

NOTE

IS EFFECTIVE LENGTH (E) OF THE ADAPTER IS 2 INCHES OR LESS AND THE ANGLE IS GREATER THAN 90° (SEE VIEW A), TORQUE TO LOWER HALF OF SPECIFIED TORQUE RANGE. IF THE LENGTH (E) OF THE ADAPTER IS 2 INCHES OR LESS AND THE ANGLE IS LESS THEN 90° (SEE VIEW B) TORQUE TO UPPER HALF OF SPECIFIED TORQUE RANGE.

VIEW A



VIEW B

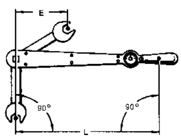


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Figure 2-106. Determining Torque Wrench Correction Factors

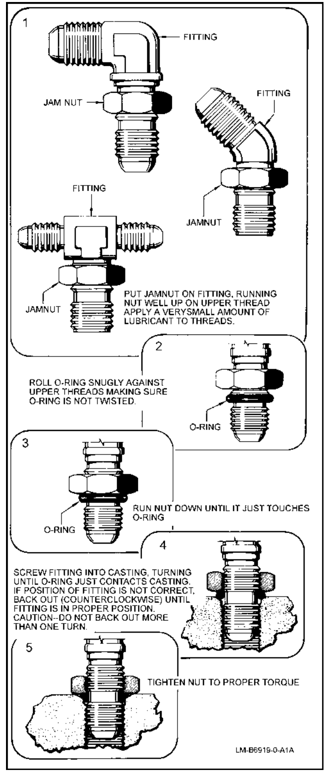

Figure 2-107. Installation of Universal Fittings

2.13.1 V-Band Clamps Install V-band clamps as follows:

a. Tighten nut to half of required torque value. Check around clamp for even seating over flanges.

b. Using a nonmetallic mallet, lightly tap around clamp to distribute band tension.

c. While increasing torque to required value, continue tapping around clamp.

d. After reaching required torque, tap around clamp again and re-check torque.

2.13.2 Hoses

CAUTION

No hose should be bent more than the bend radius specified in Table 2-39, especially when the parts are cold, because of possible damage to the Teflon liners. Kinked hoses must not be used. During installation, be sure that no hose is twisted or stretched; never over-torque connectors. When hoses are removed, cap the open ends. Do not use tape.

a. Fluid fittings shall be tightened gradually to the required torque value, backed off a quarter turn, and then tightened again. Do not attempt to correct a leak by excessive tightening. Always use two wrenches when tightening swivel coupling nuts on hoses, tubes, or fittings. Hold the stationary part with one wrench while applying torque with second wrench. Apply GT lube oil between tube/hose coupling nut and ferrule prior to tightening. See Figure 2-108.

b. Pre-formed hoses or hoses of large diameter shall not be bent or straightened (see Figure 2-109). When hoses are removed, cap the open ends. Do not use tape.

c. Before installing pre-formed hoses, visually inspect the hose interior to ensure that the Teflon lining has not been damaged. If damaged, replace the hose.

Table 2-39. Hose Minimum Bend Radii

Dash no.	Minimum Bend Radius (inches)
-3	1.50
-4	2.00
-5	2.00
-6	4.00
-8	4.62
-10	5.50
-12	6.50
-16Z	7.38
-20Z	11.00
-24Z	14.00
-32	22.00

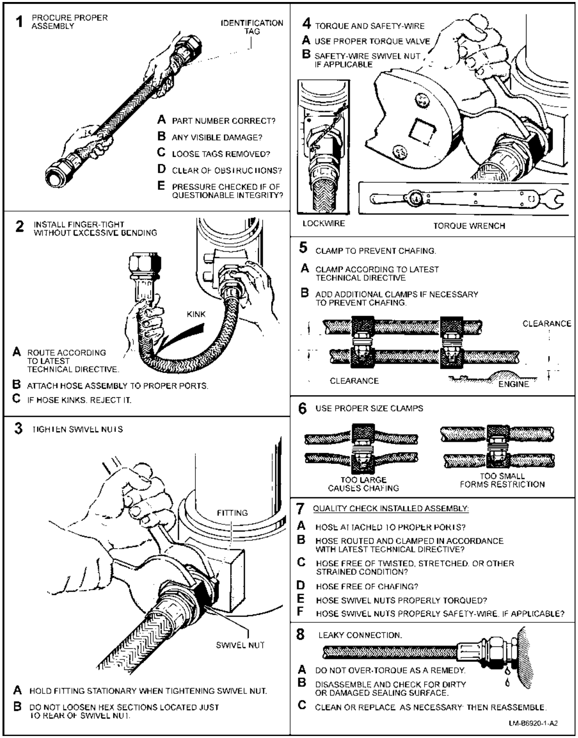

Figure 2-108. Installation of Hose Assemblies

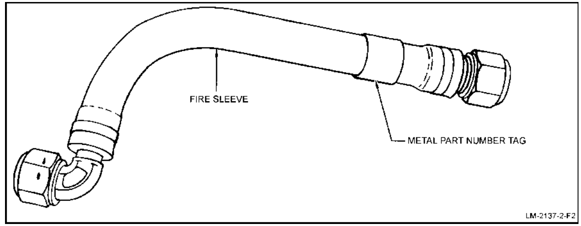

Figure 2-109. Factory Pre-formed Hoses

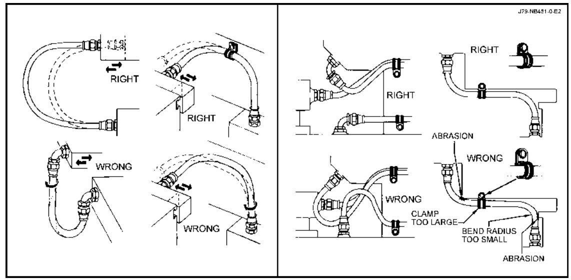

Figure 2-110. Routing and Clamping

2.13.3 Clamps Chafing of hoses and tubes must be avoided. Clamp these parts loosely in place, shift the hoses about until the best clearance is obtained, and then tighten the clamps. See Figure 2-110. Clamps must be of the proper size for the piping to permit slippage during engine thermal growth. For Series R355 and R356 clamps, lining position must be checked. Figure 2-111 shows correct lining location.

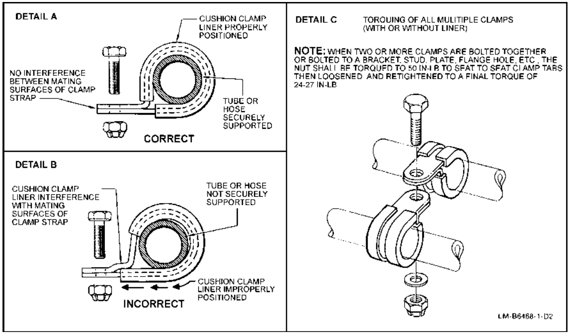

Figure 2-111. Installation of Cushion Clamps

2.13.4 Electrical Cables and Connectors During electrical cable installation, adjust the cable through the clamps to get the smoothest and largest radii. Sharp bends, twists, and kinks must be avoided. Minimum clearance between the electrical cable and any component other than hoses or other electrical cables is 1/8-inch.

CAUTION

Do not force the connectors together. If pins are not aligned, they will be bent or distorted and will not make complete contact.

a. Inspect electrical connector pins for straightness before connecting. Then insert the mating cable connector, hand-tighten the retaining nut, push the mating parts together until seated, and tighten the retaining nut as required.

b. A seal ring is located in coupling nut of each electrical connector. Inspect to make sure seal is present and serviceable before attaching the connector. Replace unserviceable seals as follows:

(1) Remove unserviceable seal.

(2) Engage new seal over barrel of connector.

CAUTION

Do not allow the seal to tip and flatten on the connector or seal's usefulness will be destroyed.

(3) Push the seal to seated position against the internal shoulder in the connector using a mating connector or blunt screw driver.

c. Electrical connectors on flexible harnesses and leads shall be hand-tightened beyond finger-tight (20 maximum) until connecting parts are in solid contact without damage. Electrical connectors, especially connectors without knurled surfaces, are to be tightened with Teflon-jawed pliers, UTICA no. 529 in order to make solid contact. Do not over-tighten. Safety-wire electrical connectors.

2.14 SHIPBOARD SPECIAL SUPPORT EQUIPMENT (SSE) REQUIREMENTS

(Ref: MRC 2340, R-25 Inspect and Inventory Condition of LM2500 Special Support and Test Equipment and S9234-AA-MMA-000/LM2500).

MRC check 2340, R-25, must be accomplished in accordance with GROOM INSPECTION prior to a deployment of 90 days.

The following is a general overview for performing Inspect and Inventory Condition of LM2500 Special Support and Test Equipment (Ref: MRC 2340, R-25). Always refer to and follow the MRC requirements when performing inspection and inventory.

2.14.1 Inspect and Inventory Condition of LM2500 Special Support and Test Equipment

NOTE

Refer to TM S9234-AA-MMA-000/LM2500 for part numbers of damaged or missing parts.

a. Using inventory sheet, record location of all support equipment.

b. Inspect each item for damage, missing parts, or lack of preservation.

c. Put on protective gear.

d. Inspect the following equipment accordingly:

(1) Stator Actuator Pressurizer.

(a) Inspect unit for damage and leaks.

(b) Replace damaged parts and tighten leaky joints

WARNING

Lube oil may cause dermatitis after prolonged contact. Wear gloves, apron, and goggles. If contact occurs, wash skin thoroughly; if clothing becomes saturated, remove immediately.

(c) Apply a light coat of MIL-L-23699 lube oil on pump linkage.

(d) Verify unit is calibrated IAW Metrology and Calibration Program (METCAL).

(2) Overspeed Transducer Clearance Gage.

(a) Inspect gage and threaded areas for damage and cleanliness.

WARNING

Avoid inhalation of, ingestion of, skin contact with, and eye contact with hazardous materials. Avoid use near heat or open flame and provide adequate ventilation. Consult work center supervisor if unsure whether ventilation is adequate and if respiratory protection is necessary.

(b) Wipe parts with lint free cloth moistened with cleaning solvent.

(c) Apply a light coat of lubricant to threads.

(d) Replace any damaged parts.

(3) Immersion Depth − Spark Plug Gage.

(a) Clean and lightly lubricate using MIL-L-23699.

(b) Ensure the “L” shaped foot on slide bar is not bent and is securely attached.

(c) Check calibration for accuracy by placing a block of known dimension, a Jo block, between vernier flange face and “L” shaped foot and compare vernier scale reading.

(d) If gage is out of calibration, adjust using calibration screw.

(e) Replace gage if damaged or cannot be calibrated.

(4) Pressure Transducer Calibration System.

(a) Inspect hoses for fraying, cuts, and damaged fittings.

(b) Inspect power cords of vacuum pump and multimeter for damage.

(c) Verify unit is calibrated IAW METCAL.

(5) Tool Set − Engine Rigging.

(a) Inspect Tools for damage and corrosion; replace any damaged parts.

(6) FOD Nylon Flexible Inlet Screen.

(a) Inspect screen for tears and/or other damage; replace if damaged.

e. Report any discrepancy to work center supervisor.

Table 2-40. LM2500 On-Board Special Support Equipment

PART NO	NOMENCLATURE
1C3569G02	Pressurizer, Stator Actuator
1C5714G03	Tool Set − Engine Rigging
2C6081G05	Wrenches, Fuel Manifold
1C6081G01 or 1C6096G01	Gage, Immersion Depth Spark Plug
1C6119G01	Guide, Expandable Bushing
1C6172G03 and G04	Tool Set, Installation/Removal − Transfer Gearbox
1C6344G01	Wrench Set, Air Tube Coupling for Non-revented Engines (FFG7CL, DD963CL, CG47CL)
1C6344G02	Wrench Set, Air Tube Coupling for Revented Engines (DDG51, AOE6CL)
1C6345G01	Gage, Clearance, Overspeed Transducer
1C6361G01	Tool Set, Radial Drive Shaft
1C6744G02	Tool Set, PLA rigging
1C6805G02	Calibration System, Pressure Transducers
1C6811P02 and P04 or 01-471-0286	Borescope Set
1C6886G01	Fixture, Lift − Inlet Screen
9415M88G01	Puller, Brg. Outer Race
1C8043G01	Inlet Screen, FOD, Nylon
HG501L-A	Heat Gun NSN 1H4940-00-364-2828
1433N	Decade Resistor NSN 7G6625-00-947-7534
1433T	Decade Resistor NSN 7G6625-00-840-4256
209A	Signal Generator NSN 1H6625-LL-HDF-D640
21189	Ohmmeter NSN 1H6625-01-079-9488
213	Oscilloscope NSN 1H6625-00-004-9536
260-6P	Multimeter NSN 1H6625-LL-HDG-D642
4308-2	Ultra Violet Test Unit NSN 1H2835-01-038-0488
5381A	Frequency Counter NSN 1H6625-LL-HDF-D643
8600A-01	Digital Multimeter NSN 6G6625-01-031-0708

2.15 LM2500 GAS TURBINE BULLETIN (GTB) NO. 12, POWER TURBINE INTERNAL INSPECTION

(Ref: GTB 12, Current Revision IAW General Gas Turbine Bulletin (GGTB) Zero)

Gas Turbine Bulletin 12 is an Intermediate Level Inspection. Ships are required to schedule the inspection IAW the Inspection times in the Detailed Instructions section of the Technical Directive. GTB 24 will be accomplished concurrently. Upon completion of the bulletin by inspection activity ships force shall comply with the Records Affected and Related Instructions Section of the Technical Directive. Refer to GGTB Zero for the current revision. GGTB Zero can be found at www.navygasturbines.org.

a. In operation, LM2500 Power Turbines (PTs) wear internally. This wear occurs in the blade tip interlocks and the nozzle support rings. Unbending of the 6th stage rotor blade retainers, interstage seal bolt failures and stage 1 nozzle insulation cover segment degradation has also occurred. Modifications have been developed to extend the wear life of these components. These modifications are being installed during new construction build and depot rebuild.

b. Ships should manage engine hours to prevent exceeding maximum time limits. If an inspection interval time occurs while a ship is on deployment (over 90 days), the ship is to notify their ISIC/TYCOM that GTB 12 is due and follow current TYCOM Departure From Specification (DFS) guidance. TYCOM will provide direction for accomplishing inspection as ship and inspection assets are available.

Engine Configuration	First Time Inspection (Hrs) TSN/TSR	Reinspection (Hrs)
100% installation of stages 4, 5 and 6, Six Nozzle Stator Segments (GTC 87) (Production commenced with PTA 1043 on DDG-51 Class ships) PTA STG 1 Blade Interlock (GTC 49) PTA STG 2-6 Blade Interlocks (GTC 58, 59, 60, 61 and 62	12500 +/- 500	4000 +/- 500
Original 2 Nozzle Stator Segments Original STG 1 Blade Interlock Original STG 2-6 Blade Interlocks Any incomplete or non-verifiable installation of GTC 58, 59, 60, 61, 62, 72, 73, 74 and 87	7500 +/- 500	3000 +/- 500

c. The amount of wear in a PT will depend on the following conditions.

(1) Overall engine age.

(2) Amount of total operating time in the gas generator speed range of 6500 to 7500 RPM with vibration levels above 3 mils.

(3) Original engine component stack-up tolerances.

(4) Engine modification configuration.

d. Catastrophic failures of PTs have resulted from excessive wear. The risk of failed pieces exiting the PT casing is moderate. The risk of failed pieces exiting the gas turbine enclosure is low to negligible. There is a small but additional risk of failed pieces exiting the engine exhaust and interfering with helo flight operations.

e. First Inspection is either TSN/TSR as applicable.

f. Reinspection time: If no wear if found in the first inspection or no additional wear in follow on inspections, the reinspection times can be increased by 1500 +/- 250 hours with authorization from FTSC. The cognizant FTSC will provide the extension approval to the inspecting activity and notify NSWCCD-SSES LCM/LCE Code 933 and TYCOM of the extension by electronic means.

g. There are PTs in service that still have GTC 72, 73 and 74 (field installation of 6 vane segments in stages 4, 5 and 6) partially installed. Amendments (b) to GTC 72, 73 and 74 rescinded the TDs and have been superceded by GTC 87 (Cast 6 vane segments).

h. Incomplete installation of GTC 72,73 and 74 does not permit extending inspection interval hours. The 12500 +/- 500 inspection hours and 4000 +/- 500 reinspection hours are based on 100% installation of cast 6 vane segments in stages 4, 5 and 6.

i. Partial installation of cast 6-vane nozzle segments for field repair does not constitute installation of GTC 87. Record only location of installed cast 6 vane nozzle segments in appropriate MGTESR forms and Six-Nozzle Segment Installation and Inspection History Map located in GTB 12.

j. Stage 2 interstage seal bolts and nuts will be replaced during inspection when Power Turbines have accumulated greater than 15,000 +/- 500 hours on all engines without depot incorporation of ECP N-231/GTC-64, production incorporation of ECP N-157 or non-verifiable incorporation of new stage 2 interstage seal bolts and nuts listed in the supply section of GTB 12. Verify Power Turbine configuration prior to commencing inspection.

k. Comply with GTB 24 concurrently with this inspection.

2.16 LM2500 GAS TURBINE BULLETIN (GTB) NO. 24, INSPECTION OF TURBINE MID-FRAME LINER FOR CLOCKING

(Ref: GTB 24, Current Revision IAW General Gas Turbine Bulletin (GGTB) Zero)

Gas Turbine Bulletin 24 is an Intermediate Level Inspection. Ships are required to schedule the inspection IAW the Inspection times in the Detailed Instructions section of the Technical Directive. GTB 12 will be accomplished concurrently. Upon completion of the bulletin by inspection activity ships force shall comply with the Records Affected and Related Instructions Section of the Technical Directive. Refer to GGTB Zero for the current revision. GGTB Zero can be found at www.navygasturbines.org.

a. LM2500 Turbine Mid-Frame (TMF) liner clocking refers to slight (i.e. as much as 0.200 inch) rotation of the TMF liner in the TMF caused by wearing contact surfaces. The rotation allows the liner to cut into the T5.4 and PT5.4 probes and if left unchecked results in their breaking and entering the power turbine causing catastrophic failure. This bulletin requires inspection of the probes and liner. If clocking is present, this inspection involves grinding the liner in the ports where the probes are installed and replacing the probes that are worn beyond limits and also directs further action to have GGs (with clocking present) evaluated for the need to conduct trim balancing. GTC 89 (Coast Metal 64 Hardcoat TMF for Wear Protection) will be inspected in accordance with this directive and if clocking is noted FTSC will be contacted for further evaluation. Additionally, this revision installs a newly developed anti-rotation pin on all engines regardless if clocking is present.

b. Ships should manage engine hours to prevent exceeding maximum time limits. If an inspection interval time occurs while a ship is on deployment (over 90 days), the ship is to notify their ISIC/TYCOM that GTB 12 is due and follow current TYCOM Departure From Specification (DFS) guidance. TYCOM will provide direction for accomplishing inspection as ship and inspection assets are available.

c. Initial inspection on all LM2500 Gas Generators having 6000 +/- 500 hours Time Since New (TSN) or Time Since Rebuild (TSR), as applicable, with reinspection in conjunction with Gas Turbine Bulletin 12.

2.17 <u>LM2500 GAS TURBINE BULLETIN (GTB) NO. 22, INSPECTION OF FIRST STAGE COMPRESSOR BLADE CARBOLOY PADS</u>

(Ref: GTB 22, Current Revision IAW General Gas Turbine Bulletin (GGTB) Zero)

Gas Turbine Bulletin 22 is an Intermediate Level Inspection. Ships are required to schedule the inspection IAW the Inspection times in the Detailed Instructions section of the Technical Directive. Upon completion of the bulletin by inspection activity ships force shall comply with the Records Affected and Related Instructions Section of the Technical Directive. Refer to GGTB Zero for the current revision. GGTB Zero can be found at www.navygasturbines.org.

a. This bulletin directs the inspection of Compressor First Stage Blade Carboloy Pads and retainers for wear. LM2500 gas turbine engines may not have had new blades installed during rework at the depot. In addition, compressor stage 1 blades with less than full carboloy pad thickness (0.020”) have been installed at the depot through January 1998. Therefore it is imperative that commands verify hours on all LM2500 first stage blades to ensure bulletin compliance. Reworked engines require validation of hours on first stage blades and inspection results if GTB 22 has been accomplished. If inspection results or status of hours on all first stage blades can not be verified, contact FTSC and schedule GTB 22 by inspection activity within 500 +/- 250 hours.

b. Time Since Repair (TSR) may not constitute the 10,000 +/- 1,000 hour time frame for initial inspection if all first stage blades have not been replaced with new blades (0.020” pad thickness) during repair.

c. Initial inspection on all LM2500 GGs will be conducted in accordance with this directive at 10,000 +/- 1000 hours TSN/TSR and reinspected based upon the condition of first stage blades and carboloy pads in accordance with the table located in GTB 22.

d. Ships should manage engine hours to prevent exceeding maximum time limits. If an inspection interval time occurs while a ship is on deployment (over 90 days), the ship is to notify their ISIC/TYCOM that GTB 22 is due and follow current TYCOM Departure From Specification (DFS) guidance. TYCOM will provide direction for accomplishing inspection as ship and inspection assets are available.

Table 2-41. Inspection Criteria and Reinspection Periodicity

Observed Condition of Wear Pad	Reinspection Timetable
100% full pad thickness and no indication of any wear on any single pad on all first stage blades (new or like new blades).	Reinspect at 10,000 hrs (+/- 1000 hrs)
Less than 50% wear of the pad, on any single pad, on one or more blades.	Reinspect in 3,000 hrs (+/- 500 hrs)
More than 50%, but less than 75% wear of the pad on any single pad on one or more blades.	Reinspect at 1,000 hr intervals (+/- 250 hrs)
More than 75% wear and/or signs of mating surface fractures on any single pad on one or more blades (minor chipping along pad edges is acceptable).	Replace worn blade(s) ASAP within 50 hrs
No pad remaining and mid-span damper base material is wearing away on any single pad on one or more blades.	Replace all 36 blades immediately. DO NOT operate engine. Contact FTSC immediately.

2.18 PLANNED MAINTENANCE SYSTEM AND INSPECTION PROCEDURES REVIEW QUESTIONS

(Answers are located the last section of the Handbook)

1. True/False. During inspections and assessments, inspectors will down equipment when ships force cannot demonstrate that they are tracking hours and performing hour base and conditional maintenance?
2. What is the definition of Coking?
3. What is the definition of Tip Clang?
4. What is the definition of a Radial Crack?
5. What is the definition of Not Serviceable?
6. What conditions warrant the accomplishment of MIP 2340, MRC R-13, Borescope Inspection?
7. What position should the Variable Stator Vanes be in during Borescope Inspection?
8. How are Compressor Rotor Blades Indexed during Borescope Inspection?
9. During Borescope Inspection you note a missing Platform corner on the concave locking blade in Stage 7, is this damage?
10. Which direction do you rotate the Compressor Rotor during Borescope Inspection?
11. How many Compressor Blades are located in the 16th stage?
12. How many Double Shank HP Turbine Blades are located in the First Stage?
13. How do you Index the HP Turbine Rotor?
14. How many Single Shank HP Turbine Blades are located in First Stage?
15. During Combustor Borescope Inspection you note Burn Through and Missing Material in the Trumpet Area. What is the maximum Serviceable Limits for Trumpet Burn Through and Missing Metal?
16. While conducting MIP 2340, MRC R-18, MFC VSV Feedback Lever and Actuation System Inspection, you note a VSV System discrepancy. What is your course of action?
17. During Compressor VSV Inspection you note side-to-side movement by hand. How do you properly measure the side-to-side movement?
18. What is the Serviceable Limit for Compressor VSV side-to-side movement?
19. What level is the level of repair for Compressor VSV Bushing and Spacer Wear?
20. What is the proper installation direction for the VSV Feedback Cable Rod-End Bearing attaching bolts?
21. From what position should you view Feedback Cable Rig Marks?
22. What instrumentation lines are disconnected prior to performing MIP 2340, MRC R-1, Detergent Wash of Gas Turbine Internal?
23. How many wrenches should be used when loosening or tightening Swivel Coupling Nuts, Hoses, Tubes or Fittings?

24. After completion of Propulsion Air Inlet System Inspection, how long do you operate the Gas Turbine with the nylon screen placed over the Bellmouth Screen?
25. While conducting MIP 2340, MRC R-20, Inspection of Gas Turbine Base Enclosure Interior and Base Enclosure Exterior, you note discrepancies. Where do you locate Inspection Criteria?
26. What is the maximum allowable span of Safety Wire between two tension points?
27. How many twists per inch are allowable for .032 inch and .020 inch diameter Safety wire?
28. What is the maximum allowable flexing at the center of a 6-inch length of Safety Wire?
29. What is the maximum number of bolts you can Safety Cable together with on Safety Cable?
30. How do you determine Breakaway (Running) Torque on Self-locking Nuts?
31. What is the proper method for installing a V-Band Clamp?
32. What is the proper method for tightening electrical connectors?
33. What Technical Directive is required to be accomplished concurrently with GTB 12?
34. What actions are required if during deployment of over 90 days GTB 12 and 24 inspection interval time occurs?
35. When is the initial inspection of GTB 22, Inspection of First Stage Compressor Carboloy Pads required?

CHAPTER 3

TROUBLESHOOTING PROCEDURES OVERVIEW

Troubleshooting is a systematic analysis of symptoms that indicate equipment malfunction. These symptoms usually appear as deviations from normal values of observed equipment parameters. Troubleshooting deals with the most common malfunctions that occur. A thorough knowledge of equipment systems with logical reasoning will solve other problems that may occur.

S9234-AD-MMO-030 contains troubleshooting procedures, fault logic diagrams, functional dependency diagrams and signal flow diagrams. Familiarity with this troubleshooting material is essential prior to performing any troubleshooting.

Well-organized troubleshooting procedures result in rapid isolation of a system fault. The procedures start with the easiest and most accessible checks and progress to harder and more detailed checks until the fault is isolated. Each step either isolates the fault or eliminates some part of the circuit from further testing. The basic methods used during troubleshooting are as follows:

1. Before starting the documented troubleshooting procedure.
   a. Find out everything about the nature of the malfunction. Write down all the symptoms and see if they follow an identifiable pattern.
   b. Check for the obvious.
   c. Find out what maintenance was performed last. Verify proper accomplishment.
2. Locate the proper troubleshooting diagram.
3. If the malfunction can be isolated to a specific anomaly, it may be appropriate to refer to applicable Troubleshooting Index Table to isolate the problem.

3.1 LM2500 STALL TROUBLESHOOTING

(Ref: S9234-AD-MMO-020/030/060/LM2500 and GTB No. 30)

The following is general overview for LM2500 Stall Troubleshooting. Always refer to and follow EOSS and NSTM requirements when performing troubleshooting.

A stall is caused by aerodynamic disturbance of the normally smooth airflow throughout the GT. Whenever the relationship between air pressure, velocity and compressor rotational speed is altered, the effective angle of attack of the blades change. If the relationship becomes incompatible, the effective angle of the compressor blades becomes excessive causing the blades to stall. All stalls must be recognized as a symptom of GT malfunction or an indication that the GT was or is being operated outside the authorized operating envelope. It should be recognized that a malfunction can cause a stall and a stall, in turn, may cause a malfunction or deterioration. High-speed stalls can result in fatigue fractures of compressor blades and severe deterioration of hot section parts. These adverse effects may cause GT failure or malfunction at the time of a compressor stall, but more commonly, the full effects of a stall are deferred and consequently become more difficult to correlate directly with a specific stall incident. The deferred effects are cumulative and can affect GT reliability, durability, and operating cost.

CAUTION

High-speed stalls can cause severe engine damage. Do not operate engines that have stalled above 7500 RPM NGG; borescope affected compressor and contact FTSC or a Marine Gas Turbine Inspector for evaluation. Do not operate engine until cause of stall has been identified and corrected.

3.1.1 Identification of Stall A stall may be indicated by varying degrees of one or more of the following indications:

a. Abnormal GT noises such as low frequency (40-50 Hz) rumble, roar or banging noise.

b. Higher than normal or fluctuating FMP.

c. Sluggish or no GT response to throttle movements (transient stall).

d. Higher than normal T5.4, rapid rise or fluctuating T5.4 and/or high T5.4 alarm/automatic shutdown.

e. Higher than normal or fluctuating vibration levels.

3.1.2 Classification of Stalls The two general classifications of stalls are steady state and transient. Each type tends to have its unique causes. Steady state stalls occur at fixed throttle position and tend to be associated with discrepancies or damage in basic GT gas stream components. Continued GT operation after this type of stall may generate additional secondary damage. Transient stalls are associated with throttle movement for both GT engine acceleration and deceleration.

The following types of stalls and their symptoms are more specific descriptions of what has actually been occurring in the fleet.

a. Off-idle Stalls can occur when the LM2500 is accelerated above idle speed. NGG will hang (stagnate) in the 6000-6500 RPM range while PT5.4 continues to rise. This condition typically results from a mismatch between the MFC acceleration schedule and VSV position. Although most commonly caused by a faulty MFC or VSV rig, another possibility is a malfunctioning CIT sensor.

b. Rotating Stalls result from aerodynamic disturbances involving specific compressor blades or groups of blades; these localized disturbances form “cells” which rotate with the affected blades. Rotating stalls can occur throughout the gas generator speed range but are most prominent between 7500-7800 RPM NGG. This condition can produce increased vibration and unusual noise, but is often difficult to detect because T5.4 and Fuel Manifold Pressure (FMP) may not rise above normal limits. The bellcrank and VSV rig incorporated by GTC No. 91 substantially corrects the rotating stall problem.

c. High-Speed Stalls are severe disruptions in compressor airflow at high power settings (NGG above 7500 RPM). Symptoms of a high-speed stall are audible “bang” or “boom” noise, sharp increase in vibration levels, and sharp increase in T5.4 and FMP. Causes include faulty MFC fuel scheduling (MFC “rich schedule shift”), VSV misrig or malfunction and misrigged VSV feedback cable.

(1) High speed stalls (stalls occurring above 7500 RPM NGG) are the most severe type of stall.

When this type of stall occurs, the massive interruption of compressor airflow permits the air pressure to surge forward. Aerodynamic disturbances during a high-speed stall are violent enough to impose severe bending stresses on LM2500 compressor blades. Compressor blades can be bent enough to cause tip contact between adjacent blades, a condition referred to as “tip clang”. This is evident by borescope inspection of the compressor in that the leading edges of one blade or blades are “tipped”. The leading edge is tipped from the concave side. It is minute, and in itself is of no consequence damage wise. It does indicate that the blade tip has made contact on the convex side of another blade. The contacted blade will have a very subtle mark near the blade tip approximately 2/3 of the cord. Meaning 2/3 of the distance from the blade leading edge toward the trailing edge. It is very subtle and can be easily overlooked during borescope inspection following a “high speed” compressor stall. This overstress condition can cause fatigue fractures, which may result in blade root failure causing catastrophic damage of the GG. Although catastrophic failure can happen immediately, more commonly it occurs during subsequent engine operation. The severity of a particular stall can only be assessed by borescope inspection of the compressor section.

(2) It is essential that LM2500 operators understand the corrective action and urgency of repair required as a result of a high-speed stall event. Compressor blades with stall damage (i.e. “tip clang”) can be replaced with new or refurbished blades; this repair can be done in-place by Intermediate Maintenance Activity personnel. GGs with tip clang must not be operated until repaired. GGs with catastrophic damage, however, must be changed out.

NOTE

Discrepancies may exist simultaneously in the basic GT and accessories.

3.1.3 Typical Causes of Stalls Stalls can be caused by one or more of the following discrepancies.

a. MFC discrepancy.

b. CIT sensor discrepancy.

c. VSV feedback cable binding bent, broken or rigged incorrectly.

d. Severe build-up of contaminates on compressor internal or external components. (Contamination may be caused by: waterwash detergent and dirt build-up if engine is not rinsed properly during water wash, oil leaking from number 3 bearing sump due to an 8^{th} stage bleed air (sump pressurization)/VSV rigging discrepancy, bearing sump labyrinth seal or bearing malfunction, and/or excessive sand or salt water ingestion).

e. Bent or broken VSV lever arm(s).

NOTE

The CDP sensing tube is required to be disconnected during water wash. If CDP sensing line is not disconnected during water wash, the water in the sensing line may contribute to a stall.

f. Plugged, full of water or broken CDP sensing line.

g. VSVs rigged incorrectly at bellcrank or actuation lever pushrods, specifically stages 3 through 6.

h. VSV actuation lever (master lever) spherical/slot loaded bearings and pushrods excessively worn (loose) or binding.

i. VSV actuator, actuator guide, bracket, and spherical bearings broken, loose or binding.

j. VSV shank(s), actuation ring(s) or Pin(s), broken or bent.

k. Compressor or down stream Foreign Object Damage (FOD) and Domestic Object Damage (DOD).

l. Excessive amount of water in intake and/or clogged demister pads (with malfunctioning blow-in-doors, see MIP 2513 for proper maintenance practices).

3.1.4 Preventative Actions for Stall

a. Recent stalls have been associated with incorrectly rigged VSV feedback cables. Feedback cables have also been accidentally stepped on and bent causing binding and mis-adjustment. It is recommended that each time the GT module is entered, a quick visual inspection of the VSV system components be conducted.

b. To prevent stalls, maintenance and operating personnel need to pay particular attention to; engine cleanliness both internally and externally; compressor and VSV component inspections (in accordance with the PMS's MRCs) slowly degrading and/or immediate change in engine performance.

c. Deterioration of a MFC and VSV function can cause CDP and PT5.4 to slowly increase above desired performance levels, substantially reducing the stall margin of the affected engine. Once an engine actually stalls, CDP and PT5.4 will decrease and T5.4 will increase in relationship to NGG and the severity of the stall.

d. Supervisory personnel should periodically review LM2500 operating parameters and analyze engine performance. The existence of a torque split between paired engines can also signal a pre-stall condition and should be investigated and corrected.

e. Improved and recurring training in performance monitoring/watchstanding, GT component inspections/maintenance, and stall identification will also assist in decreasing stall related engine damage.

3.1.5 Stall Isolation To determine which GT experienced a stall, check for:

a. Abrupt increase in T5.4 trend.

b. Abrupt increase in fuel flow trend (if fuel flow is not an instrumented parameter, look for an increase in FMP).

c. Abrupt increase in vibration level trend.

3.1.6 Start Stall Troubleshooting Procedure See Figure 3-1 and Figure 3-2.

WARNING

Before entering enclosure, ensure that the requirements in EOSS are met.

CAUTION

Before starting a gas turbine that has experienced a hot start, a prestart motoring check must be performed per Propulsion Gas Turbine Module Fuel Test in S9234-AD-MMO-020/LM2500 to determine if FMP is within limits of Propulsion Gas Turbine Module Operating Limits in S9234-AD-MM0/LM2500.

NOTE

A start stall is characterized by a hung start, slow acceleration to IDLE, higher than normal FMP (or fuel flow) and higher than normal T5.4. Occasionally, the stall will continue at IDLE power. A stall at IDLE can be recognized by one or a combination of any of the following symptoms: higher than normal T5.4, higher than normal FMP, or NGG does not increase or is sluggish when throttle is advanced from IDLE position.

a. Perform prestart motoring check of GT per Propulsion Gas Turbine Module Normal Motoring Table. FMP should be 80-200 PSI. If fuel pressure is high, troubleshoot per High Starting Fuel Manifold Pressure figure in S9234-AD-MMO-030/LM2500.

b. If step a. shows FMP to be normal, the trouble could be in the variable vane system. Incorrect variable vane position can cause stall. Inspect the variable vane system for obvious damage or malfunction. Check variable vane feedback cable for proper rigging.
The variable vanes should be closed during GT startup. Inspect all variable vane linkage for proper rigging and for damage. Inspect vane actuators for correct adjustment of rod by comparing with opposite actuator. Inspect the MFC to CIT sensor and VSV actuator lines and fittings for tightness, damage, leaks and ensure the lines are not crossed. Visually inspect Inlet Guide Vanes (IGV) and first stages of compressor for FOD. Correct all discrepancies.

c. If step b. does not reveal any discrepancies, perform waterwash per PMS.

d. If step c. does not correct problem, perform borescope inspection of GG. Inspect for damage in compressor, combustor and turbine sections. Inspect TMF for collapsed liner.

e. If step d. does not correct problem, replace CIT sensor. If CIT sensor does not correct problem, contact your local FTSC for guidance.

3.1.7 Operating Stall Troubleshooting Procedure The following procedure shall be followed in the event of a GT stall:

WARNING

Before entering enclosure, ensure that the requirements in EOSS are met.

a. Record engine stall or suspected stall in the Marine Gas Turbine Equipment Operating Log along with GT operating conditions at the time of occurrence.

b. If a Transient Stall occurs during a start, shutdown to clear the stall. Restart and if stall recurs, troubleshoot per Figure 3-3 and correct cause.

c. If a Transient Stall (acceleration - deceleration) occurs below 7500 RPM, NGG, retard the throttle to IDLE to clear the stall.

   (1) Verify that T5.4 and NGG are normal at IDLE. If the stall cannot be cleared, shutdown, troubleshoot and correct the cause of the stall.

   (2) If the stall is cleared by retarding the throttle to IDLE, slowly advance the throttle to determine if stall recurs.

   (3) If stall does not recur, proceed with normal operations. At the earliest opportunity, troubleshoot and correct the cause of the stall.

   (4) If stall does recur, the GT may be operated, if necessary, up to five percent below the NGG at which stall occurs. At the earliest opportunity, troubleshoot and correct the cause of the stall.

d. If any Steady-State Stalls or Transient Stalls occur above 7500 RPM NGG, (referred to as “High Speed Stall”) shutdown GT (normal or emergency shutdown). If it is severe GT will shutdown on High PT5.4 or Vibrations.

   (1) Troubleshoot per Figure 3-3 and correct the cause of the stall.

   (2) Borescope inspect the compressor. Pay particular attention to stages 3-6 for evidence of tip clang.

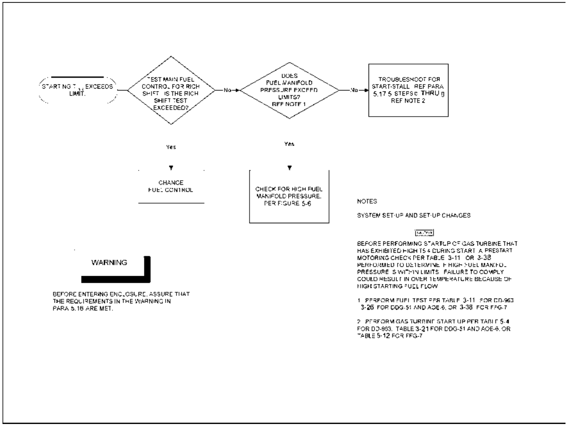

Figure 3-1. Starting T5.4 Exceeds Limits

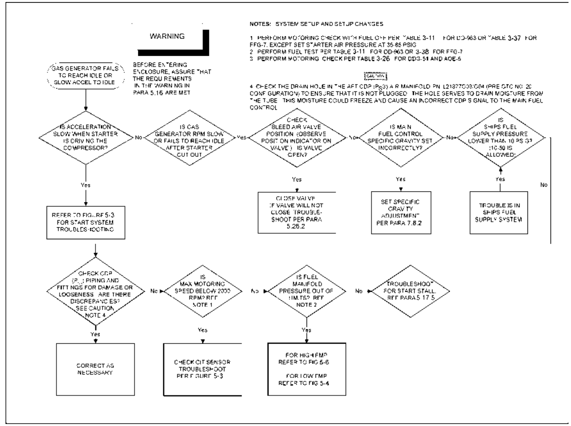

Figure 3-2. Gas Generator Fails to Reach Idle or Slow to Accelerate to Idle

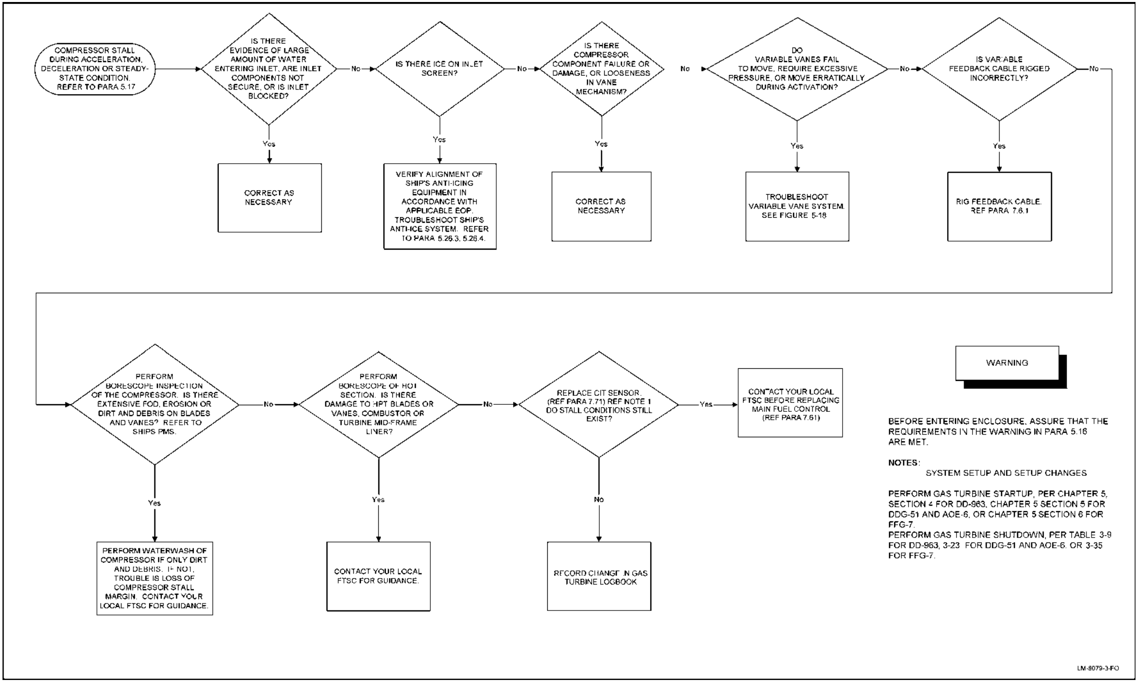

Figure 3-3. Compressor Stall and/or High $T_{5.4}$ During Acceleration, Deceleration or Steady-State Condition

3.2 LM2500 TORQUE SPLIT TROUBLESHOOTING

(Ref: S9234-AD-MMO-020/030/LM2500)

The following is general overview for LM2500 Torque Split Troubleshooting. Always refer to and follow EOSS and NSTM requirements when performing troubleshooting. This procedure provides a sequence of checks, repairs, and calibrations to assist in diagnosing the cause of an excessive torque split which may result in failure to demonstrate FULL POWER capability. An excessive torque split is defined as a difference of more than 6000 FTLBs in the indicated torques of two engines operating on the same shaft. Torque splits may be divided into two categories: real and calculated splits. See Possible Sources of Excessive Torque Splits table for some common causes of both types of torque splits.

a. Real torque splits occur when there is an actual difference in the torque produced by paired engines. This can be caused by such things as differences in NGG between engines, a malfunctioning MFC, misrigged VSV system, a malfunctioning CIT Sensor (CIT Sensor "hot shift" or "cold shift").

   (1) CIT Sensor Hot Shift is when the CIT Sensor internally malfunctions (or inlet screen is clogged) and projects an inlet temperature much higher than the actual. The MFC schedules the stator vanes more closed. May cause loss of power. Indications will be lower than normal CDP, PT5.4 and torque.

   (2) CIT Sensor Cold Shift is when the CIT Sensor internally malfunctions and projects an inlet temperature much lower than the actual. The MFC schedules the stator vanes more open. May cause a stall. Indications will be higher than normal CDP, PT5.4 and torque.

b. Calculated torque splits are caused by instrumentation errors, which result in erroneous inputs to the torque computer. For example, if a shift in the calibration of the PT inlet pressure (Pt5.4) system sent a signal to the torque computer that was ten PSI lower than the actual pressure, the torque computer would indicate a significantly lower torque than was actually being produced by the engine.

3.2.1 Torque Split Troubleshooting Procedures

a. Obtain DDI printouts or manually record parameters on both engines at Flank I, II, and III conditions or as close to these conditions as possible (observe applicable operational limitations). The Flank conditions Vs. Shaft Horsepower Table shows nominal readings that would be obtained under conditions specified in the table. These values will vary depending on atmospheric conditions, engine configuration and hull condition. These values are provided only as a guide. It is only required that the correct shaft speed (±2 RPM) be achieved without excessive torque split.

b. If an excessive torque split (more than 6000 FTLB) exists, see Figure 3-4 for DD-963 and FFG-7 Class Ships or Figure 3-5 for DDG-51 Class Ships, for troubleshooting procedures.

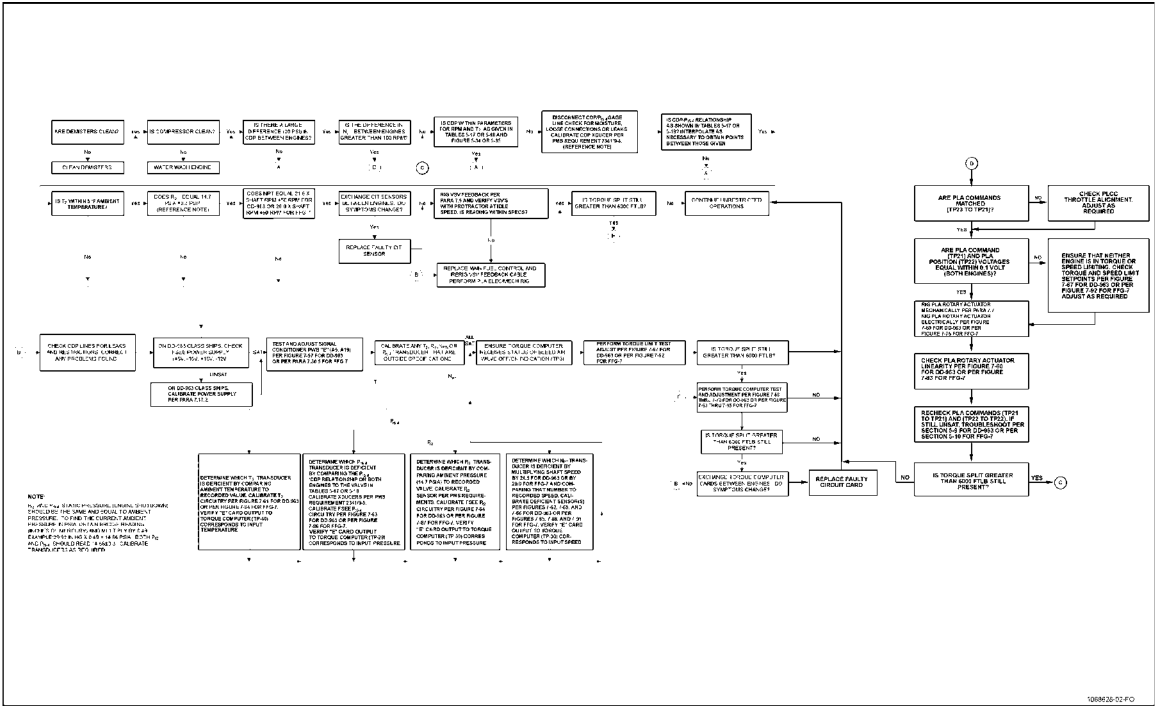

Figure 3-4. Troubleshooting Chart for Excessive Torque Split, DD-963 and FFG-7

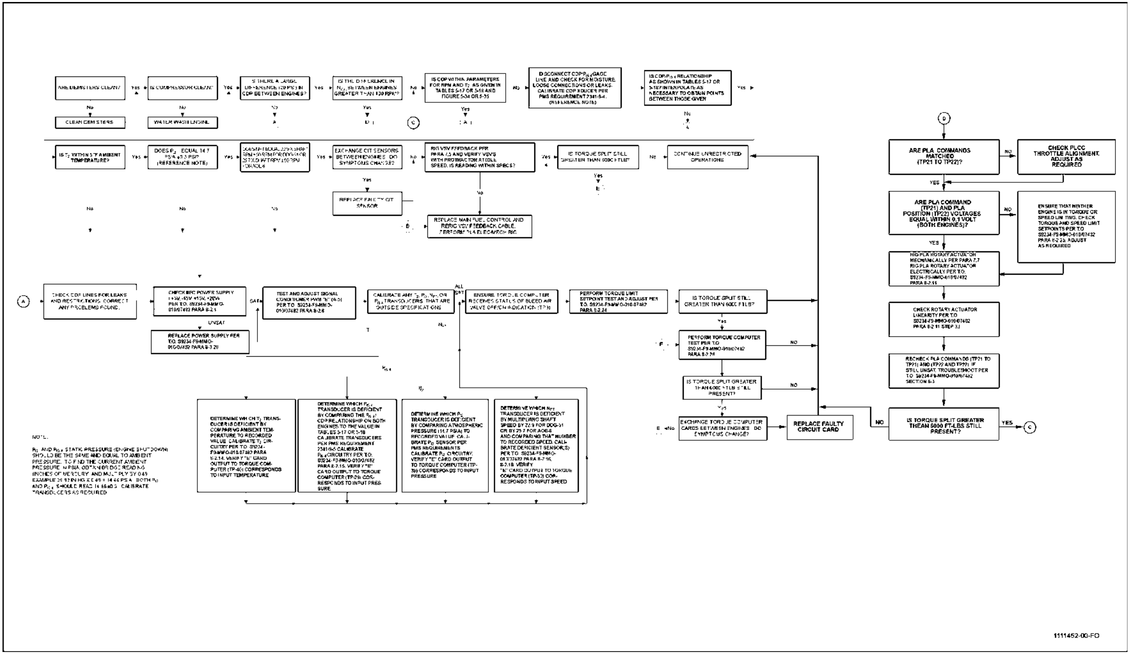

Figure 3-5. Troubleshooting Chart for Excessive Torque Split, DDG-51

Table 3-1. Compressor Discharge Pressure and $P_{t5.4}$ As Functions Of Compressor Inlet Temperature (T_2) and N_{GG}. (Main Fuel Controls PN L16716P14, P20, P24, P25, P27 and P28)

		T_2 (°F)						
N_{GG}(RPM)		40	50	60	70	80	90	100
8000	CDP (PSIG)	137.27	129.92	119.54	112.27	105.60	97.83	91.49
	$P_{t5.4}$(PSIA)	36.32	34.58	32.65	31.18	29.87	28.78	27.25
8100	CDP (PSIG)	150.23	140.15	131.23	122.14	114.73	108.08	101.01
	$P_{t5.4}$ (PSIA)	39.07	36.95	35.08	33.21	31.69	30.39	29.00
8200	CDP (PSIG)	162.24	152.75	142.93	134.09	125.29	117.35	111.09
	$P_{t5.4}$ (PSIA)	41.67	39.63	37.55	35.69	33.89	32.25	30.99
8300	CDP (PSIG)	175.38	164.48	155.83	145.62	137.12	128.50	120.25
	$P_{t5.4}$ (PSIA)	44.55	42.18	40.32	38.15	36.31	34.56	32.86
8400	CDP (PSIG)	186.26	177.96	167.27	157.30	149.50	139.95	131.70
	$P_{t5.4}$ (PSIA)	46.94	45.15	42.81	40.65	38.93	36.97	35.35
8500	CDP (PSIG)	195.72	188.08	180.09	169.95	161.13	152.01	143.41
	$P_{t5.4}$ (PSIA)	49.02	47.37	45.73	43.43	41.51	39.55	37.73
8600	CDP (PSIG)	205.58	197.40	189.87	182.42	173.19	163.90	155.05
	$P_{t5.4}$ (PSIA)	51.19	49.42	47.80	46.18	44.17	42.12	40.22
8700	CDP (PSIG)	214.75	207.23	199.04	191.62	184.83	176.36	166.66
	$P_{t5.4}$ (PSIA)	53.24	51.45	49.82	48.21	46.25	44.89	42.76
8800	CDP (PSIG)	224.33	216.15	208.84	200.64	193.89	186.69	179.40
	$P_{t5.4}$ (PSIA)	55.36	53.59	51.99	50.20	48.75	47.19	45.56
8900	CDP (PSIG)	233.23	224.54	217.55	210.43	202.80	195.58	188.96
	$P_{t5.4}$ (PSIA)	57.29	55.46	53.94	52.38	50.71	49.15	47.72
9000	CDP (PSIG)	241.01	233.86	225.52	219.33	212.38	204.40	197.78
	$P_{t5.4}$ (PSIA)	59.11	57.55	55.72	54.49	52.81	51.10	49.67

NOTE

When T_2 falls between the printed line values, interpolate for needed value. Though the mid-values are not linear, this should result in a reasonable approximation. See MMO-030, Figure 5-34 through 5-36.

DDG-51 Class Ships read CDP in PSIA. Add 14.7 to the ship's PSIA reading before using this table

Table 3-2. Compressor Discharge Pressure and $P_{t5.4}$ As Functions Of Compressor Inlet Temperature (T_2) and N_{GG}. (Main Fuel Controls PN L16716P16, P17, P18, P22, and P23)

		T_2 (°F)						
N_{GG}(RPM)		40	50	60	70	80	90	100
8000	CDP (PSIG)	132.75	124.21	116.06	108.01	101.31	94.64	88.84
	$P_{t5.4}$ (PSIA)	35.40	33.60	31.94	30.51	29.07	27.82	26.76
8100	CDP (PSIG)	145.34	135.93	126.61	118.72	111.75	104.09	97.28
	$P_{t5.4}$ (PSIA)	38.02	35.94	33.72	32.24	31.09	29.62	28.33
8200	CDP (PSIG)	157.69	148.01	138.63	130.02	120.84	114.47	107.12
	$P_{t5.4}$ (PSIA)	40.68	38.61	36.62	34.71	33.13	31.65	30.21
8300	CDP (PSIG)	169.85	160.03	151.01	141.17	132.80	124.01	117.08
	$P_{t5.4}$ (PSIA)	43.34	41.21	39.67	37.19	35.44	33.62	32.20
8400	CDP (PSIG)	183.67	172.55	162.62	153.38	144.18	135.65	127.78
	$PT_{5.4}$ (PSIA)	46.36	43.97	41.71	39.85	37.85	36.06	34.42
8500	CDP (PSIG)	196.29	185.80	175.12	165.21	156.59	147.44	138.59
	$P_{t5.4}$ (PSIA)	49.15	46.86	44.68	42.38	40.51	38.57	36.69
8600	CDP (PSIG)	207.77	198.20	188.19	178.12	167.93	159.13	150.58
	$P_{t5.4}$ (PSIG)	51.69	49.60	47.43	45.23	43.00	41.17	39.26
8700	CDP (PSIG)	218.82	209.01	200.22	190.73	180.82	171.09	162.03
	$P_{t5.4}$ (PSIA)	54.13	51.82	50.08	48.07	45.86	43.72	42.68
8800	CDP (PSIG)	228.06	219.76	211.47	202.37	193.03	183.82	174.28
	$P_{t5.4}$ (PSIA)	56.23	54.40	52.59	50.59	48.22	46.55	44.45
8900	CDP (PSIG)	237.01	229.58	221.49	213.54	204.15	195.58	186.74
	$P_{t5.4}$ (PSIA)	58.17	56.60	54.83	53.08	51.02	49.15	47.23
9000	CDP (PSIG)	243.55	236.97	230.17	222.98	214.90	207.09	198.32
	$P_{t5.4}$ (PSIA)	59.64	58.23	56.83	55.58	53.40	51.70	49.79

NOTE

When T_2 falls between the printed line values, interpolate for needed value. Though the mid-values are not linear, this should result in a reasonable approximation. See MMO-030, Figure 5-34 through Figure 5-36.

Contact FTSC if GT has a MFC lower than a P24

c. If an excessive torque split does not exist and all other operating parameters are within limits, continue unrestricted operations.

d. To determine which engine is not performing properly use charts “Compressor Discharge Pressure and PT5.4 As Functions of Compressor Inlet Temperature (T2) and NGG”. (For the applicable MFC) and graphs for “Nominal CDP vs NGG” and ”Nominal PT5.4 vs NGG” (For the applicable MFC) located in S9234-AD-MMO-030/LM2500. Do not assume that the under-performing engine is the bad engine. Verify that CDP and PT5.4 are within parameters for RPM and T2 as given in the tables. When T2 falls between the printed line values, interpolate for needed value. Though the mid-values are not linear this should result in a reasonable approximation.

e. Refer to Possible Sources of Excessive Torque Split Table, as you can see from the table, PT5.4 carries the most weight in torque computation for every 1.0 PSIA change in PT5.4 torque will change 1230 FTLBs. If you have a greater than 6,000 FTLB torque split you can very easily verify if CDP and PT5.4 are within parameters for a given RPM and T2. CDP and PT5.4 pressures ratios are directly linked together. If CDP increases or decrease PT5.4 will follow in a linear manner. If CDP is truly low or high, then PT5.4 will be low or high by the same ratio. If PT5.4 is low or high, calculated torque will be low or high. This is a real torque split. If PT5.4 is not linear with CDP you have a calculated torque split that is an instrumentation error.

Table 3-3. Flank Conditions Vs. Shaft Horsepower

Flank	Shaft Speed (RPM)	N_{GG} (RPM)	N_{PT} (RPM)	SHP	Calculated Torque (FTLB)	$P_{t5.4}$ (PSIG)
I	122	8220/8228	2718	9,253	17,880	35.5
II	152	8552/8562	3223	15,430	25,144	44.3
III	168	8804/8894	3600	21,500	31,367	51.4
(1) Nominal values listed above are provided as a guide only and are not limits.						
(2) Nominal values listed above are with 80 °F inlet air temperature, 29.92 in. Hg barometric pressure, four in. H_2O inlet pressure loss, and six in. H_2O exhaust pressure loss.						

Table 3-4. Possible Sources Of Excessive Torque Split

Indication	Source	Type
Large difference in N_{GG} between paired engines (> 100 RPM)	1. PLA command split, difference from PLCC to FSEE	Real
	2. PLA mechanical and/or electrical rigging incorrect.	Real
	3. PLA rotary actuator not linear.	Real
	4. MFC fuel output low.	Real
Low CDP, FMP, $T_{5.4}$, and $P_{t5.4}$ (compared to paired engine)	CIT sensor "hot shift". Schedules stator vanes closed.	Real
Low $P_{t5.4}$ only (compared to paired engine)	Calibration/sensor error or leaks in sensor line.	Calculated*
***Effect of calibration errors on torque:**		
Signal	Error	Torque Error FTLB
N_{PT}	10 RPM	-109
	-10 RPM	109
$P_{t5.4}$	1.0 PSIA	1230
	-1.0 PSIA	-1230
P_{t2}	0.1 PSIA	-217
	-0.1 PSIA	217
T_2	10 °F	394
	-l0 °F	-394

f. Check VSV rigging IAW S9234-AD-MMO-050/LM2500. A minor rigging error can have major impact on engine performance. It is of paramount importance to ensure that the stationary rig point and the MFC feedback lever rig point are matched when VSVs are in the full open position. This rigging directly effects CDP and PT5.4. PT5.4 is the most significant input to the torque computer.

g. When the VSV feedback lever rig mark is rigged below the stationary rig mark a loss of engine power will occur. The opposite occurs if the feedback lever rig mark is rigged above the stationary rig mark. The engine will produce too much power for the given speed, which depending on outside air temperature could lead to a stall.

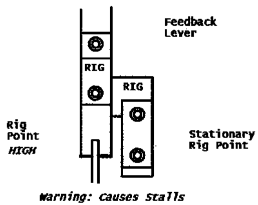

Figure 3-6. Rigged High

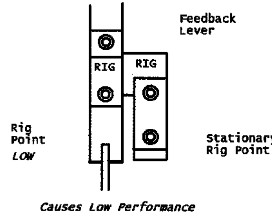

Figure 3-7. Rigged Low

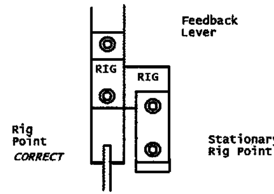

Figure 3-8. Rigged Correctly

3.2.2 UNDERSTANDING TORQUE AND ENGINE PARAMETER RELATIONSHIPS

a. T2 and CIT sensor. The T2 RTD is mounted in the forward crossbeam in the module. Its probe passes through the crossbeam and senses the inlet temperature to the gas generator. It is an electrical device, which sends its signal to the FSEE and is used for torque computation. The CIT sensor is a hydro-mechanical device, which outputs a fuel pressure to the main fuel control representing the inlet temperature. There is no readout.

b. PT2 (GTM inlet total pressure in PSIA) sensor. The PT2 pressure probe is mounted at the top of the compressor front frame. It senses ambient air pressure and it is supplied to the PT2 pressure transducer under the module floor via tubing. The transducer sends its signal to the FSEE and is used for torque computation.

c. PT5.4 (GTM power turbine inlet pressure in PSIA) sensor. The PT5.4 pressure probe is mounted in the turbine mid-frame. It senses power turbine inlet pressure and it is supplied to the PT5.4 pressure transducer under the module floor. The transducer sends its signal to the FSEE and is used for torque computation.

d. NPT (power turbine speed) transducers. The NPT transducers produce a frequency (Hz) representing NPT speed. The transducer sends its signal to the FSEE and is used for torque computation.

e. FSEE torque computation is only as accurate as the inputs are.

3.2.3 <u>Effect of Ambient Air Pressure on Engine Operation</u>

a. The power and efficiency of a gas turbine engine is affected by both outside and inside variables. Air has volume, which is directly affected, by its temperature.

b. As the temperature decreases, the volume of air for a given mass decreases and its density increases. Consequently, the mass weight of the air increases which in turn increases the efficiency because less energy is needed to achieve the same compression at the combustion chambers. Also cooler air causes lower burning temperatures. The resulting temperatures extend turbine life. For example, a propulsion gas turbine is operating at 100% gas generator speed with 100% power turbine speed at an ambient (external) temperature of 70 degrees F. If the temperature were increased to 120 degrees F., the volume of air would increase and the mass weight would decrease.

c. Since the amount of fuel added is limited by the inlet temperature the turbine will stand, the mass weight flow cannot be achieved; the result is a loss of net power available for work. The plant may be able to produce only 90 to 95% of its rated power.

d. On the other hand, if the ambient temperature were to drop to 0 degrees F., the volume of air would decrease and the mass weight is increased.

e. Since the mass weight of fuel is increased and heat transfer is better at high pressure, less fuel is needed to increase volume; the result is a heavier mass of air at the required volume. This situation produces quite an efficient power plant with a gas generator speed of 85 to 90% and a power turbine of 100%.

3.2.4 <u>Relationship of CIT (T2) and NGG to Stator Vane Angle</u>

a. For any given CIT (T2), increase NGG RPM and the stator vane angle will be scheduled more open. Decrease NGG RPM and the stator vane angle will be scheduled more closed.

b. For a given NGG RPM, the stator vanes will be scheduled more closed on a 100 degree F day than on a 60 degree F day.

c. For a given CIT (T2) an increase in NGG RPM, will result in an increase of vane angle. A decrease in NGG RPM will result in a decrease of vane angle.

d. For a given NGG RPM a decrease in CIT (T2) will result in a increase in vane angle. An increase in CIT (T2) will result in a decrease in vane angle.

3.2.5 Relationship of CIT (T2) and NGG to CDP

a. For any given CIT (T2) an increase in NGG RPM, will result in a CDP increase. A decrease in NGG RPM, will result in a CDP decrease.

b. For any given NGG RPM, CDP in PSIG is higher on a 60 degree F. day, and CDP is lower on a 100 degree F. day.

c. CDP follows the stator vane schedule. The stator vane angle cannot be observed above idle RPM so CDP can be used as a representation of the stator vane scheduled angle. Therefore CDP becomes a key parameter.

3.2.6 Relationship of CDP and PT5.4

a. If CDP increases or decreases PT5.4 will increase or decrease.

3.2.7 Record Data

a. When a ship has balanced systems, data should be recorded and preserved for future reference, to be used as a base line when there is a problem. Record data at increments of 100 RPM between 8000 RPM and full power. Record both paired and single engines.

3.3 LM2500 T5.4 THERMOCOUPLE SYSTEM TROUBLESHOOTING

(Ref: S9234-AD-MMO-020/030/LM2500)

WARNING

Before entering enclosure, ensure that the requirements in EOSS are met.

CAUTION

Do not exceed starter duty cycle.

a. Check T5.4 indicator; if temperature is above 200 F allow T5.4 to cool, or cool by motoring. To motor, set starter inlet air pressure at 20-22 PSIG and motor as necessary, staying within the following starter motoring duty cycle: ten min on, 20 min off for any number of cycles (max starter inlet air temperature of 200 F for ten min motoring) or five min on, two min off, five min on, 18 min off in any 30 min period

b. Disconnect GG T5.4 aft thermocouple lead from feed-through flex-lead connector on right side (4:30 o’clock position) of GG.

c. Check insulation resistance of GG aft thermocouple lead by measuring with an ohmmeter from pin A to connector shell (ground). Minimum acceptable resistance is 500 ohms.

d. Check continuity of GG aft thermocouple lead by measuring with an ohmmeter from pin A to pin B.

Take a second continuity measurement, reversing ohmmeter leads. Average the two readings by adding them together and dividing by two. Average resistance must be 1.9-2.3 ohms.

e. Correct discrepancies that are out-of-limits.

f. Connect GG T5.4 aft thermocouple lead to base feed through flex-lead connector and hand-tighten and safety-wire.

g. If T5.4 thermocouple system resistance measurements are within limits, troubleshoot ship's instrumentation.

h. If T5.4 thermocouple system is not within limits, separate the individual leads and harnesses and measure continuity and insulation resistance of each part per T5.4 System Components − Electrical Tests Table. Replace each component that is out-of-limits.

Table 3-5. $T_{5.4}$ System Components - Electrical Tests

Nomenclature	Ref No.	Ohmmeter Connec-tions	Conductor Resistance Limits [1]	50 VDC Megger Connections [3]	Minimum Insulation Resistance
Base Feed through Connector	E73000	[7] A-to-B	3.2 to 5.8 Ohms	A-to-B	10 Megohms
				A-to-C	10 Megohms
				B-to-C	10 Megohms
Aft Hard Lead	69502	[2] A-to-B	[5] 2.3 to 3.0 Ohms	A-to-[4]	1K Ohms
		[2] A-to-C		A-to-B	1K Ohms
		[2] A-to-D		B-to-[4]	1K Ohms
		[2] A-to-B	[6] 2.8 to 3.6 Ohms		
		[2] A-to-C			
		[2] A-to-D			
T/C Harnesses:					
Top Right	69700	A-to-B	1.65 to 2.00 Ohms	A to [4]	1K Ohms
Bottom Right	69703	A-to-C	1.80 to 2.20 Ohms	A to [4]	1K Ohms
Top Left	69702	A-to-D			
	69701	A to B			
		A to C			
[1] Average of two measurements. Reverse ohmmeter leads for second measurement.					
[2] Jumper wire connected between Pins A and B on forward connector; tester measurements taken at aft connector. No. 16 female socket contacts required on jumper.					
[3] Megger checks made at forward connector only with jumper wire removed.					
[4] Connector shell.					
[5] Applies to top right and bottom right connectors.					
[6] Applies to top left and bottom left connectors.					
[7] Jumper wire connected between Pins A and B on aft connector; tester measurements taken at forward disconnected Lug A (No. 10 lug) and Lug B (No. 8 lug).					

3.4 LM2500 MAIN FUEL CONTROL RICH SCHEDULE SHIFT TROUBLESHOOTING

(Ref: S9234-AD-MMO- 030/060/LM2500)

NOTE

The following procedure is to be performed when MFC schedule shift is suspected.

a. Ensure starter regulator valve inlet pressure is 35 PSIG minimum.

b. Inspect starter stator for evidence of erosion per S9234-AD-MMO-060/LM2500. Replace starter stator or replace starter if limits are exceeded.

c. If steps a. and b. are within limits, perform three consecutive starts/restarts and observe the difference between the starting peak and steady state T5.4. Accomplish the starts/restarts as follows:

   (1) Start GT and operate at IDLE for five minutes.

   (2) Shutdown, then restart as soon as NGG reaches zero RPM. Observe and record starting temperature peak.

   (3) Operate at IDLE for two minutes, then observe and record steady state temperature.

   (4) Repeat steps b and c two more times.

d. If the average temperature difference of the three starts is less than 170 degrees F, no further action is required.

e. If the average temperature difference exceeds 170 F, replace the MFC.

3.5 LM2500 LUBE OIL SYSTEM TROUBLESHOOTING

(Ref: FTSCLANT Lube Oil Expert System)

1	Oil, consumption no obvious leaks
2	Smoke in Module after extended low power operation
3	Smoke in Module after GG or PT Change Out (no fire)
4	Oil consumption after Compressor Case Opening
5	Oil leaking from “A” Sump
6	Oil leaking from “B” Sump Drain into Oily Waste Tank or oil leaking from “B” Sump Vent Horns
7	Oil leaking from “C” Sump Drain into Oily Waste Tank or oil leaking from “C” Sump Vent Horns
8	Oil leaking from Starter Accessory Gearbox Drain
9	Oil leaking from Fuel Pump Accessory Gearbox Drain
10	Oil leaking from Fuel Pump FWD Flange Accessory Gear Box Drain
11	Oil leaking from Accessory Gearbox Drains Into Oily Waste Tank
12	Oil on Module Deck in area of Waste Tank Drains
13	Air/Oil Separator troubleshooting
14	Oil leaking on Module Deck from unknown location
15	Oil leaking from “A” Sump Supply Tube at Compressor Front Frame
16	Oil leaking from Jacking Pad, cover removed, engine secured
17	Oil leaking from any supply line hose or tube fitting
18	Oil leaking from Turbine Mid Frame during engine lay-up
19	High lube oil temperature
20	High Accessory Gearbox Scavenge temperature (above 300 deg F)
21	Oil leaking from VSVs
22	Oil dripping from Accessory Gearbox
23	Chaffing of “C” Sump Lube Oil Supply Line at TMF Strut
24	No or low lube oil pressure
25	High lube oil pressure
26	LOS&C level drops, engine secured
27	Lube and Scavenge Pump Inlet Screen contamination

REFERENCES:

A. NAVSEA S9234-AD-MMO-010/LM2500, REV 4, DESCRIPTION AND OPERATION
B. NAVSEA S9234-AD-MMO-020/LM2500, REV 3, INSTALLATION AND SCHEDULED MAINTENANCE
C. NAVSEA S9234-AD-MMO-030/LM2500, REV 4, TROUBLESHOOTING
D. NAVSEA S9234-AD-MMO-040/LM2500, REV 4, REFERENCE DIAGRAMS
E. NAVSEA S9234-AD-MMO-050/LM2500, REV 4, CORRECTIVE MAINTENANCE
F. NAVSEA S9234-AD-MMO-060/LM2500, REV 7, CORRECTIVE MAINTENANCE
G. NAVSEA S9234-AD-MMO-070/LM2500, REV 6, ILLUSTRATED PARTS LIST (GAS TURBINE ASSEMBLY)
H. NAVSEA S9234-AD-MMO-080/LM2500, REV 6, ILLUSTRATED PARTS LIST (B/E AND LS & CA)
I. NAVSEA S9234-AD-MMO-090/LM2500, REV 6, ILLUSTRATED PARTS LIST (CONTROLS AND ACCESSORIES)
J. NAVSEA S9234-AB-MMD-020/LM2500, VOL 2, PART 1, REV 2, GAS GENERATOR OVERHAUL AND REPAIR INSTRUCTIONS

3.5.1 Oil Consumption, No Obvious Leaks This problem is normally identified when either the low lube oil alarm sounds or a watch stander notes a low oil condition in the Lube Oil Storage and Conditioning Assembly (LOSCA) tank. FFG 7 class ships may note this condition on the Demand Display Indicator (DDI) readout. High oil consumption is defined as oil consumption in excess of 2 gallons per 24 hr operating period. The actual operating limit IAW reference (B), table 3-4, item 11.c, is 946 cc’s per hour (6 gallons per 24 hr operating period). The 6-gallon per 24 hr operating period limit is considered the maximum safe operating limit for the engine until the consumption problem can be identified and corrected. Verify high oil consumption. If consumption does not exceed 2 gallons per 24 hr operating period, continue to monitor for indications of increased oil consumption.

If oil consumption is verified as being high, the next step is to identify the leakage path. There are several paths that do not produce obvious signs of leakage in the module. Recommend the following to identify the leakage path:

a. Inspect all scavenge element strainers in accordance with MIP 2340/R-6 for indications of a bearing failure. Refer to section titled "**LUBE AND SCAVENGE PUMP INLET SCREEN CONTAMINATION**" for assistance in identifying different types of contaminants. If a bearing failure is indicated for the B, C, or D-sumps, contact FTSC for further assistance. If contaminates are found in A-sump or AGB strainer, problem may be in accessory gearbox and will require additional evaluation. Save collected pieces for possible later evaluation until source is positively identified or engine is replaced.

b. If maintenance was recently accomplished requiring removal of sump pressurization tubing, inspect tubing couplings and flanges for blockage. If blocked, remove blockage and monitor consumption.

c. Run engine at idle. Secure module fan. Check 8th stage air pressurization line couplings from 8th stage manifold to sump inlets for air leaks. You can do this by carefully feeling around the couplings for airflow. Be careful not to actually touch any of the hot piping. If found, correct leaks and monitor consumption.

d. Check the part number on the side of the A- and B-sump nozzle. If GTC 53 is incorporated it should be L21442G03. If not, request installation of GTC 53.

e. There are two types of gas generators in the fleet. Most have Paired Blade High Pressure Turbine (HPT) blades but a few of the newer ones, mostly on DDGs and a few CGs, are configured with Single Shank Turbine (SST) blades. Single shank gas generators have an additional set of three vent "horns" located around the C-sump. Check for C-sump vent leakage as follows:

f. For Paired Blade Turbines (PBT) turbines, with the engine secured, inspect the base of the power turbine, sixth stage blades, reference (G), figure 8-83, item 64, and surrounding areas for signs of oil accumulation or coking. If found contact FTSC for further assistance. There are two methods for checking the sixth stage blades:

(1) Enter the exhaust in accordance with MIP 2340 to inspect the blades.

(2) Using the ship's standard borescope kit with a rigid probe, borescope the base of the blades by removing the turbine rear frame cover plate, reference (E), figure 7-17, item 19. Inspect the base of the blades and surrounding area for oil accumulation, wetting or coking. For SSTs, inspect for oil leakage at the C-sump vent horns (1, 5, and 7 o'clock positions). Internal inspection can be done with a flexible borescope at 5 o'clock position. If oil is leaking from the C-sump horns, go to the section titled **"OIL LEAKING FROM C-SUMP DRAIN INTO OILY WASTE TANK, OIL LEAKING FROM C-SUMP VENT HORNS (SINGLE SHANK GG ONLY)."**

g. Remove and inspect the air/oil separator flame arrestor, reference (H), figure 9-34, item 8, in accordance with MIP 2340/R-21 for indications of clogging. If clogged, clean, reinstall and monitor oil consumption.

h. With the engine secured, disconnect the following drain lines from the lube oil drain manifold, reference (G), figure 8-39, item 12, at the aft side of the accessory gear box and safety wire 8 oz lube oil sample bottles to the drain fittings:

(1) Starter drain tube, figure 8-39, item 21

(2) Both fuel pump drains, figure 8-39, items 15 and 18

(3) Lube/scavenge pump drain hose, figure 8-39, item 13

(4) B-sump drain tube, reference (G), figure 8-44, item 24 from tee, reference (G), figure 8-44, item 27. Safety wire an oil sample bottle to the open end of the B-sump drain tube.

(5) Aft lube oil drain hose, reference (H), figure 9-34, item 24, that runs from the tee, reference (G), figure 8-44, item 27, to the oily waste drain penetration in the left side of the module floor. The output of the tee with the B sump drain line disconnected is C-sump leakage. Safety wire an 8 oz oil sample bottle to the open end of the tee.

(6) Air/oil separator (AOS) exhaust tube drain hose, reference (H), figure 9-35, item 64, safety wire

an 8 oz oil sample bottle to the open end of the tube fitting.

i. Operate the engine for approximately 30 minutes at each of the following gas generator speeds: 5000, 7500, full power RPMs. Record the following data at each power setting **(see the attached survey sheets):**

1. TIME
2. NGG
3. SCAVENGE TEMPERATURES FOR A-, B-, C-, D-SUMPS AND AGB
4. GTM COOLER OUTLET TEMPERATURE
5. PT5.4
6. T5.4
7. PERCENT PLA
8. LUBE OIL CONSUMPTION DURING 30-MINUTE PERIOD

j. After each speed run, return to idle, check each sample bottle for oil accumulation. Maximum leakage for any single sample bottle is 5 cc per hour (approximately 0.2 of an oz per hour). Depending on which bottle accumulates the oil, go to one of the following sections:

1. **OIL LEAKING FROM STARTER ACCESSORY GEARBOX DRAIN.**
2. **OIL LEAKING FROM FUEL PUMP ACCESSORY GEARBOX DRAIN.**
3. **OIL LEAKING FROM B-SUMP DRAIN INTO OILY WASTE TANK.**
4. **OIL LEAKING FROM C-SUMP DRAIN INTO OILY WASTE TANK.**

k. If source of oil consumption is still unidentified, several remote, but, possible paths exist:

(1) Check Air/Oil separator drain line.

(2) Ensure that all the vent line joints are properly torqued, (reference (G), figure 8-43):

(a) Bolts at B-sump vent seal, items 15 and 17: 55 to 70 in-lbs.

(b) Bolts at AOS flange, item 2: 55 to 70 in-lbs.

(c) Bolts at A-sump vent seal, item 8: 55 to 70 in-lbs.

(d) Nuts on flexible sleeve couplings at seals, items 4, 5,12, 19 and 20: torque hand tight.

(3) If bolts and flexible sleeve coupling nuts were all properly torqued, disassemble the vent line from coupling sleeves at seals, items 19 and 20, forward. Install new seals, reference (G), figure 8-43, items 2, 4, 5, 8, 12, 15, 17, 19 and 20. Wholesale replacement is recommended since it is extremely difficult to isolate a specific seal failure during engine operation. The most likely problem seals are items 5, 8, 17, 19 and 20. Refer to reference (E), figure 7-30 for flexible sleeve coupling assembly procedure.

(4) Leakage of the LOSCA drain valve, reference (H), figure 9-48, item 6. To test this valve, disconnect the drain line down stream of the valve where it attaches to the LOSCA. On some ships you can check for leakage by inspecting the point where the LOSCA drain valve dumps into the oily waste funnel. Inspect for oil leakage. If leaking, repair or replace the valve.

(5) Leakage of Lube Oil from Gas Turbine Module (GTM) LOSCA to Main Reduction Gear (MRG) system via Lube Oil Cooler.

3.5.2 Smoke In Module After Extended Low Power Operation

NOTE

Any seal leakage may continue to occur after its cause has been corrected due to contamination of the seal labyrinth. Full power operation for 30 to 90 minutes should clear the seals and restore normal operation.

a. There are two types of gas generators in the fleet. Most have paired blade high-pressure turbine (HPT) blades, but, a few of the newer ones, mostly on DDGs and a few CGs, are configured with single shank HPT blades. Single shank gas generators have an additional set of three vent "horns" located around the C-sump. For paired blade turbines (PBT), oil leakage from, and smoke coming out of the B-sump vent "horns”, reference (G), figure 8-41, item 12, is a common occurrence after extended periods of low power operation (NGG between 5000 and 6800 RPMs). For single shank turbines (SST), smoke and oil misting may also occur around the 5:00 o’clock and 7:00 o’clock C-sump vent horns. These symptoms are caused by insufficient sump sealing air pressure at the lower RPMs. Historically, insufficient sealing air pressure was a very common problem due to inadequate airflow through the A- and B- sump air ejector, reference (G), figure 8-43, item 41. GTC 53 installs a larger capacity ejector. Recommend the following in the order they are presented:

(1) Inspect the scavenge line in the area of gasket, reference (G), figure 8-40, item 77, for any indication of oil leakage. If any wetting of the flange is found, loose flange bolts or a faulty gasket is indicated. Replace the gasket and torque bolts.

(2) Insure that the vent damper is fully open during engine operation. For FFGs, insure bypass damper is fully open during engine operation. Note cooling fan is secured when the engine develops more than 3000 horsepower. Refer to MIP 2513 for FFG vent damper maintenance requirements.

(3) Inspect the A- and B-sump air ejector for blockage by shining a flashlight into the ejector through the nozzle screen. Remove any obstructions.

(4) Check the part number on the side of the A- and B-sump nozzle. If GTC 53 is incorporated it should be L21442GO3. If not, request installation of GTC 53.

(5) Next, operate the engine at high power (NGG greater than 8000 RPMs) for approximately 1-1/2 hours. In most cases, this should clear the sump of excess oil and eliminate the leakage and smoke.

(6) It is unlikely, but the air ejector may be internally clogged. Verify flow at ejector inlet with hand. Be careful not to actually touch any of the hot piping. Remove the ejector and look through

the long run of the nozzle. Remove any obstructions.

3.5.3 Smoke In Module After GG Or PT Changeout (No Fire)

NOTE

Any seal leakage may continue to occur after its cause has been corrected due to contamination of the seal labyrinth. Full power operation for 30 to 90 minutes should clear the seals and restore normal operation.

a. There are two common causes for smoke to form in the module after a gas generator or power turbine change out. Neither one is detrimental to the engine. When GGs and PTs are removed, they are in a vertical position when moving through the inlet. Residual oil in the bearing sumps can flow into the outer vent cavities and become trapped. When the engine is run, this trapped oil will heat up and produce smoke in the module. Normally, smoking will stop after approximately 1-1/2 hours of operation at a power level above 8000 NGG.

b. A second cause is burning off of penetrating oil used during removal of the engine. Normally smoking will stop within the first hour of engine operation.

3.5.4 Oil Consumption After Compressor Case Opening

a. If you notice oil consumption after the compressor case was opened, the most likely cause is faulty sealing of the A- or B-sump vent lines or their connection to the air/oil separator. These lines must be disconnected to allow access to the case for opening. During reassembly, a sealing problem may occur. Refer to reference (G), figure 8-43, and proceed as follows:

(1) The sump vent line is typically disconnected from the following seal areas during a compressor case opening and are the most likely source of a seal problem: Seal item 5, 8, 17, 19, and 20

(2) First ensure that all the vent line joints are properly torqued:

(a) Bolts at B-sump vent seal, items 15 and 17: 55 to 70 in-lbs.

(b) Bolts at air/oil separator flange, item 2: 55 to 70 in-lbs.

(c) Bolts at A-sump vent seal, item 8: 55 to 70 in-lbs.

(d) Nuts on flexible sleeve couplings at seals, items 4, 5, 12, 19 and 20: torque hand tight.

(3) If bolts and flexible sleeve coupling nuts were all properly torqued, disassemble the vent line from coupling sleeves at seals, items 19 and 20, forward. Install new seals, reference (G), figure 8-43, items 2, 4, 5, 8, 12, 15, 17, 19 and 20. Wholesale replacement is recommended since it is extremely difficult to isolate a specific seal failure during engine operation. The most likely problem seals are items 5, 8, 17, 19 and 20. Refer to reference (E), figure 7-30 for flexible sleeve coupling assembly procedure.

b. If oil consumption continues after completion of the above procedure, go to the section titled "**OIL CONSUMPTION, NO OBVIOUS LEAKS**" to determine the oil loss path.

3.5.5 Oil Leaking From A-Sump

a. This problem is usually noticed when oil is dripping from VSVs or found during troubleshooting for oil consumption from an unknown source and puffs of white smoke are observed coming from the exhaust. You may also notice this problem when inspecting the center body (bullet nose) and find oil dripping.

b. If oil is dripping from the VSVs, go to the section titled "**OIL LEAKING FROM VSVs**."

c. If you see puffs of white smoke in the exhaust, go to section "**OIL LEAKING FROM VSVs**."

d. Check bullet nose for indications of oil dripping from seal area. If oil is in seal area, replace o-ring, reference (G), figure 8-8, item 5.

e. Inspect the inlet drain piping. Verify that inlet drain piping is isolated from the module oily waste drain lines. If not isolated, verify check valves installed and functioning correctly.

f. Inspect pressurization tubing for blockage. Has recent maintenance been accomplished? If so, check affected tubing.

(1) Operate engine at idle. Check 8th stage air pressurization line couplings from 8th stage to A-sump inlet for air leaks. You can do this by carefully feeling around the couplings for airflow. Be careful not to actually touch any of the hot piping. Correct leaks.

g. Check VSV actuators to insure lines are connected correctly. If not, reconnect IAW reference (G), figure 8-30. This problem usually occurs after a maintenance action that required disconnecting or removing VSV actuator lines. Another symptom will be low engine power since VSVs will be closed when they should be open.

h. Check A-sump and AGB-sump scavenge oil strainers for contamination using MIP 2340. Refer to section titled "**LUBE AND SCAVENGE PUMP INLET SCREEN CONTAMINATION**" for assistance in identifying various types of contaminates. If suspect material is found in the A-sump or AGB screens, the source must be further identified.

(1) Inspect the inlet gearbox and A-sump area for any distress. If suspect material is identified as epoxy particles that are hard and breakup easily, check the inlet gearbox cover plate, reference (G), figure 8-52, item 7.

(2) Check for indications of damage or looseness by gently tapping on the plate with your fingertips. If the plate appears loose, the epoxy seal inside of the Inlet Gearbox (IGB) may have failed. If you are not sure after checking with your hand, you can test the integrity of the epoxy seal by removing the IGB and pouring about 3/4 of an inch of fuel oil into the gear shaft assembly, reference (G), figure 8-52, item 6. If the fuel leaks out, replace the IGB.

i. Compare CDP to NGG using figure previously provided to determine if there is a problem with VSV positioning.

3.5.6 Oil Leaking From B-Sump Drain Into Oily Waste Tank Oil Leaking From B-Sump Vent Horns

NOTE

Any seal leakage may continue to occur after its cause has been corrected due to contamination of the seal labyrinth. Full power operation for 30 to 90 minutes should clear the seals and restore normal operation.

a. Run the engine at idle. Is there heavy oil mist coming from the B-sump horns?

(1) Check B-sump vent piping, reference (G), figure 8-43, item 14, for obstructions. If obstructed, clear and monitor B-sump drain leakage. If not obstructed, go to section titled "**AIR/OIL SEPARATOR TROUBLESHOOTING**."

b. Check the following:

(1) Insure that the vent damper is fully open during engine operation. For FFGs, insure bypass damper is fully open during engine operation. Note cooling fan is secured when the engine develops more than 3000 horsepower. Refer to MIP 2513 for FFG vent damper maintenance requirements.

(2) Inspect the A- and B-sump air ejector for blockage by shining a flashlight into the ejector through the nozzle screen. Remove any obstructions.

(3) Check the part number on the side of the A- and B-sump nozzle. If GTC 53 is incorporated it should be L21442GO3. If not, request installation of GTC 53.

(4) Next, operate the engine at high power (NGG greater than 8000 RPMs) for approximately 1-1/2 hours. In most cases, this should clear the sump of excess oil and eliminate the leakage and smoke.

(5) It is unlikely, but the air ejector may be internally clogged. Verify flow at ejector inlet with hand. Be careful not to actually touch any of the hot piping. Remove the ejector and look through the long run of the nozzle. Remove any obstructions.

c. If leakage and misting continue after checking above items, disconnect the B-sump scavenge system tube, reference (G), figure 8-40, item 76 at the B-sump discharge point. Does a large quantity of oil leak out? If no, internal B-sump problem is indicated. Contact FTSC for further assistance. If yes, one of the following is indicated:

(1) A clogged B-sump scavenge oil screen, reference (E), figure 7-120 and 7-121, view A. Remove and inspect the screen from the lube oil and scavenge pump IAW MIP 2340. If the screen is clogged, evaluate the particles removed from the screen for indications of lube oil system contamination or bearing failure. Save particles for possible later evaluation. If the system is contaminated, other scavenge oil screens may show similar conditions of blockage or residue build up. If a bearing failure is

indicated, contact FTSC additional guidance. If bearing failure is not indicated, clean the screen, save particles for possible later evaluation, re-install and monitor leakage from the B-sump drain.

(2) Obstructed B-sump scavenge system piping. Remove piping system, reference (G), figure 8-40, items 76, 86 and 91, and check for obstructions. If obstruction exists, clear, reinstall piping and monitor B-sump leakage.

(3) A failed scavenge pump element. Check finger strainer for metallic particles IAW MIP 2340. If the element is faulty, replace the lube oil and scavenge pump, ref (G), figure 8-36, item 1.

d. If B-sump leakage continues to exceed limits after correcting deficiencies found above, internal B-sump problems are indicated. Contact FTSC for additional guidance.

3.5.7 <u>Oil Leaking From C-Sump Drain Into Oily Waste Tank Oil Leaking From C-Sump Vent Horns (Single Shank GG Only)</u>

NOTE

Any seal leakage may continue to occur after its cause has been corrected due to contamination of the seal labyrinth. Full power operation for 30 to 90 minutes should clear the seals and restore normal operation.

a. Run the engine at idle. Is there oil accumulation or signs of coking at the base of the power turbine sixth stage blades or in the case of a single shank turbine configured with a re-vent system, is there heavy oil mist coming from the C-sump horns? If no, go to paragraph below. If yes, go to paragraph b below.

(1) Check C-sump vent piping, reference (G), figure 8-43, items 18 and 24, for obstructions. If obstructed, clear and monitor C-sump drain leakage. If not obstructed, go to section titled "**AIR/OIL SEPARATOR TROUBLESHOOTING**."

b. Check the following:

(1) Insure that the vent damper is fully open during engine operation. FFG only, insure bypass damper is fully open during engine operation. If not open, troubleshoot for vent damper problems. For FFGs see MIP 2513 for vent damper maintenance requirements.

(2) Inspect the C- and D-sump air ejector reference (G), figure 8-43, item 55, for blockage by shining a flashlight into the ejector through the nozzle screen. Remove any obstructions and monitor leakage.

(3) Check the part number on the side of the nozzle. It should be L21443GO2. If not, install correct ejector and monitor leakage.

(4) Next, operate the engine at high power (NGG greater than 8000 RPMs) for approximately 1-1/2 hours. In most cases, this should clear the sump of excess oil and eliminate the leakage and smoke.

(5) It is unlikely, but the air ejector may be internally clogged. Remove the ejector and look through

the long run of the nozzle. Remove any obstructions.

c. If leakage and misting continue after checking above items, disconnect the C-sump scavenge system tube, reference (G), figure 8-40, item 52, at the C-sump discharge point. Does a large quantity of oil leak out? If no, internal-C sump problem is indicated. Contact FTSC for additional assistance. If yes, one of the following is indicated:

(1) A clogged C-sump scavenge oil screen, reference (E), figure 7-120 and 7-121, view A. Remove and inspect the screen from the lube oil and scavenge pump in accordance with MIP 2340. If the screen is clogged, evaluate the particles removed from the screen for indications of lube oil system contamination or bearing failure. Save particles for possible later evaluation. If the system is contaminated, other scavenge oil screens may show similar conditions of blockage or residue build up. If a bearing failure is indicated, contact FTSC for additional guidance. If bearing failure is not indicated, clean the screen, save particles for possible later evaluation, reinstall and monitor leakage from the C-sump drain.

(2) Obstructed C-sump scavenge system piping. Remove piping system, reference (G), figure 8-40, items 52, 64, 71 and 72, and check for obstructions. If obstruction exists, clear, reinstall piping and monitor C-sump leakage.

(3) A failed scavenge pump element. Check finger strainer for metallic particles. If the element is faulty, replace the lube oil and scavenge pump, reference (G), figure 8-36, item 1.

d. If C-sump leakage continues to exceed limits (it may take up to 45 minutes of high power operation to see this condition) after correcting deficiencies found above, internal C-sump problems are indicated. Conduct oil survey and plot sump temps versus NGG IAW attachment (1). Contact FTSC for additional guidance.

NOTE

Deteriorated HPT rotor o-ring is a common cause of this problem.

3.5.8 Oil Leaking From Starter Accessory Gearbox Drain

a. This problem is normally discovered when troubleshooting the lube oil system for lube oil consumption when obvious leaks are not observable. Leakage at the starter is verified when oil leaks from the open end of starter tube drain line reference (G), figure 8-39, item 21.

b. The most common cause of leakage is a failed, damaged, improper sized or missing starter spline shaft o-ring, reference (G), figure 8-31, item 4. Leakage only occurs at higher operating power levels (NGG above 8000 RPMs) when oil into the AGB exceeds the capacity of the scavenge pump so that the AGB fills with oil to the level of the starter shaft. The most common occurrence of o-ring problems happens just after starter maintenance or replacement. Replace the o-ring using the starter replacement procedure, reference (E), para. 7.67, 7.67.1 and 7.67.3.

c. If the starter drain continues to leak after replacement of the shaft o-ring, mechanical seal, reference

(G), figure 8-55, item 116 may have failed. If the carbon ring portion of the seal has failed, and the mating wear ring is still good, the carbon ring can be replaced without disassembling the gearbox. This repair has worked several times. Proceed as follows:

(1) Remove the starter IAW reference (E), paragraphs, 7.67 and 7.67.1.

(2) Remove key washers and bolts, reference (G), figure 8-55, items 118 and 119.

(3) Remove seal retainer, reference (G), figure 8-55, item 117.

(4) Remove washers and bolts, reference (G), figure 8-55, items 113 and 114.

(5) Carefully remove the carbon ring portion of the seal, reference (G), figure 8-55, item 116. The oil film between the two faces of the seal may make it difficult to remove. Use two small flat tipped screwdrivers to evenly pry the seal outwards.

(6) If the carbon ring is obviously damaged then it is not necessary to replace o-ring, reference (G), figure 8-55, item 115. If the carbon ring appears satisfactory, remove o-ring item 115.

(7) Inspect the face of the seal wear surface to insure that it is undamaged and smooth to the touch. If there is any dirt on the wear surface, flush it with lube oil applied from a spray bottle. If the surface is damaged, replacing the carbon ring will not stop the leak. Contact FTSC for further guidance.

(8) Replace o-ring, reference (G), figure 8-55, item 115, if removed. An agile, relatively small person can sit cross legged in front of the AGB to replace this o-ring. It takes two hands and patience. Lubricate the o-ring with lube oil.

(9) Carefully install the carbon ring, reference (G), figure 8-55, item 116. Lubricate with engine oil. Push the ring in evenly and slowly until it contacts the wear ring.

(10) Install washers and bolts, reference (G), figure 8-55, items 113 and 114. Torque bolts, item 114, 24 to 27 in-lbs.

(11) Install seal retainer, reference (G), figure 8-55, item 117.

(12) Install new key washers, reference (G), figure 8-55, item 118 and bolts, item 119. Torque bolts 24 to 27 in-lbs. An over torque to 40 in-lbs. is permitted to align the tabs of the key washers to the flats on the bolt heads.

(13) Install a new starter splined shaft o-ring, reference (G), figure 8-31, item 4.

(14) Reinstall the starter IAW reference (E), para 7.67.3.

3.5.9 Oil Leaking From Fuel Pump Accessory Gear Box Drain

a. This problem is normally discovered when troubleshooting the lube oil system for lube oil consumption when obvious leaks are not found. Leakage at the fuel pump is verified when oil leaks from the open end of fuel pump tube nipple, reference (G), figure 8-39, item 15. Insure that the fluid leaking is lube oil and not fuel oil. If fuel is leaking, replace the fuel pump.

b. The most common cause of leakage is a failed, damaged, improper sized or missing fuel pump splined shaft o-ring, reference (G), figure 8-32, item 2. Leakage only occurs at higher operating power levels (NGG above 8000 RPMS) when oil into the AGB exceeds the capacity of the scavenge pump so that the AGB fills with oil to the level of the fuel pump shaft. The most common occurrence of o-ring problems happens just after fuel pump replacement. Replace the o-ring using the fuel pump replacement procedure, reference (E), para. 7.65, 7.65.1 and 7.65.2.

c. If the fuel pump still leaks after proper replacement of the shaft o-ring, mechanical seal, reference (G), figure 8-55, item 77 may have failed. If the carbon ring portion of the seal has failed, and the mating wear ring is still good, the carbon ring can be replaced without disassembling the gearbox. This repair has worked several times with the fuel pump seal. Proceed as follows:

(1) Remove the fuel pump IAW reference (E), paragraphs 7.65 and 7.65.1.

(2) Remove key washers and bolts, reference (G), figure 8-55, items 78 and 79.

(3) Carefully remove the carbon ring portion of the seal, reference (G), figure 8-55, item 77. The oil film between the two faces of the seal may make it difficult to remove. Use two small flat tipped screwdrivers to evenly pry the seal outwards.

(4) If the carbon ring is obviously damaged then it is not necessary to replace o-ring, reference (G), figure 8-55, item 76. If the carbon ring appears satisfactory, remove o-ring item 76.

(5) Inspect the face of the seal wear surface to insure that it is undamaged and smooth to the touch. If there is any dirt on the wear surface, flush it with lube oil applied from a spray bottle. If the surface is damaged, replacing the carbon ring will not stop the leak. Contact FTSC for further guidance.

(6) Replace o-ring, reference (G), figure 8-55, item 76, if removed. Lubricate the o-ring with oil.

(7) Carefully install the carbon ring, reference (G), figure 8-55, item 77. Lubricate with engine oil. Push the ring in evenly and slowly until it contacts the wear ring.

(8) Install new key washers, reference (G), figure 8-55, item 78 and bolts, item 79. Torque bolts 24 to 27 in-lbs. An over torque to 40 in-lbs. is permitted to align the tabs of the key washers to the flats on the bolt heads.

(9) Install a new fuel pump splined shaft o-ring, reference (G), figure 8-32, item 2.

(10) Reinstall the fuel pump IAW reference (E), paragraph 7.65.2.

3.5.10 Oil Leaking From Fuel Pump Fwd Flange AGB Drain

a. This problem is normally discovered when troubleshooting the lube oil system for lube oil consumption when obvious leaks are not observable. Leakage at the fuel pump is verified when oil leaks from the open end of fuel pump drain hose, reference (G), figure 8-39, item 18.

b. Leakage only occurs at higher operating power levels (NGG above 8000), when oil into the AGB exceeds the capacity of the scavenge pump so that the AGB fills with oil to the level of the fuel pump shaft.

c. In an emergency, the hose or nipple, reference (G), figure 8-39, items 18 or 20 can be capped to prevent lube oil loss until the seal, reference (G), figure 8-55, item 69 can be replaced.

d. Leakage at this port if probably caused by failure of mechanical seal, reference (G), figure 8-55, item 69. If the carbon ring portion of the seal has failed, and the mating wear ring is still good, the carbon ring can be replaced without disassembling the gearbox. This repair has worked several times. Proceed as follows:

(1) Remove V-band, adapter cover and gasket, reference (G), figure 8-55, items 65, 66 and 67.

(2) Remove key washers and bolts, reference (G), figure 8-55, items 70 and 71.

(3) Carefully remove the carbon ring portion of the seal, reference (G), figure 8-55, item 69. The oil film between the two faces of the seal may make it difficult to remove. Use two small flat tipped screwdrivers to evenly pry the seal outwards.

(4) If the carbon ring is obviously damaged then it is not necessary to replace o-ring, reference (G), figure 8-55, item 68. If the carbon ring appears satisfactory, remove o-ring item 68.

(5) Inspect the face of the seal wear surface to insure that it is undamaged and smooth to the touch. If there is any dirt on the wear surface, flush it with lube oil applied from a spray bottle. If the surface is damaged, replacing the carbon ring will not stop the leak. Contact FTSC for further guidance.

(6) Replace o-ring, reference (G), figure 8-55, item 68, if removed. Lubricate the o-ring with oil.

(7) Carefully install the carbon ring, reference (G), figure 8-55, item 69. Lubricate with engine oil. Push the ring in evenly and slowly until it contacts the wear ring.

(8) Install new key washers, reference (G), figure 8-55, item 70 and bolts, item 71. Torque bolts 24 to 27 in-lbs. An over torque to 40 in-lbs. is permitted to align the tabs of the key washers to the flats on the bolt heads.

(9) Install a new gasket, reference (G), figure 8-55, item 67.

(10) Reinstall V-band, adapter cover and gasket, reference (G), figure 8-55, items 65, 66, and 67.

3.5.11 <u>Oil Leaking From AGB Drains Into Oily Waste Tank</u>

a. This problem is usually noticed when oil is discovered around the right-side module floor drain, reference (H), figure 9-34 item 22, or when troubleshooting lube oil consumption problems. This usually indicates one of the following:

(1) Leakage from one of the three AGB drains or the lube oil/scavenge pump. Go to the module for troubleshooting "**OIL CONSUMPTION, NO OBVIOUS LEAKS**." Use the section that pertains to isolating AGB leakage problems.

(2) High oily waste tank level. Oil can be forced into the module through the oily waste drain if the tank is flooded and the tank is not isolated from the drain lines with an air break. Check the following:

(a) Drain lines blocked

(b) Drain lines not isolated from oily waste tank

3.5.12 Oil On Module Deck Near Waste Tank Drains (Mid-Module)

a. There are two mid module oily waste drains. The right side module drain (Reference (H), figure 9-34, item 22) acts as an overboard drain for oil leakage from the AGB and air/oil separator exhaust tube. The left side drain (Reference (H), figure 9-34, item 24) acts as an overboard drain for oil leakage from B- and C-sumps and air/oil separator exhaust tube.

b. Oil accumulation around one of these drains is usually noticed during module inspections during idle operation or just after securing the engines.

c. This problem is caused by one of the following:

(1) Leakage from one of the three AGB drains or the lube oil/scavenge pump, leakage from either the B or C-sump drains or excessive leakage from the air/oil separator exhaust tube. Go to the section for troubleshooting "**OIL CONSUMPTION, NO OBVIOUS LEAKS**."

(2) High oily waste tank level. Oil can be forced into the module through the oily waste drain if the tank is flooded and the tank is not isolated from the drain lines with an air break. Check the following:

(a) Drain lines blocked

(b) Drain lines not isolated from oily waste tank

(c) For FFGs only, ensure mid-module loop seal is not dry. If it is, re-establish seal by pouring approximately 1 gallon of water into the drain.

3.5.13 Air/Oil Separator Troubleshooting

a. Check air/oil separator discharge piping-drain, reference (H), figure 9-35, item 64 for excessive oil drainage. Is drainage excessive? If no, go to sections titled "**OIL LEAKING FROM B-SUMP DRAIN INTO OILY WASTE TANK**" or "**OIL LEAKING FROM C-SUMP DRAIN INTO OILY WASTE TANK**." If yes, proceed as follows:

(1) Check air/oil separator discharge piping, reference (H), figure 9-35, items 5, 6, and 7 for obstructions, particularly the flame arrestor, item 8. Were obstructions found? If yes, clear and monitor leakage. If no, remove the air/oil separator cover, reference (G), figure 8-53, item 2, and check seals and impeller.

(2) Are cover seals damaged? If yes, replace cover and monitor consumption.

(3) Is impeller cracked? If yes, replace air/oil separator.

(4) Check seal pressurization line, reference (G), figure 8-43, item 39, for obstructions. If obstructed, clear and monitor consumption.

(5) Check scavenge line, reference (H), figure 9-36, item 34 for obstructions. If obstructed, clear and monitor consumption.

(6) Check for a failed scavenge pump element. Check the finger strainer for metallic particles IAW MIP 2340. If the element is faulty, replace the lube oil and scavenge pump, reference (G), figure 8-36, item 1.

3.5.14 Oil Leaking On Module Deck From Unknown Location

a. A common problem is identification of the exact source of an external oil leak in the module. Typically, a hard to locate leak will be small causing noticeable oil wetting of the module floor after several hours of operation for several days with the engines secured. This problem is complicated by the number of fittings, lines and components that interface with the lube oil system in the forward section of the engine. Another complicating factor is migration of the oil away from the leak due to normal airflow through the module and airflow from the starter during starts.

b. The best approach for identifying these oil leaks is to first thoroughly clean around the suspected leak area in accordance with MIP 2340 as follows:

(1) Use “Simple Green”® mixture, soft scrub brushes, toothbrushes and paintbrushes as necessary to access difficult areas.

(2) Using detergent solution and beginning at the top of the engine and working towards the bottom, scrub away salt deposits, grease and oily residue from area affected. Put some of the solution into a spray bottle and spray into hard to reach places.

(3) Rinse soapy solution from engine using hot distilled water. Spray bottles may work best for this rinse.

(4) Using an air hose regulated to approximately 10 PSIG, air dry engine starting at the top and working towards the bottom.

(5) Operate the engine at idle for approximately 30 minutes. Secure the engine and check for signs of oil leakage. If none are found, run the engine for a longer period of time, and/or at higher power until the first signs of a leak are found. At this point, you should be close to the source of the leak.

(6) If oil leakage was significant after the first 30-minute run and you can not identify the source, re-clean the engine and operate for a shorter period of time. Re-inspect the engine. At some point, you should get close to the source of the leak.

3.5.15 Oil Leaking From A-Sump Supply Tube At Compressor Front Frame

a. Oil accumulating around the compressor front frame at the Sump oil supply tube wear bushing, reference (G), figure 8-58 sheet 1, item 22, and number 3 damper bearing line (if applicable), reference (G), figure 8-58 sheet 2, item 41, can be caused by one of the following:

(1) Oil migration from another area of the engine.

(2) Failure of o-ring reference (G), figure 8-8, either item 15 or item 18.

(3) Failure of the braze joints at the braze coupling, reference (G), figure 8-58, item 24.

(4) Test for oil migration by cleaning the wear coupling, braze coupling, tube elbow, reference (G), figure 8-58, item 29, number 3 bearing damper seal line (if applicable) item 41, and surrounding area in accordance with guidance provided in the section titled "**OIL LEAKING ON MODULE DECK FROM UNKNOWN LOCATION.**" If oil does not re-accumulate after testing, oil leak is not associated with the A-sump supply tube assembly. Continue troubleshooting until you identify source of oil leak.

NOTE

Contact FTSC prior to proceeding to step (5).

(5) Replace o-rings, reference (G), figure 8-7, items 13 and 14 as follows:

(a) Remove the inlet screen IAW reference (E), paragraphs 7.54 and 7.54.1.

(b) Remove the center body IAW reference (E), paragraphs 7.57 and 7.57.1.

(c) Remove the radial drive IAW reference (E), paragraphs 7.58 and 7.58.1.

(d) Remove the inlet gearbox IAW reference (E), paragraphs 7.59 and 7.59.1. Pay particular attention to detail a of figure 7-109 when removing inlet gear box.

(e) Remove oil tube, reference (G), figure 8-7 sheet 1, item 4, and o-ring, item 13, by removing four screws, item 11.

(f) Remove the A-sump oil supply hose, reference (G), figure 8-38, item 1.

(g) Move the oil supply tube, reference (G), figure 8-58, item 21, radially inward into the transfer gearbox by gently tapping on the wear bushing, item 22, with a mallet and flat tipped screwdriver. Move the bushing just far enough to remove o-ring, reference (G), figure 8-7, item 13, from around the tube in the inlet gearbox area.

(h) Install new o-ring, reference (G), figure 8-7, item 13, coated with petrolatum or lube oil. Carefully ease tube-assembly back into strut cavity.

(i) Install oil tube, reference (G), figure 8-7, item 4, and o-ring, item 14 to completely seat oil supply tube, figure 8-58, item 21, in the strut cavity. Remove oil tube figure 8-7, item 4 and o-ring item 14.

(j) Pressure test the o-ring, figure 8-7, item 13 and braze coupling, figure 8-58, item 24 as follows:

1. Install cover-plate, GE part number LC6867PO4 and o-ring seal over the open end of the supply tube in the transfer gearbox area. If cover plate

is not available, use the flange face of the oil tube, reference (G), figure 8-7, item 4, as a template to manufacture a blank flange. Make a matching gasket from Garloc gasket material for the blank flange.

2. Using the VSV pump, pressurize the A-sump oil supply tube assembly at the tube elbow, figure 8-58, item 29, to 100 PSIG and let set at this pressure for approximately 1 hour. If pressure drops off, look for leaks around the brazed coupling or the test flange. If the gasket is leaking, replace with a slightly thinner one and retest. If the braze joint is leaking, repair procedure is covered in reference (J), para 8.147. Reference (J) is a depot level technical manual and not readily available to the fleet. FTSC will forward a copy of para 8.147 upon request. Another possible source for loss of pressure is a defective VSV pump assembly. Test assembly by blanking off hose end and pumping against the blanked end. Pump assembly should hold 100 PSIG pressure for one hour.

(k) After completing a successful pressure test remove the VSV pump and blank flange.

(l) Install oil tube, reference (G), figure 8-7, item 4, and new o-ring, item 14. Torque bolts, reference (G), figure 8-7, item 11, 55 to 70 in-lbs.

(m) Install new o-ring, reference (G), figure 8-7, item 17, on the forward end of supply tube, item 4.

(n) Install inlet gearbox IAW reference (E), paragraph 7.59.2.

(o) Install radial drive shaft IAW reference (E), paragraph 7.58.2.

(p) Install center body IAW reference (E), paragraph 7.57.2.

(q) Install inlet screen IAW reference (E), paragraph 7.54.2.

(r) Install A-sump oil supply hose, reference (G), figure 8-38, item 1.

(6) Test engine IAW section titled "**OIL LEAKING ON MODULE DECK FROM UNKNOWN LOCATION**."

3.5.16 <u>Oil Leaking From Jacking Pad, Cover Removed, Engine Secured</u>

a. Oil leaking from the manual jacking pad is normally discovered when the cover plate, reference (G), figure 8-55, item 156, is removed for engine rotation during borescope inspections. The accessory gearbox (AGB), which normally holds no lube oil, can fill up over several days when the engine is secured if check valve, reference (H), figure 9-15, item 6, is leaking by internally. To test for leak by, disconnect hose, reference (H), figure 9-15, item 16, at the lube oil pump and put the open end of the hose into a 1gallon can. If oil continually drains after an hour, a faulty check valve is indicated. Replace check valve.

b. This is normally not a major problem since the AGB will be scavenged out when the engine is started. Reference (E) does not provide guidance for replacing the check valve, however, torque values for the 1-1/4 union nuts are provided in the procedure for replacing the oil supply duplex filter, reference (F), para. 7.139, 7.139.1 and 7.139.2.

3.5.17 Oil Leaking From Any Supply Line Hose Or Tube Fitting

a. Once an oil leak has been definitely isolated to a particular hose or tube fitting, proceed to one of the following technical manual sections for repair: (Reference (E) applies)

(1) Corrections of leaks, general: para 7.4.9.

(2) Bulkhead fittings: para 7.4.13.

(3) Gaskets and o-ring seals: para 7.4.15.

(4) Tubes: para 7.4.16.

(5) Hoses: para 7.4.17.

NOTE

Refer to GGTB 17 for leak criteria.

3.5.18 Oil Leaking From Turbine Mid Frame During Engine Lay-Up

a. Oil leaking from the 6:00 o'clock positions of the turbine mid frame flanges after performance of reference (B), para 4.2.2 will occur if sumps are not completely scavenged of oil injected from the lube oil cart. This condition is not detrimental to the engine. Excess lube oil will be scavenged when the engine is motored or shortly after operating the engine. In a worst case condition, operation at high power for approximately 1-1/2 hours will clear the B- and C-sumps of excess oil. The engine can also be rotated using the jacking pad to empty out the sumps. While performing this, ensure oil supply cutout valve is closed.

3.5.19 High Lube Oil Temperature

a. Lube oil temperatures are monitored at six locations:

(1) A-sump scavenge temperature

(2) B-sump scavenge temperature

(3) C-sump scavenge temperature

(4) D-sump scavenge temperature

(5) AGB (accessory gear box) scavenge temperature

(6) Oil cooler discharge temperature

(a) Figure 3-9 shows typical oil temperature curves for the six locations. The curves were generated from data taken by an FFG under the following test conditions:

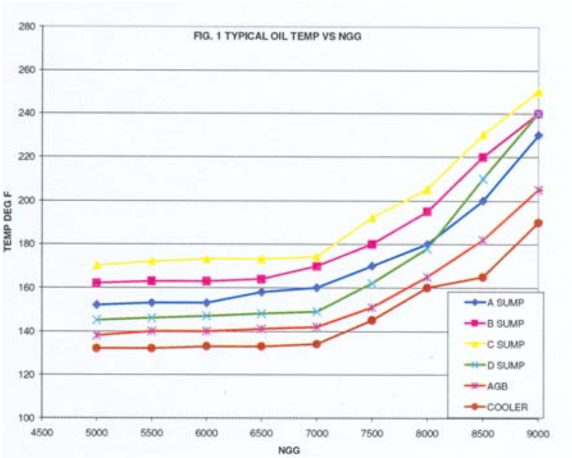

Figure 3-9. Typical Oil Temp vs. NGG

1. Full power mode (both engines driving the shaft)
2. 5 minutes operation at 500 RPM increments from 5000 NGG to full power. Four reading a full power, 5 minutes apart.
3. Average T2 was 50°F.
4. From Figure 3-9, you can see some general trends for lube oil temperatures:

   a Typically, B-, C-, and D-sumps operate hotter than A-sump and the "AGB". This is caused by the hotter operating environment of the B-, C- and D-sumps.

   b D-sump crosses over A- sump when the engine begins to develop power around 8000 NGG RPMs.

   c All the curves are relatively smooth without sharp turns. As a comparison, on Figure 3-10, you can see a sharp upward turn of the AGB temperature curve at 8000 NGG. This is caused by "AGB" flooding and is discussed in detail in the section titled "**HIGH ACCESSORY GEARBOX SCAVENGE TEMPERATURES.**" Para. (5) and (6) will help isolate and correct high oil temp problems.

5. Are all scavenge temperatures high? If no, go to paragraph (6). By high we mean that they have increased above previous levels, but have not necessarily reached alarm temperature. We also consider temperatures high that are 50°F higher than the other engine(s) operating under similar conditions.

NOTE

Increased T2 and module temperatures, which occur in hot climates will cause an over all increase in lube oil temperatures.

a If all scavenge temperatures are high, check the LOSCA cooler discharge temperature. Is the temperature below 200 degrees?

b Is MRG lube oil cooler outlet above 120°F?

c Reduce reduction oil temperature to 115 +/- 5 degrees by one of the following methods:

d DDs, DDGs, CGs - adjust or repair temperature control valves to the cooler.

e FFGs - Change diverting orifice diameter in 4 inch red gear oil supply line from 2 inches to 1-5/8 inch bore and balance orifice diameter in 3 inch red gear oil supply line from 1-5/8 inches to 1-1/2 inch bore, if not previously accomplished.

f Is module temperature above 250 degrees?

g If module temperature is above 250 degrees, check vent damper IAW reference (C), figure 5-57. If the damper is not working properly, repair or replace. Also check:
- Bypass damper
- Blow-in doors
- Demisters for blockage

6. Only one scavenge temperature is high.

a Check scavenge temperature RTD and circuit IAW reference (C), para. 5-16.12. is either one faulty? If yes, repair or replace RTD or circuit.

b AGB scavenge temperature is the only high one, go to section titled "**HIGH ACCESSORY GEAR BOX SCAVENGE TEMPERATURES**."

c If you have not isolated the problem at this point, the next approach is to collect a set of operating data. Test the engine IAW attachment (1). Graph the results and compare with typical curves shown in Figure 3-9 and Figure 3-10. Analysis of the graphs should help isolate the problem.

3.5.20 <u>High Accessory Gearbox (AGB) Scavenge Temperature (Above 300 Deg F)</u>

a. If the AGB scavenge temperature increases rapidly when GG speed exceeds 8000 RPM and then rapidly drops off when power is reduced, and there is a temporary reduction in the LOSCA tank level at high power, then lube oil is collecting in the AGB. Heat is generated in the AGB as the gears churn the oil. The oil cooler discharge temperature will increase in conjunction with the increased AGB temperature. See Figure 3-10 for an example:

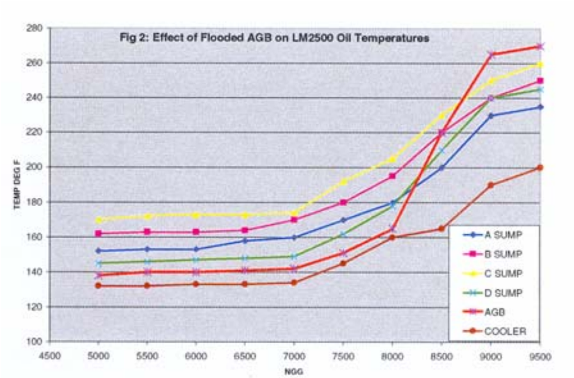

Figure 3-10. Effect of Flooded AGB on LM2500 Oil Temperatures

b. In a 5-element lube/scavenge pumps, a single scavenge pump element evacuates lube oil from the AGB and all oil extracted by the air/oil separator. On some engines, the combined flow at high power levels exceeds the capacity of the single element allowing accumulation of oil in the AGB. GTC 83 solves the problem by adding a separate element for scavenging the air/oil separator. GTC 93 changes plumbing of scavenging pumps and sumps. Prior to requesting accomplishment of either GTC 83 or GTC 93 replace AGB scavenging hose, since it is possible that hose has collapsed internally.

3.5.21 Oil Leaking From VSVs

a. Oil is leaking from VSVs.

b. Oil is leaking all the way around the compressor case. Is the oil residue dark and muddy looking? If dark and muddy looking, this indicates a long-standing condition.

(1) First step is to clean the compressor case IAW MIP 2340. Inspect the inlet drain piping. Verify that drain piping is isolated from the module oily waste drain lines. If not isolated, verify check valves installed and functioning correctly.

(2) Check bullet nose for indications of oil dripping from seal area. If oil is in seal area, replace o-ring, reference (G), figure 8-8, item 5.

(3) With engine at idle, is exhaust smoky?

(a) If exhaust is smoky, this indicates A-sump seal pressurization air supply problem. Proceed as follows:

1. Inspect pressurization tubing for blockage. Has recent maintenance been accomplished? If so, check affected tubing.

2. Run engine at idle. Check 8th stage air pressurization line couplings from 8th stage to A- sump inlet for air leaks. You can do this by carefully feeling around

the couplings for airflow. Be careful not to actually touch any of the hot piping. Correct leaks.

3. Check VSV actuators to insure lines are connected correctly. If not, reconnect IAW reference (G), figure 8-30. This problem usually occurs after a maintenance action that required disconnecting or removing VSV actuator lines. Another symptom will be low engine power since VSVs will be closed when they should be open.

4. Check A and AGB sump scavenge oil strainers in accordance with MIP 2340 for contamination. Refer to section titled "Lube And Scavenge Pump Inlet Screen Contamination" for assistance in identifying various types of contaminants. If the suspect material is found in the AGB screen, the source must be further identified. Inspect the inlet gearbox and A-sump area for any distress. If suspect material is identified as epoxy particles which are hard but breakup easily, check the inlet gearbox shaft plug, reference (G), figure 8-52, item 7, for indications of damage or looseness by gently tapping on the plate with your finger tips. If the plate appears loose, the epoxy seal inside of the IGB may have failed. If you are not sure after checking with your hand, you can test the integrity of the epoxy seal by removing the IGB and pouring about 3/4 of an inch of fuel oil into the gear shaft assembly, reference (G), figure 8-52, item 6. If the fuel leaks out, replace the IGB.

c. Oil only on bottom of compressor case and VSVs is usually caused by oil from a starter. If starter was recently replaced or repaired, clean engine and monitor for additional oil accumulation. Otherwise, check oil level in starter IAW MIP 2340. If level is low, this indicates starter problem. Fill starter, clean engine, and test. If problem continues and starter oil level is low again, replace starter.

3.5.22 <u>Oil Dripping From Accessory Gear Box</u>

a. Oil leaking around forward side of AGB. Inspect bevel area where radial drive shaft sleeve, reference (G), figure 8-7, item 22, enters the gearbox. Check bevel for pooling of oil. If oil is found, replace o-rings reference (G), figure 8-7, items 20 and 23. Replacing the o-rings requires lowering the AGB from the gas generator and is an "I" level task, and is deferred to an IMA.

b. Residual oil around the AGB may be from a starter failure or current starter leak. If starter was recently replaced or repaired, clean engine and monitor for additional oil accumulation. Otherwise, check oil level in starter IAW current MIP 2340. If level is low, this indicates starter problem. Fill starter, clean engine, and test. If problem continues and starter oil level is low again, replace starter.

c. Fuel leaking from the VSV actuators or CIT sensor can appear to be oil leaking from the AGB if the fuel drips down onto the gearbox. Go to section "**OIL LEAKING FROM UNKNOWN SOURCE**."

d. Oil leaking from A-sump vent line connection at the aft side of the compressor front frame, 1 o'clock position, may appear to be oil leaking from the AGB if oil drips down onto the gearbox. Go to section titled "**OIL LEAKING ON MODULE DECK FROM UNKNOWN SOURCE**."

3.5.23 Chaffing Of C-Sump Lube Oil Supply Tube At Turbine Midframe Strut

a. Chaffing of C-sump lube oil supply tube, reference (G), figure 8-77, item 32, at its entry to turbine mid frame strut number 7 is caused by vibration. GTC 79 adds a vibration dampening bracket and clamp on the C-sump lube supply line. GTC 79 kits are currently available.

b. Extreme chaffing of the wear sleeve on this tube is reason for concern because it cannot be repaired in place. Gas generator change-out is required. If chaffing has not cut into the tube base metal more than 0.015 inches (tube wall thickness is 0.035"), a GTC 79 bracket can be added to prevent future deterioration of the sleeve. Contact FTSC.

3.5.24 No Or Low Lube Oil Pressure

a. Verify system alignment and calibration. Lube oil supply pressure should increase above 6 PSIG within 45 seconds of start. Once the engine is running, lube oil pressure should conform to lube oil curve limits of reference (B), figure 3.9.

b. Check LOSCA lube oil level (oil level below low level sight glass)? If yes, service oil tank.

c. Is there evidence of leaks down stream of the lube oil pump? If yes, tighten fittings or replace defective components.

d. Connect a 0-100 PSI gage to instrumentation valve for oil pressure transducer and start engine. Does gage read normal oil pressure? If yes, check calibration of oil pressure transducer in accordance with reference (E), para 7.16.

e. Disconnect oil supply line to pump and check for inadequate flow. Is the flow restricted? If yes, trouble is restriction in oil tank or lube oil supply line. See reference (D), figure 6-3 for DD 963s or figure 6-71 for FFGs. Pump rotation can be verified by using a telescoping mirror to look inside an open finger strainer port while rotating the pump.

f. Replace lube oil pump and recheck. Does new pump correct problem? If yes, done. If no, trouble is an internal leak. Contact FTSC for further assistance.

3.5.25 High Lube Oil Pressure

a. Ensure correct system alignment and transducer calibration. Lube oil supply pressure should rise above 6 PSIG within 45 seconds of start. Once the engine is running, pressure should meet the curve limits of reference (B), figure 3.9.

b. Inspect all lube oil tubes downstream of pump. Are tubes damaged or restricted? If yes, repair or replace defective component.

c. Check all scavenge screens, scavenge filter elements and supply filter elements for contamination. Is contamination present? If yes, clean all filters and screens. Drain and refill oil tank. Determine contamination source. Repair or replace defective component. Operate and secure engine, repeat inspection. If not, trouble is clogged or damaged oil jet. Contact FTSC for further assistance.

3.5.26 LOSCA Level Drops Engine Secured

a. Inspect engine and LOSCA for possible leaks. If leaks are found, repair or replace faulty component. If you have difficulty finding a specific leak, go to section titled, "**OIL LEAKING ON MODULE DECK FROM UNKNOWN LOCATION**."

b. Is check valve, reference (H), figure 9-15, item 6, leaking by? To test, disconnect hose, reference (H), figure 9-15, item 16, at the lube oil pump and put the open end of the hose into a one-gallon can. If oil continually drains after an hour, check valve is bad. Replace check valve. Reference (C) does not provide guidance for replacing the check valve, however, torque values for the 1-1/4 union nuts are provided in the procedure for replacing the oil supply duplex filter, reference (F), para. 7.132, 7.132.1 and 7.132.2.

c. Is oil coming from the lube oil pump drain line, reference (G), figure 8-39, item 13? Disconnect the drain hose at the lube oil pump. Put a 1 gallon can under the open fitting on the pump. If oil continually drains after an hour, the lube oil pump seal is faulty. Replace the lube oil pump. In an emergency, you can cap the drain port on the 5-element pump (N/A on 6-element pump).

d. Remove AGB finger strainer. Monitor open port for continuous leakage for 12 hours. If leaking more than 5 cc/hour, replace the lube oil pump.

3.5.27 Lube And Scavenge Pump Inlet Screen Contamination

NOTE

Tag each screen immediately after removal to positively identify sump location and prevent intermixing.

a. Individually remove and inspect inlet screens per MIP 2340. If foreign material is found in the lube and scavenge pump inlet screens, analyze as follows and perform corrective action. Replace any screens that exhibit damage.

b. Isolate source of foreign material by identifying screen as TGB, B-, C-, D- or AGB (i.e., Oil sump location). (See reference (E), figure 7-120 or 7-121.)

c. Examine material removed from screens. Normal fuzz “melts” in your hand when “pinched”. If the material can be identified as bearing materials, such as roller, ball or race fragments, component replacement is the required corrective action. Bearing races, rollers and balls are made of magnetic material; therefore, separation of any magnetic materials will help identification. Main gas turbine bearing failures require replacement of the gas generator or power turbine or both depending on which sump strainers produce the particles. Inlet and transfer gearboxes can be replaced individually.

d. Main gas turbine bearing distress usually increases gas turbine vibration; therefore, gas turbine log sheets should be reviewed for significant changes in gas turbine logged parameters. Also, insure that the vibration system is operating correctly.

e. If the suspect material is found in the TGB screen, the source must be further identified. Inspect the inlet gearbox and A-sump area for any distress. If suspect material is identified as epoxy particles that breakup easily, check the inlet gearbox shaft plug, reference (G), figure 8-52, item 7. Check for indications of damage or looseness by gently tapping on the plate with your fingertips. If the plate appears loose, the epoxy seal inside of the IGB may have failed. If you are not sure after checking with your hand, you can test the integrity of the epoxy seal by removing the IGB and pouring about 3/4 of an inch of fuel oil into the gear shaft assembly, reference (G), figure 8-52, item 6. If the fuel leaks out, replace the IGB.

f. If the suspect material is identified as pieces of o-ring, gasket, safety-wire, coke, machining chips, seal rubber strip material, or gas turbine bearing retainer tangs; increase inspection and notify FTSC.

Survey Sheet

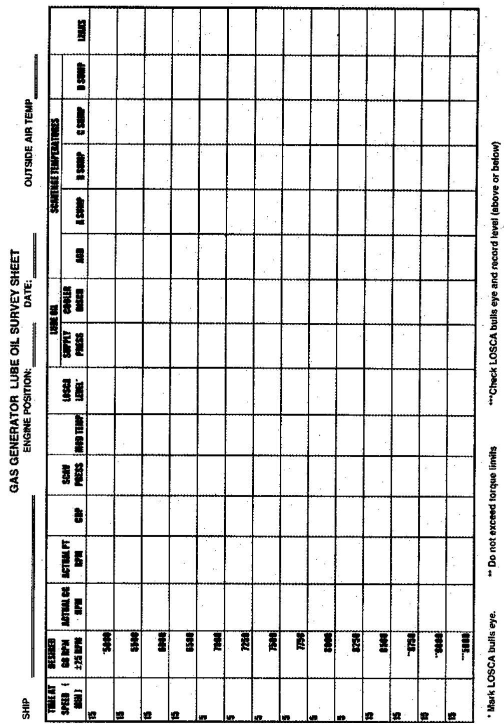

Figure 3-11. Survey Sheet

3.6 TROUBLESHOOTING PROCEDURES REVIEW QUESTIONS

(Answers are located the last section of the Handbook)

1. What is the definition of a Compressor Stall?
2. What are the indications of a Stall?
3. What are the two General Classifications of Stalls?
4. What is the definition of a “High Speed Stall”?
5. What are the two categories of Torque Splits?
6. What is considered an excessive Torque Split?
7. What is the definition of CIT Sensor Hot Shift?
8. How many FT LBS will torque change for every 1.0 PSIA change in PT5.4?
9. What could a VSV Feedback Lever Rig Mark, rigged above the Stationary Rig Mark lead to?
10. Does a Gas Turbine Engine run more efficient on a hot or cold day?
11. What is the maximum allowable LM2500 oil consumption per 24 hour operating period?
12. What is the maximum allowable leakage from the Starter Accessory Gearbox Drain line in a one hour period?
13. What is the common cause for smoke in module after extended low power operation?
14. What is the common cause for a LOSCA level drop when the engine is secured?
15. What course of action is required if chaffing of the C-Sump Oil Supply Tube at the TMF Strut is found?

CHAPTER 4

CORRECTIVE MAINTENANCE OVERVIEW

4.1 INTRODUCTION

Corrective maintenance procedures consist of actions to restore failed equipment to an operational condition within predetermined parameters. Corrective maintenance procedures are presented in a format similar to Maintenance Requirement Cards (MRCs) of the Planned Maintenance System (PMS). Corrective maintenance procedures are intended for alignment, adjustment, repair, or replacement of faulty equipment after fault isolation has been accomplished.

Corrective maintenance procedures for the LM2500 equipment were developed as part of the PMS. These procedures are intended to enhance shipboard usability and to correlate corrective maintenance support documentation with actual shipboard equipment configuration. Corrective maintenance procedures provide personnel detailed guidance for the performance of a specified maintenance requirement.

4.2 CORRECTIVE MAINTENANCE PROCEDURES

Corrective maintenance procedures are listed in S9234-AD-MMO-050/LM2500 and procedures are located in S9234-AD-MMO-050/060/LM2500. The following table lists the current Corrective Maintenance procedures.

Table 4-1. Corrective Maintenance Procedures

S9234-AD-MMO-050/LM2500	S9234-AD-MMO-060/LM2500
Accelerometer	
	Accelerometer Power Supply
	Accelerometer Signal Conditioner
Actuator, Power Lever Angle (PLA)	

Table 4-1. Corrective Maintenance Procedures - Continued

S9234-AD-MMO-050/LM2500	S9234-AD-MMO-060/LM2500
	Actuator, Vent Damper
Actuator, VSV	
Bracketing and Piping	
Cable, VSV	
	Cap, Oil Tank filter
Centerbody	
	Conditioner, Accelerometer Signal
	Conditioner, Flame Detector Signal
	Conditioner, Ice Detector Signal
Control, Main Fuel	
	Damper, Vent
	Detector, Flame
	Detector, Fuel Inlet Temperature
	Detector, Ice
Detector, Scavenge Oil Temperature	
	Detector, Ultraviolet Module
Driveshaft, Radial	
Electrical, Harness	
Exciter, Ignition	
	Filter, Duplex, Oil Scavenge
	Filter, Duplex, Oil Supply
Filter, Fuel	
	Fire Sleeves
	Flame Arrestor
	Flexible Joints, Inlet and Exhaust
	Free Standing Electronics Enclosure (FSEE), DD-963

Table 4-1. Corrective Maintenance Procedures - Continued

S9234-AD-MMO-050/LM2500	S9234-AD-MMO-060/LM2500
	FSEE, FFG-7
	Gage, Fuel Filter Differential Pressure
	Gage, Lube Oil Supply Filter Differential Pressure
	Gage, Scavenge Oil Filter Differential Pressure
	Gas Generator (GG) Replacement, DD-963
	GG Replacement, DDG-51 Position 2A
	GG Replacement, FFG-7
Gear box, Inlet	
Gear box, Transfer	
	Halon Warning Bell, DDG-51
Harnesses, Electrical	
	Heater, Fuel and Enclosure
	Heat Exchanger Lube Oil
	Helical Coils Inserts
	High Metal
	High Speed Coupling Shaft (HSCS) Replacement, DD-963
	HSCS Replacement, DDG-51 Position 2A
	HSCS Replacement, FFG-7
Igniter, Spark	
Inlet Duct	
Inlet Plenum Seal	
Inlet Screen	Insert, Helical Coil
	Insert, Key-Locked
	Insert, Lok-Thred
	Insert, Tap-Lok
	Instrumentation Valves, BEA
	Instrumentation Valve Lube Oil Scavenge Filter Replacement
	Instrumentation Valve Packing Replacement
	Intake Duct Preparation, DD-963

Table 4-1. Corrective Maintenance Procedures - Continued

S9234-AD-MMO-050/LM2500	S9234-AD-MMO-060/LM2500
	Key-Locked Inserts
	Lamp, Incandescent
Lead, PT Speed Pickup	
Lead, PT Vibration Pickup	
Lead, Spark Igniter High Tension	
Leads, Electrical	
Leads, Ignition Exciter Input	
Leads and Harnesses, Thermocouple	
	Light Fixtures
	Limit Switch, Vent Damper
	Lok-Thred Inserts
	Lok-Thred Studs
Main Fuel Control (MFC)	
Manifold, Fuel, Left	
Manifold, Fuel, Right	
Maintenance Practices	
	Nozzle, C02 Discharge
	Nozzle, Halon Discharge
Nozzles, Fuel	
Piping, GG	
PLA Actuator	
	Power Supply, Accelerometer
	PT Replacement, DD-963
	PT Replacement, DDG-51 Position 2A
	PT Replacement, FFG-7
Probe, Compressor Inlet Pressure	
Probe, PT Inlet Pressure	

Table 4-1. Corrective Maintenance Procedures - Continued

S9234-AD-MMO-050/LM2500	S9234-AD-MMO-060/LM2500
Pump, Fuel	
Pump, Lube and Scavenge	
	Seals, BEA Access
Sensor, Compressor Inlet Temperature (CIT)	
Sensor, GG Speed	
	Sensor, Ice Detector
	Sensor, Lube Oil Level, FFG-7
	Sensor, Oil Tank Discharge Temperature
Sensor, PT Speed	
	Sensor, Total Inlet and Enclosure Discharge Temperature
Separator, Air-Oil	
	Shock Mounts, Individual
	Signal Conditioners
	Silencers
Starter Stator and Blades, Pneumatic	
Starter, Pneumatic	
	Studs, Lok-Thred
	Switch, Door Position FFG-7
	Switch, Fire Alarm
	Switch, Fire Extinguish Inhibit
	Switch, Inlet Illumination, CG-47 and DDG-51
	Switch, Light
	Switch, Lube Oil Level, DD-963
	Switch, Temperature
	Switch, Vent Damper Limit
	Tap-Lok Inserts
Thermocouples	

Table 4-1. Corrective Maintenance Procedures - Continued

S9234-AD-MMO-050/LM2500	S9234-AD-MMO-060/LM2500
Transducers, GT Vibration	
Transducers, PT Speed	
	Transducers, Pressure
	Valve, Air Regulating, Starter
	Valve, Bleed Air Shutoff
	Valve, Fuel Check
Valve, Fuel Pressurizing	
	Valve, Fuel Purge
	Valve, Fuel Purge Check
	Valve, Instrumentation, BEA
	Valve, Instrumentation, Lube and Scavenge
	Valve, Isolation Check C and D Sump (Before GTC no. 51)
Valve, Liquid Fuel Shutoff	
	Valve, Lube Oil Check
	Valve, Lube Oil Tank Drain
	Valve, Oil Scavenge Check
	Vent Damper
Vibration Transducers	
	Windows, Enclosure Glass
	FSEE
	Circuit Breakers, CB1/CB2, Assembly A2
	Circuit Breakers, Fuel Valve Power, CB1/CB2
	Power Amplifiers AR1/AR2
	Power Resistors R2 and R9
	Power Supply Set
	Printed Wiring Board (PWB)
	Relays K1 through K4

Table 4-1. Corrective Maintenance Procedures - Continued

S9234-AD-MMO-050/LM2500	S9234-AD-MMO-060/LM2500
	Running Time Meter
	Voltage Regulator VR1/VR2
	AC Distributor A5
	Circuit Breaker, Fuel Valve Power, CB1 (A3/4)
	Counter M1, Engine Starts
	Engine Time Meter M2
	Filters, FL1, FL2
	Power Amplifier AR1
	PWB A1 through A11 and A21 through A28
	Relays K1/K2
	Resistor, Current Limiting R1
	Resistor, Power R2
	Running Time Meter M1
	Voltage Regulator VR1

4.3 LM2500 ENGINE REPLACEMENT

(Ref: S9234-AD-MMO-060/LM2500, S9234-BF-MMI-020/LM2500 and General Gas Turbine Bulletin 23)

4.3.1 Overview Engine replacement is a large undertaking requiring involvement from all levels of the Chain Of Command. Proper planning for a full-scale engine replacement evolution is necessary to ensure that all safety procedures, particularly man-aloft chits and electrical safety, are strictly followed; tools are properly inventoried; each member's responsibilities are clearly understood; and procedures are strictly followed as outlined in S9234-AD-MMO-060/LM2500 and S9234-BF-MMI-020/LM2500. Security is also of vital importance. Anticipating the need for clearances and escorts for IMA and civilian personnel can save tremendous time.

A planning meeting including all team members, assigned ship's force personnel, and other personnel responsible for ancillary tasks (crane operators, FTSC etc.) is the easiest, most efficient way to relay information to the entire team about individual responsibilities, team responsibilities, ship's responsibilities and schedule. The meeting should outline the entire evolution, stressing safety and the checkpoints that all personnel will be required to work toward. The team leader should stress that, although schedule is important, safety considerations come first and any breach of safety to save time cannot be tolerated.

Intermediate Maintenance Activities (IMAs) will be tasked with performing the engine replacement. The IMA team leader will be responsible for the entire evolution. The IMA will typically request ships force to prepare the engine and intakes IAW S9234-AD-MMO-060/LM2500 prior to the start of the evolution. At the planning meeting ship's responsibilities should be clearly outlined.

4.3.2 Ships Force Preparations

a. The following is general overview for performing ship's preparations for an engine replacement. Always refer to and follow the steps in S9234-AD-MMO-060/LM2500 assigned by the IMA team leader.

b. It is recommended to apply penetrating oil and allow for soak time prior to removal of fasteners. Ensure all fasteners removed are bagged and properly identified.

c. Unbolt ships top hat BERP panel.

d. If applicable unbolt Anti-Icing Manifold.

e. If applicable Unbolt Silencers.

f. Gain access into inlet plenum and remove Inlet Screen.

g. Remove Inlet Duct and Bullet Nose.

h. Remove Inlet Plenum Barrier Wall.

i. The IMA team will coordinate with the crane to remove the Top Hat, Anti-Icing Manifold, Silencers, Inlet Duct, Bullet Nose and Inlet Plenum Barrier Wall.

j. If the Power Turbine is being replaced, it is required to remove the rear panels of the module and gain access to the exhaust duct so the IMA team can perform Gas Turbine Assembly to Ship's Main Reduction Gear Assembly Alignment Check (H & J Alignment Check).

k. Remove all interfacing connections from the GG and PT (if applicable) to the module subbase as outlined by the IMA Team Leader IAW S9234-AD-MMO-060.

l. After the IMA team has completed the engine replacement, ship's force may be tasked with reinstalling the components they removed during preparations. In addition there are gas turbine checks outlined in S9234-AD-MMO-060/LM2500 that must be adhered to prior to operational testing.

4.3.3 General Gas Turbine Bulletin (GGTB) 23, Procedures For Marine Gas Turbine Replacement Authorization and Shipment The purpose of this bulletin is to establish procedures for obtaining authorization for and coordinating replacement of Marine Gas Turbines (MGTs) installed in U.S. Navy ships. This bulletin also provides guidance and defines responsibilities for returning failed/removed MGTs. Additionally an Accountability and Configuration Shipping/Receiving Checksheet is provided for MGT assemblies. The checksheet is required to be completed and faxed to NSWCCD-SSES within 24 hours of a MGT assembly change-out; for both the MGT assembly being received and for the failed MGT assembly being removed. The checksheet assists in accountability, accuracy of MGT configuration management, failure rate history and documenting MGT shipping container condition. It also provides information for cost effective rebuild and repair, thereby efficiently directing limited assets and repair funds to increase MGT fleet readiness.

NOTE

Due to the high dollar value of MGTs, the limited number of replacement MGTs, and the high cost that will accrue to the Type Commander (TYCOM) and the respective Gas Turbine Program Offices for their premature or unnecessary removal, specific procedures must be established when a need for possible replacement is recognized. **The procedures in GGTB 23 will be followed for any gas turbine removal and replacement on board U.S. Navy ships.**

The following is a LM2500 Accountability and Configuration Shipping Checksheet.

GENERAL GAS TURBINE BULLETIN NO. 23

LM2500 Gas Turbine Engine
Accountability and Configuration Shipping/Receiving Checksheet

NO.	ITEMS INSTALLED (√ Check Box) YES	NO	NOMENCLATURE * Any change in Selected Components status is required to be documented in MGTESRs "Selected Component Record" NAVSEA Form 9400/8	REMARKS (For Organizational Activities returning failed MGT, document known discrepancies of components)	INTIALS
1.			* MAIN FUEL CONTROL		
2.			* FUEL PUMP		
3.			* LUBE & SCAVENGE PUMP		
4.			* C.I.T. SENSOR		
5.			* STARTER		
6.			VSV ACTUATORS (2)		
7.			AIR/OIL SEPARATOR		
8.			IGNITER EXCITER BOXES (2)		
9.			T5.4 HARNESS (ALL 4 SECTIONS)		
10.			FUEL NOZZLES (30)		
11.			FUEL MANIFOLD		
12.			SPEEDPICKUPS (For Power Turbine Only)		
13.			ALL INTERNAL PARTS ARE INSTALLED. NO INTERNAL PARTS HAVE BEEN REMOVED (BLADES/VANES/NOZZLES, ETC.)		
14.	CONDITION (SAT) (UNSAT)		P/N ENGINE SHIPPING CONTAINER S/N		
15.	PASS ( )	FAIL ( )	LM2500 SHIPPING CONTAINER: "PRESSURE CHECK AND PREPARATION" Ref: S9234-AB-MMD-030/LM2500, CHAP.14, PARA.14.3 S9234-AD-MMO-060/LM2500, SECTION 7.7 Do Not ship GG/PT if shipping container does not hold pressure. Contact NSWCCD-SSES (215) 897-7618, 7711, 1313 (DSN: 443-)		

16. MGT assembly and Shipping Container Damage Noted: (attach paper as needed) The type and condition of the shipping stand shall be noted and status of completeness. The quality and quantity of fastening or locking devices will be noted. THE FAILED/RETROGRADE MGT SHALL NOT BE RELEASED FROM THE SHIP/SIMA UNTIL RECEIPT OF THE DISPOSITION MESSAGE HAS BEEN RECEIVED FROM NAVICP MECHANICSBURG. THE FAILED/RETROGRADE MGT SHALL BE SHIPPED IN ACCORDANCE WITH THE DISPOSITION MESSAGE.

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Figure 4-1. LM2500 Accountability and Configuration Shipping Checksheet

GENERAL GAS TURBINE BULLETIN NO. 23

17. GG/PT Serial Number ______ CASREP Number ______ Date ______

GG/PT Location (i.e. 1A/1B…) ______ Ship's Name ______ Hull # ______

INDICATE: ( ) SHIPPING ENGINE ( ) RECEIVING ENGINE

Ship/Repair/Depot Name and local shipping address:

Name (Please Print) Phone Number Email Command
Ship's Chief Engineer or designated Marine Gas Turbine Engine Service Record Custodian or Repair/Depot Facility Receiving/Shipping Representative as applicable.

Name/Rate (Please Print) Phone Number Email Command
IMA Team Leader: (for ship installation/removal)

Name/Rate (Please Print) Phone Number Email Command
Marine Gas Turbine Inspector or Fleet Technical Support Center Representative, if applicable, for ship installation/removal.

The listed hardware is required to be shipped with the LM2500 Gas Turbine. Authorization must be obtained from NSWCCD-SSES, 933 Life Cycle Manager prior to removing/transferring any hardware to new engine/or retaining onboard, call NSWCCD-SSES Philadelphia Code 9353 2S COG Manager at: DSN: 443-8706, commercial: (215) 897-8706, Fax: DSN: 443-8684, Fax: commercial (215) 897-8684.
ALL ITEMS, EXCEPT MISCELLANEOUS HARDWARE, ARE TO BE INVENTORIED PRIOR TO ENGINE BEING RELEASED/RECEIVED. INDICATE IF ITEMS ARE INSTALLED/REMOVED PRIOR TO SHIPPING/RECEIVING THE ENGINE. IN REMARKS SECTION INDICATE ANY DISCREPANCIES.

18. I CERTIFY THAT ALL ENTRIES ARE TRUE AND COMPLETE.

Name: (Signature) Phone Number Command Date
Ship's Chief Engineer/designated Marine Gas Turbine Engine Service Record Custodian or Repair/Depot Facility Receiving/Shipping Representative as applicable.

Fax this check sheet to NSWCCD-SSES Code 9353, 2S COG Manager: Fax: DSN: 443-8684, Fax: commercial (215) 897-8684 by COB the day the engine is shipped. Enclose one copy within the MGTESR Log Book.

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Figure 4-2. LM2500 Accountability and Configuration Shipping Checksheet

4.4 LM2500 GAS TURBINE ASSEMBLY TO SHIP'S MAIN REDUCTION GEAR ASSEMBLY ALIGNMENT CHECK (H & J ALIGNMENT CHECK)

(Ref: S9234-AD-MMO-020/LM2500 and S9234-BF-MMI-020/LM2500)

Gas Turbine to Ship's Main Reduction Gear Assembly Alignment Check (H & J Alignment Check) is required to be conducted prior to and after Power Turbine (PT) replacement, High Speed Coupling Shaft (HSCS) replacement, Shock (resilient) mount replacement and MRG assembly or reduction gear input shaft replacement.

Table 4-2. Gas Turbine Alignment Limits and Procedures

Activity	Alignment Correction Procedure	Alignment Limits
PT or HSCS Changeout (Non-Shipyard)	Shim gas turbine in Base Enclosure	In-service or Calculated In-Service Limits
Main Reduction Gear Assembly Work (Non-Shipyard)	Shim gas turbine in Base Enclosure	In-service or Calculated In-Service Limits
Eight or Less Shock Mount Replacement (Non-Shipyard)	Shim gas turbine in Base Enclosure	In-service or Calculated In-Service Limits
More than Eight Shock Mount Replacement (SIMA or Shipyard)	Move Base Enclosure	Shock Mount Replacement Limits
Main Reduction Gear Assembly Work (Shipyard)	Move Base Enclosure	Shock Mount Replacement Limits

4.4.1 When To Apply The Correct Alignment Limit

a. The following describes situations in which alignment limits apply and the type of re-alignments that can be performed during non-shipyard and shipyard maintenance.

(1) Shock (resilient) mount replacement alignment tolerance limits are tighter than in-service limits to ensure that the gas turbine can be operated for a maximum elapsed time before re-alignment becomes necessary. The tighter limits increase the probability that the HSCS will operate without failure.

(a) Shock mount replacement alignment tolerance limits apply when it is necessary to replace more than eight shock mounts.

(b) Alignments satisfying the shock mount replacement alignment tolerance limits are done at the shipyard. Vertical, athwartship, and axial misalignment is corrected by repositioning the Base Enclosure.

1. To correct vertical misalignment, shim under all of the Base Enclosure shock mounts evenly.

2. To correct athwartship misalignment, move the Base Enclosure port or starboard.

3. To correct axial misalignment, move the Base Enclosure fore or aft, or change the effective length of the reduction gear input shaft.

(2) In-service alignment tolerance limits ensure that the gas turbine can be operated safely until a re-alignment becomes necessary.

(a) In-service alignment tolerance limits apply through all other shipyard availabilities, when eight or less shock mounts are replaced, when the PT or HSCS are replaced, and when the MRG assembly or reduction gear input shaft is replaced.

(b) Alignments satisfying the in-service alignment tolerance limits can be done by the ship's force or by the Shore Intermediate Maintenance Activity (SIMA) at non-shipyard, or at the shipyard. Vertical and axial misalignment are corrected by repositioning the gas turbine inside the Base Enclosure.

1. To correct vertical misalignment, shim under the gas turbine mounts in the Base Enclosure.

2. To correct axial misalignment in the Base Enclosure, move the gas turbine fore or aft within the tolerance of the mount boltholes. External to the Base Enclosure, axial misalignment can be corrected by changing the effective length of the reduction gear input shaft.

(3) Calculated in-service alignment tolerance limits provide for the maximum amount of allowable axial misalignment based on the amount of the angular misalignment so that the gas turbine can be operated safely until a re-alignment becomes necessary.

(a) Calculated in-service alignment tolerance limits apply in the field when eight or less shock mounts are replaced, when the PT or HSCS are replaced, and when the MRG assembly or reduction gear input shaft is replaced, if after completing the in-service alignment data sheet, the Angular Alignment Variations are within limits but the Total Variation is not within limits.

(b) Alignments satisfying the calculated in-service alignment tolerance limits can be done by the ship's force or by the SIMA. Vertical and axial misalignment are corrected by repositioning the gas turbine inside the Base Enclosure just as for the in-service limits.

4.4.2 <u>LM2500 Shock (Resilient) Mount Replacement Periodicity and Departure From Specifications (DFS) Guidance</u> When mounts are nearing their installed life IAW S9234-AD-MMO-060/LM2500, table 7-99, submit a work request to have a LM2500 Gas Turbine Assembly to Ship's Main Reduction Gear Assembly Alignment Check performed and conduct a Shock Mount Inspection IAW S9234-AD-MMO-060/LM2500. Submit results with a DFS requesting to TYCOM. If data submitted is satisfactory a three year DFS maybe granted. Repeat process for a DFS extension requests.

Table 4-3. LM2500 Gas Turbine Resilient Mount Inspection Time*

SHIP CLASS	ENGINE ROOM	MODULE	APPROX. RAKE ANGLE	INSP. TIME
AOE-6	FWD/MER 1	2A/2B	0.5 Degrees	19 Years
AOE-6	AFT/MER 2	1A/1B	2.0 Degrees	16 Years
CG-47/DD-963	FWD/MER 1	2A/2B	2.5 Degrees	15 Years
CG-47/DD-963	AFT/MER 2	1A/1B	3.5 Degrees	13 Years
DDG-51	FWD/MER 1	1A/1B	3.0 Degrees	14 Years
DDG-51	AFT/MER 2	2A/2B	4.5 Degrees	11 Years
FFG-7	MER 1	1A/1B	7.0 Degrees	6 Years
* Inspection times are plus or minus 1 year; Calculate from commissioning date for ships with original mounts. For ships with mounts replaced, use date stamped on mounts and/or logged in Ancillary Equipmemt section of Marine Gas Turbine Equipment Service Record. Note: Rake angle is approximate.				

4.4.3 <u>H & J Alignment Check Overview</u> Prior to commencing H & J alignment check ensure the ship is trimmed in the normal manner fore and aft, ship is level athwartship, ship is in the water and liquid load is between 75 and 85 percent of total liquid loading.

a. Disconnect HSCS shroud assembly if applicable and remove base enclosure aft wall access panels.

b. Gain access into gas turbine exhaust duct, and rig portable lighting.

c. Disconnect and rig inner deflector out of the way using inner deflector lift fixture.

d. Install three support stabilizers at the 12, 5 and 7 o'clock positions between the bolt flange of the inner deflector and the exhaust duct inner bolt circle.

e. Lubricate the ship's main reduction gear assembly with the electric lube oil pump.

f. Install the HSCS indexing fixture on aft flange of exhaust duct at the 12 o'clock position.

g. Rotate HSCS CCW, aft looking forward, as necessary to position TOP mark on aft anti-deflection ring at 12 o'clock position.

h. Using a suitable marking pen, start at HSCS TOP location (as stamped on aft anti-deflection ring) and mark on outside diameter of aft anti-deflection ring 12, 3, 6 and 9 o'clock positions, forward looking aft. There are 12 bolts in each 90 degree segment on the HSCS; count 12 bolts between marked o'clock positions.

i. Rotate the HSCS CCW, aft looking forward, a minimum of 10 complete revolutions; stop at 12 o'clock position. Establish the axial position of the ship's reduction gear input shaft by measuring and recording the applicable ship class S, K or B and C measurement IAW the procedure and figures in S9234-AD-MMO-020/LM2500 or S9234-BF-MMI-020/LM2500.

j. Determine the required preload for the dial indicators IAW the procedure and figures in S9234-AD-MMO-020/LM2500 or S9234-BF-MMI-020/LM2500.

k. Screw alignment fixture rod on the second bolt, CW, aft looking forward, from the TOP mark on aft side of forward coupling. Install dial indicator and preload dial indicator so that it indicates on the distance piece forward flange IAW figure 10-34.

l. Screw alignment fixture rod on the second bolt, CCW, aft looking forward, from the TOP mark on fwd side of aft coupling. Install dial indicator and preload dial indicator so that it indicates on the distance piece aft flange IAW figure 10-34.

m. Check that the stems of the dial indicators are in line with each other at the 12 o'clock position and that both dial indicators are reading the correct preload values.

n. Rotate HSCS CCW, aft looking forward. If alignment fixture dial indicators are installed correctly, both indicators should read zero through an entire revolution. If readings vary from zero for any position, recheck the alignment fixture setup and repeat until all positional readings are zero.

o. Reposition both dial indicators radially to indicate on rim face of fore and aft anti-deflection rings of HSCS. Do not change the axial positions of indicators and do not re-zero indicators.

p. Rotate HSCS CCW, aft looking forward, a minimum of three times and compare the values and readings for each clock position. All comparable values and reading should be identical and consistent for each clock position. When rotating the HSCS CCW, the 9 o'clock position will be the first o'clock position to align with the indexing fixture; make sure that the readings are related to the correct o'clock position. If the HSCS is rotated past any o'clock position when taking readings, do not turn HSCS back, but make another complete revolution until indexing fixture pointer is over the correct mark.

q. Record the data on the applicable ship class Alignment Calculation Record located in S9234-AD-MMO-020/LM2500, S9234-BF-MMI-020/LM2500 or use the computer based program available from FTSC. The forward coupling measurements and data will be used in the H-Drop Calculation section, and aft coupling measurements and data will be used in the J-Drop Calculation section of the applicable Alignment Calculation Record. Prior to recording the dial indicator readings ensure you subtract pre-load. The number permanently stamped adjacent to TOP marking on each anti-deflection ring in the neutral drop dimension and is considered a negative number for calculation purposes.

r. Complete all calculations on applicable Alignment Calculation Records located in S9234-AD-MMO-020/LM2500, S9234-BF-MMI-020/LM2500 or computer based program available from FTSC. If results show Angular Misalignment or an out of limits Total Variation, contact FTSC for guidance. The gas turbine may need to be shimmed or shock mounts may need to be replaced.

4.4.4 Terms Used With H & J Calculations

a. "Neutral Drop" The manufacturers measurement for coupling deflection on that particular assembly when the coupling was built (Not stretched).

b. "Measured Drop" These are the readings taken from the dial indicators with the preload removed. These are in raw terms.

c. "Calculated Drop" This identifies the current position of the coupling when you took your readings. This measurement is the actual stretch for that position in raw terms.

d. "Average H Stretch" This is the average calculated drop based on the figures from the Calculated Drop, which is used to remove stretch from the angular measurement.

e. "Actual Angularity" This represents the angular offset of the coupling in raw terms.

f. "Target Angularity" This is a given set value for each engine position used to compensate for thermal growth (Vertical) and thrust (Horizontal) motion of the engine.

g. "Angular Variation" This is a usable value which identifies the actual angular offset beyond target limits.

h. "Axial Variation" This identifies the actual stretch by taking the difference between both H & J and removing the design stretch limits of the type of clutch installed. The resultant value represents the average increase or decrease in the distance between the MRG and GTM.

i. "Total Variation" This measurement identifies the alignment of each coupling with respect to both axial and angular position.

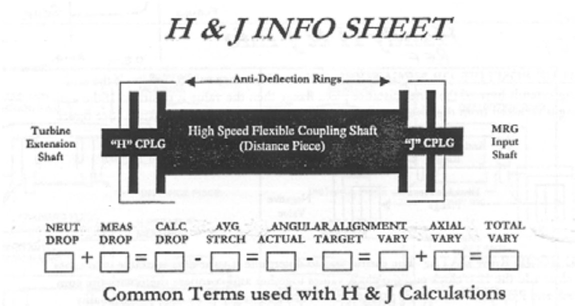

Figure 4-3. H & J Info Sheet

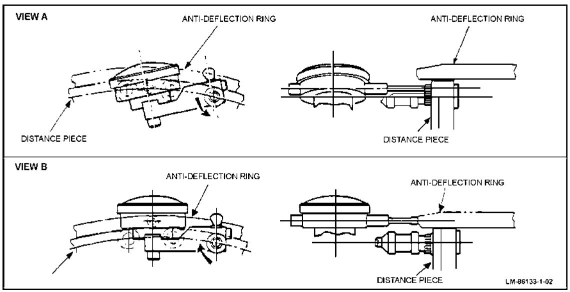

Figure 4-4. Dial Indicator Positions

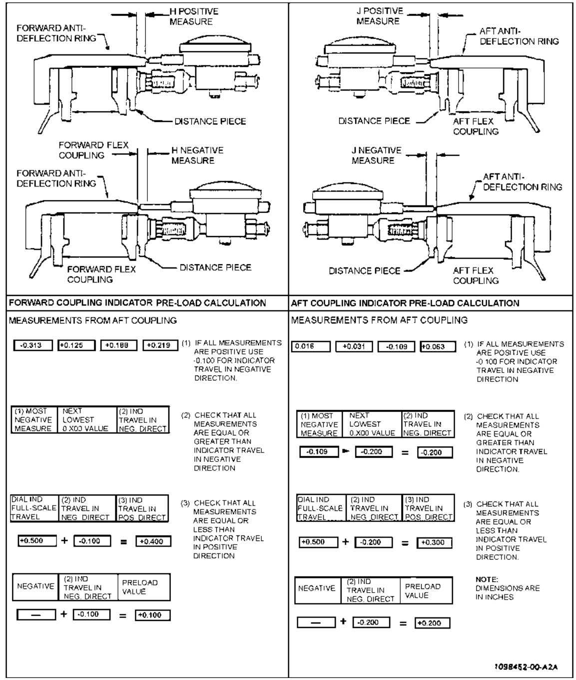

Figure 4-5. Sample Preload Calculation Worksheet

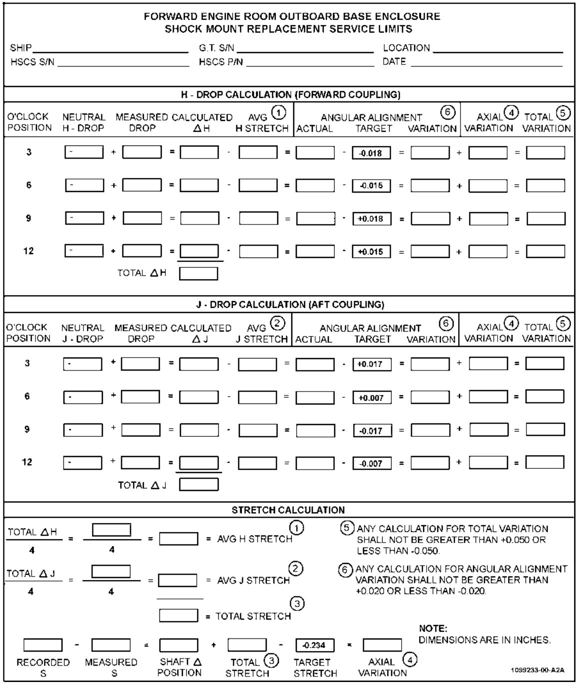

Figure 4-6. Alignment Calculation Record - DD-963 and CG-47 With SSS Clutch

4.5 CORRECTIVE MAINTENANCE REVIEW QUESTIONS

(Answers are located the last section of the Handbook)

1. In what maintenance manual would you find the corrective maintenance procedure for the MFC?
2. When replacing a LM2500 Power Turbine, what alignment check is required to be accomplished prior to and after replacement?
3. When is General Gas Turbine Bulletin 23 required to be adhered to?
4. What is the installed life for DDG FWD/MER LM2500 Shock (Resilient) Mounts?
5. What liquid load is required prior to performing H & J Alignment?

CHAPTER 5

MARINE GAS TURBINE INSPECTOR PROGRAM

5.1 OVERVIEW

(Ref: OPNAVINST 9234.1A Marine Gas Turbine Inspector Program, General Gas Turbine Bulletin Nr. 11, Revision 2)

a. As the number of marine gas turbines in the fleet continues to grow, the scope and number of repairs carried out at the organizational and intermediate level have become much larger. The Marine Gas Turbine Inspector program has been established to identify and qualify uniformed representatives to ensure that repairs and inspections are conducted in accordance with prescribed standards and procedures.

b. Marine Gas Turbine Inspectors (MGTIs) function as a Technical Representative extension of the CINCs as do the Fleet Technical Support Centers (FTSCs). To ensure a single coordinated maintenance response to Marine Gas Turbines on the waterfront, all Marine Gas Turbine technical decisions and recommendations (including engine replacement recommendation) by MGTIs are to be coordinated with the appropriate FTSC. Deviations and waivers from published technical guidance are to be handled in accordance with the Joint Fleet Maintenance Manual (CINCLANTFLT/CINCPACFLINST 4790.3).

c. Following a technical assist, the MGTI will submit a formal report in the Technical Assist Visit Report (TAVR) format as detailed by the CINCs. In addition to the required distribution, ensure the following are included: the cognizant Type Commander, cognizant FTSC, NSWCCD-SSES (Code 9336).

d. MGTIs are assigned to Intermediate Maintenance Activities (IMAs), Staffs, Training Commands, FTSCs and ships. MGTIs have the following capabilities and authority:

(1) Organizational

(a) Capabilities

1. Respond to requests from ships force for technical assistance and troubleshooting.

2. Provide concurrent and follow-up training to prevent recurrence of failure mode.

3. Perform periodic inspections including gas turbine inspections and pre-deployment assessments.

4. Review Marine Gas Turbine Equipment Service Records with Marine Gas Turbine Logbook Signature Authority.

5. Make engine replacement recommendations to NSWCCD-SSES via appropriate FTSC.

(b) Requests for Assistance − MGTI provides technical assistance, inspection and assessment support. Follow standard Type Commander instructions for requesting technical assistance support through the Local Area Maintenance Coordinator.

(2) Intermediate

(a) Capabilities

1. Respond to requests from IMAs for technical assistance and troubleshooting.

2. Provide concurrent and follow-up training.

3. Act as team leader for in-place gas turbine repairs and changes if attendant IMA Shop 31T does not have a team leader qualified for the specific repair. The MGTI must be a certified team leader in the specific repair.

4. Recommend team member and team leader qualification with the following requirements:

a The MGTI is a certified Team Leader in the Specific Task.

b The team member or team leader undergoing certification is not part of the MGTIs command.

c The MGTI must act solely in a qualified capacity, not as an instructor.

d The MGTI must provide a message to the command of the team member or team leader undergoing certification, the cognizant FTSC and CINC and NSWCCD-SSES (Code 933.1) upon certification.

(b) Request for Assistance − MGTI provides assistance to IMAs without an attached MGTI. Follow standard Type Commander instructions for requesting technical assistance support through the Local Area Maintenance Coordinator.

e. Training and Certification:

(1) The following prerequisites apply for entry into the MGTI training program:

(a) Pay grade of E7 or senior in the Gas Turbine System Technician (GS) rating.

(b) Graduate from GS Class “C” School.

(c) 12 years time in service, 8 years in the GS rating.

(d) Commanding officer recommendation.

(e) TYCOM endorsement. Prior to each class convening date TYCOMs will send out a message requesting candidates submit a package for entry into the MGTI training program.

(2) Initial MGTI training will be obtained via a master level course taught at Engineering School Ship Great Lakes. Bureau of Naval Personnel (BUPERS) will act as quota control for the MGTI course. The follow-on training will include intensive on-site training under the guidance of FTSCs and end-of-training competency verifica-

tion. The end-of-training competency verification will be based on results of the following:

(a) Written classroom exams

(b) Homework problems

(c) Written case studies

(d) Oral examinations

(e) Performance of predeployment grooms

(f) Written reports

(3) Following final verification of competency, FTSCs will recommend certification to NSWCCD-SSES. Upon final Certification, NSWCCD-SSES will recommend award of Navy Enlisted Classification 4136 and will issue a 36-month certification. Certification will remain valid provided the MGTI conducts at least two Gas Turbine Readiness Reviews and attends one MGTI seminar during the previous 12 months.

(4) MGTI seminars will be conducted at least semi-annually near the major fleet concentrations. These seminars include inspection criteria, changes in procedures and practices, lessons learned, recent casualty reports, new developments and upcoming programs. The seminars provide critical feedback to the technical community.

CHAPTER 6

TECHNICAL REFERENCES

6.1 TECHNICAL DIRECTIVES

(Ref: General Gas Turbine Bulletin Zero)

a. A Technical Directive (TD) is a document issued by NAVSEA directing the accomplishment and recording of modifications and one-time inspections to Marine Gas Turbine Equipment (MGTE) under the technical cognizance of NAVSEA. All Technical Directives are listed in General Gas Turbine Bulletin Zero (GGTB 0). GGTB 0 can be found at www.navygasturbines.org. Always refer to GGTB 0 for the latest revision/amendment prior to using a TD.

b. The two types of Technical Directives are Changes and Bulletins.

(1) Changes:
A Change directs the accomplishment and recording of a configuration change; that is, a material change, a modification, or an alteration in the design of affected MGTE. A Change is normally disseminated as a Formal (hard copy) Change; however, urgent time compliance requirements of a Change often dictate dissemination by naval message or, if enclosures are required, by naval letter. In these instances, the action is designated as an "Interim Change" indicated by a capital "I" preceding the Technical Directive designation. An Interim Change is usually superseded by a Formal Change.

(2) Bulletins:
A Bulletin normally directs a one-time inspection to determine whether a given condition exists and specifies what action is to be taken if the condition is found. It may contain instructions for corrective action using approved repair procedures, provided no change in material or configuration is involved. It may direct changes to procedures, adjustments, etc., which must be accomplished within a specified period. It may also direct action to issue changes to manuals and/or publications to prescribe continuing requirements for the same or related inspections. Bulletins, as described above, are disseminated as naval messages or, when enclosures are required, by naval letters. General Bulletins, which provide information affecting multiple applications, may also be issued when appropriate.

c. There are four action categories of Technical Directives, each of which is determined by the importance and urgency of accomplishment of work involved. The four categories are: Immediate Action, Urgent Action, Routine Action and Record Purpose.

(1) **Immediate Action**
The Immediate Action category is used when an incorrect, unsafe condition exists which could result in fatal or serious injury to personnel, destruction of valuable property, or extensive damage. Such conditions embody risk determined to be intolerable and require a Technical Directive which, with Chief of Naval Operations (CNO)

concurrence, will require compliance prior to the next use of the equipment in the operational environment under which the adverse condition exists. The lack of complete remedial instructions is not cause for delay of the issuance of Immediate Action Technical Directives.

(2) **Urgent Action**
The Urgent Action category is used when potentially hazardous conditions exist which, if uncorrected, could result in injury to personnel, damage to valuable property, or unacceptable reduction in operational efficiency. Such conditions embody risk considered to be tolerable within a definite time limit. This category may also include mission capability, reliability and maintainability changes which are of major importance. These conditions require the preparation of a Technical Directive effecting corrective action within a specific period. The time period is specified in the Compliance Section of the Technical Directive. Non-compliance by the expiration of the specified period may result in a restriction on further use of the equipment.

(3) **Routine Action**
The Routine Action category is used when there are reliability, capability or maintainability deficiencies which would, if uncorrected, become a hazard through prolonged usage or have an adverse effect on operational life or general service utilization of equipment. Such conditions embody a degree of risk determined to be tolerable within a broad time limit. These conditions require the preparation of a Technical Directive effecting corrective action within a specified period.

(4) **Record Purpose**
The Record Purpose category is used when a modification has been completely incorporated by the contractor or in-house activity in all accepted MGTE prior to issuance of the Technical Directive and does not require retrofit or modification of the repairables in the Navy's possession.

d. Technical Directives are updated by Amendments (Changes) and Revisions.

(1) **Amendments (Changes)**
An Amendment (Change) to a Technical Directive contains information, which clarifies, corrects, adds to, deletes from, makes minor changes in, or cancels an existing Technical Directive or previous Amendment (Change). Amendments are identified alphabetically, e.g., Amendment A, B, C.

(2) **Revisions**
A Revision is a completely new edition of an existing Technical Directive. It supersedes the original directive or latest revision and all existing Amendments. A Revision carries the same number as the directive it supersedes, but is designated as Revision 1, 2, etc.

e. The General Gas Turbine Bulletin Nr. 0 ("Zero") Index numerically lists four classes of LM2500, 501-K17, 501-K34, GTCP 100-82, T1000S-28AA, T1302S-28AA, TF40B, T-62T-40-7 Technical Directives, and General Gas Turbine Bulletins which have been issued as of the date of issue of the "Zero" Index.

f. The classes of directives are:

(1) **Gas Turbine Changes/Bulletins (GTCs/GTBs)**
These directives are issued when an action required affects an integral part of the marine gas turbine assembly. All parts, components and assemblies contained in a gas turbine assembly parts list are considered an integral part of a gas turbine. Compliance with a GTC/GTB requires entry in the engine log book (Marine Gas Turbine Equipment Service Record). It is the responsibility of the engine custodian at the time the GTC/GTB is accomplished to make the log book entry in accordance with instructions contained in the Technical Directive. For installed gas turbines, ship's force should also report compliance with a GTC/GTB through the Maintenance and Material Management (3M) System by use of the Ship's Configuration Change Form (OPNAV 4790/CK). Compliance may also be required to be reported by additional means, e.g., message or naval letter.

(2) **Ancillary Equipment Changes/Bulletins (AYCs/AYBs)**
These directives are issued when the action required affects equipment that is associated with the marine gas turbine system but not included in the gas turbine assembly parts list. The following equipment falls within this category:
LM2500

(a) Lube Storage and Conditioning Assembly.

(b) Electronic Enclosure Assembly.

(c) Base/Enclosure Assembly.
Compliance with an AYC/AYB shall be reported by ship's force, at the time the AYC/AYB is accomplished, through the 3M System by use of the Ship's Configuration Change Form (OPNAV 4790/CK). Compliance may also be required to be reported by additional means, e.g., message, naval letter.

(3) **Special Support Equipment Changes/Bulletins (SECs/SEBs)**
These directives are issued when the action required affects gas turbine special support equipment.

(4) **General Gas Turbine Bulletins (GGTBs)**
These directives are general in nature and are issued for informational purposes. They provide information covering multiple applications affecting all ships. As with all TDs it is recommended you become familiar with all current GGTBs. The following is a summary of current GGTBs.

- **GGTB 0.** General Technical Directive (Zero) Index.
- **GGTB 1.** Requisitioning Procedures for Gas Turbine Modification Kits.
- **GGTB 2.** Special Baseline Service Life Evaluation Borescope Inspections.

- **GGTB 3.** Marine Gas Turbine Logbooks and Service Records.
- **GGTB 4.** Marine Gas Turbine Semi-Annual Operating Data Report.
- **GGTB 5.** Baseline for Marine Gas Turbine Equipment Operating Hours and Number of Starts.
- **GGTB 6.** Gas Turbine Flex Hose Guidance.
- **GGTB 7.** MGT Equipment Service Records for 501 Series Engines.
- **GGTB 8.** GTE Operation in Environments Containing High Levels of Airborne Particles.
- **GGTB 9.** MGT Logbooks and Service Records
- **GGTB 10.** Guidance for GT Resilient Mount Changeout Criteria.
- **GGTB 11.** Marine Gas Turbine Inspectors.
- **GGTB 12.** Use of Synthetic Web Slings for Rigging Gas Turbine Engines.
- **GGTB 13.** No Subject.
- **GGTB 14.** Test and Evaluation of Non-Production Hardware on Gas Turbine Equipment.
- **GGTB 15.** Toxic Hazard from Synthetic Lube Oil Venting in Gas Turbine Modules.
- **GGTB 16.** Reporting Requirements for Fleet Modifications.
- **GGTB 17.** Fluid Leakage in Gas Turbine Modules.
- **GGTB 18.** Accepted Gas Turbine Waterwash Detergents.
- **GGTB 19.** Corrosion Inhibiting (C/I) MIL-L-23699E Turbine Oil
- **GGTB 20.** Transfer of Gas Turbine Responsibilities from NAVSEA 03 to NSWCCD-SSES Instruction.
- **GGTB 21.** LM2500 and 501-K17/K34 Borescope Inspection Equipment.
- **GGTB 22.** Load Testing of Special Support Equipment (SSE) Lifting Tools for the LM2500 and 501-K17/K34 Engines.
- **GGTB 23.** Procedures for Marine Gas Turbine Replacement Authorization and Shipment.
- **GGTB 24.** Requirements and Guidance for Non-Operational Marine Gas Turbines (MGTs) Used for Training.

g. Ships are responsible for maintaining **only those Technical Directives listed in the Zero index that have not been rescinded/canceled**. Since a Technical Directive is not issued until the required modification kit has been stocked in the supply system, some Technical Directive numbers are missing from the numerical sequence listing.

h. Marine Gas Turbine Technical Directives are rescinded when:

(1) Directive is superseded by another directive.

(2) Directive has been incorporated in all affected units.

(3) Information has been incorporated in all applicable handbooks.

(4) When rescission date is reached.

(5) As otherwise indicated.

i. Use of "Compliance Level" and "To Be Accomplished By" columns in the numerical listings:

(1) The "Compliance Level" column indicates the maintenance level at which the Technical Directive is to be accomplished, i.e, O - Organizational, I − Intermediate or D - Depot.

(2) The "To Be Accomplished By" column indicates the activity required to perform the work of incorporating the Technical Directive.

j. Technical Directives are automatically distributed to all ships and activities concerned with the MGTE. A full, up-to-date listing of Technical Directives is provided on the U.S. Navy Marine Gas Turbine website (www.navygasturbines.org). Hardcopy requests for a full Technical Directive listing or for individual Technical Directives should be sent to NSWCCD-SSES Code 93, 5001 South Broad St., Philadelphia, PA 19112 or via e-mail to gtkitstd@nswccd.navy.mil.

k. Requisitioning procedures for Gas Turbine Modification Kits:

(1) GGTB No. 1 provides the procedures for requisitioning technical directive modification kits for Gas Turbines, ancillary equipment and special support equipment.

(2) The modification kits are budgeted and issued as NSWCCD-SSES owned material for ONE-TIME installation in specified equipment by organizational, intermediate and/or depot maintenance activities as part of a modification program and, therefore, are not considered items of supply nor within the scope of the Federal cataloging program. Consequently Kit Identification Numbers (KINs), in lieu of National Stock Numbers (NSNs), are assigned for purposes of identification, requisitioning and reporting. Inventory management for kits associated with MGT equipment has been assigned to Naval Surface Warfare Center Carderock Division in Philadelphia, PA (NSWCCD-SSES). Philadelphia Naval Business Center, Code 9332, Building 1000, Philadelphia, PA 19112. Point of Contact (POC) for questions regarding the requisition of kits may be addressed to Mr. Thomas P. Habib, Commercial: (215) 897-7287, DSN: 443-7287, Fax: (215) 897-8468.

(3) Authority to requisition a modification kit is provided by the applicable TD issued by NSWCCD-SSES. All modification kits in support of TDs will be ordered by e-mail requisition. Requisitioning activities are not charged for the modification kits as NSWCCD-SSES has already procured them. The only approved utilization of a modification kit is for ONE-TIME incorporation of the appropriate TD: it is never to be used to replace defective part(s)/component(s) that would normally be requisitioned from the supply system. There should never be an urgency placed on any kit requisition since modification kits are to be utilized for ONE-TIME incorporation of an issued TD, not to replace a defective part.

(4) Some activities have submitted modification kit requisitions via CASREPs, OP immediate Naval Messages etc. This is an unacceptable method of kit requisition. Kit installation should be a planned activity and requisition of the necessary

modification kits should be addressed well in advance of the planned installation dates. The practice of submitting URGENT requisitions for modification kits is not authorized by NSWCCD-SSES.

(5) Since all Marine Gas Turbine Equipment modification kits are to be ordered only by e-mail, further clarification of requirements to ensure requisitions are properly prepared and formatted is appropriate. There are several types of kits supporting the NSWCCD-SSES Marine Gas Turbine Program. Each kit request requires specific supporting data before a kit will be issued against the equipment being modified.

(6) A GTC kit is physically installed on an engine, with few exceptions. The serial number of the engine being modified must be provided on the e-mail request.

(7) An AYC kit is physically installed on any part of a gas turbine "unit" other than the engine itself. The serial number of the base enclosure assembly (BEA) being modified must be provided on the e-mail requisition.

(8) An SEC is ordered by providing the hull number of the ship. If the SEC is permanently installed provide the BEA serial number on the e-mail requisition.

(9) "Spare" kits so designated must be turned over to the ship's supply department as the NAVSEA initial outfitting storeroom allowance for the new configuration of that component. A configuration update (4790)/CK, or SNAP equivalent must also be completed.

(10) To order a modification kit, send e-mail request to GTKITSTD@nswccd.navy.mil upon approval of the requisition, NSWCCD-SSES will send status to originator. Submit the following in the request: Ships Address (FPO), Shipping Address (Cannot be FPO), Ship name, Ship Hull number, Ship Unit Identification Code Number (UIC), Module Serial Number(s) or Engine Serial Number(s), Point of Contact (POC), Phone number of POC, Number of Kits by KIN number, Type of Engine, Request all ships in Japan provide info e-mail to SRF Yokuska. Request all ships provide info e-mail to ISIC/local MGTI. Info appropriate off-ship team if they are required for install. Off-ship team (typically IMA), info ship for kits being ordered.

The following table is a description of some of the most recent LM200 TDs. Refer to GGTB 0 for full listing.

Table 6-1. Recent LM2500 TDs

TD	Purpose and Description	Compliance
GTC 75, Installation of Redesigned VSV Stage 5 and 6 Vane Arms	Purpose: To retrofit LM2500 Variable Stator System 5th and 6th stage lever arms with an improved design to increase reliability. Complied with GTC 78 concurrently.	D level change on all GGs processed for repair. Dependency: prior incorporation of GTC 26, 36 and 91. Comply with GTC 78 concurrently.

Table 6-1. Recent LM2500 TDs - Continued

TD	Purpose and Description	Compliance
GTC 77, R1D, AYC 31, R1 Accelerometer Vibration Sensing System Modification	Purpose: To introduce a product improvement to the LM2500 by replacing the GG and PT Velocity Vibration Sensing System with an Accelerometer Sensing System. This change requires AYC 31, R1 to modify the base/enclosure.	I level change. Comply with AYC 31, R1 concurrently. Order kits IAW GGTB 1.
GTC 78, LM2500 Compressor Variable Stator Life Extension Improvements	Purpose: To retrofit LM2500 Variable Stator System Improvements for a significant increase in GG service life. This change replaces actuation lever arm and actuator guide bracket spherical bearings with slot loaded bearings, installs IGV, Stg 1 and 2 new design machined solid aluminum ring segments, replaces existing Teflon lever arm pin sleeves with new design Vespel lever arm sleeves and installs new Q8050 vane flanged bushings and washers. New flanged bushings are installed on the outside of the compressor case as in stages 3-6 (GTC 26).	D level change on all GGs processed for repair. Dependency: prior incorporation of GTC 26, 36 and 91. Comply with GTC 75 concurrently.
GTC 79, R2A, Addition of Vibration Dampening Bracket and Clamps on “C” Sump Lube Oil Supply Line	Purpose: To introduce wear prevention bracket and clamp onto the C-Sump lube oil supply tube. The bracket will clamp to the tube from the No. 7 strut cap on the Turbine Mid Frame (TMF). In addition three additional cushioned clamps are added to further stabilize the C-Sump lube oil supply tube. This will prevent chafing of the lube oil supply tube, which could result in supply tube failure and subsequent engine replacement.	O and D level change. Order kits IAW GGTB 1.
GTC 83, R1 Improved LM2500 Lube and Scavenge Pump for Production and Retrofit.	To provide modification instructions to add an additional air/oil separator scavenge element to the LM2500 Lube and Scavenge Pump and install the associated lube oil system changes on applicable GGs at the depot. The new pump part number is L24407P07. Organizational level incorporation of the new 6-element pump is only accomplished at the direction of FTSC on GGs that exhibit high lube oil scavenge temperatures at high power due to gearbox lube oil flooding. The additional scavenge element will reduce lube oil levels in the AGB, prevent gearbox flooding and higher than normal scavenge temperatures particularly the AGB and C-sump.	O and D level change. D level on applicable GGs processed at the depot. O level order new pump IAW GGTB 1 only when directed by FTSC.
GTC 85A, Addition of Turbine Rear Frame Insulation Blankets	To add Turbine Rear Frame insulation blankets to the stiffening ribs on the outer case of the frame for the prevention of Turbine Rear Frame cracking. The insulation blankets prevent the ribs from cooling at a much faster rate than the frame struts.	O, I and D level change. D level will install on all PTs processed for repair. Order kits IAW GGTB 1.
GTC 91, LM2500 Variable Stator rerig, by installation of a Modified Bell Crank	To rerig the High Pressure Compressor (HPC) Variable Stator Vanes (VSVs) by incorporation of a modified bell crank to eliminate aerodynamic instability in the 7300 to 7800 RPM range. This change requires skilled depot or Intermediate level personnel to inspect the VSV system and install the new bell crank and complete a rerig of the existing Variable Stator Vane System using a Master Setting Fixture. Change cancels GTC 92, VSV rerig by adjustment of Vane arm Turnbuckles.	I and D level change. D level on all GGs processed for repair and I Level change when directed.

Table 6-1. Recent LM2500 TDs - Continued

TD	Purpose and Description	Compliance
GTC 92, A Cancelled since modification kits have been provided by GTC 91	To rerig the High Pressure Compressor (HPC) Variable Stator Vanes (VSVs) by adjustment of Vane Arm Turn buckles. Inspect each VSV actuator lever arm for a vibropeened mark identifying incorporation of GTC 92. This mark will typically, but not exclusively be located in the lower, outboard facing, clear area between the 5th and 6th VSV pushrods. If found contact FTSC and IMA to install GTC 91 at earliest opportunity.	I and D level change. Cancelled by GTC 91.
GTC 93, A LM2500 Lube and Scavenge Pump AGB and TGB Scavenge Line Rerouting and Modification	To reduce the lube oil level in the Accessory Gearbox (AGB), thereby reducing the possibility of high lube oil scavenge temperatures. This change will reduce the lube oil level in the AGB by using the higher capacity transfer gearbox scavenge element in the lube oil pump. Incorporation of this change will be based on whether high AGB scavenge temperatures exist in a particular installed engine and if it is recommended by the local FTSC to reduce the problem.	I level change when directed by FTSC. Order kits IAW GGTB 1.
GTC 95, A Improved Power Lever Angle (PLA) Actuator **AYC 42,** Power Lever Angle (PLA) Actuator Connector/Cable Improvement	To replace the old style bayonet connector and install a new threaded connector for the PLA Actuator (GTC 95) and provide the improved threaded connector/cable for connection to the Base/Enclosure Assembly (AYC 42) at the organizational level. Currently Kits are available IAW GGTB 1 to replace the existing PLA Actuator and associated cabling. NSWCCD will ship five kits to a ship, which includes one spare for their supply storeroom. The ship must send back all of the old PLAs so they can be overhauled. The depot will send the required AYC 42 cable in the shipping container for "0" level compliance when RFI engines are released to the fleet.	O and D level change. D on all GGs processed for repair. Order kits IAW GGTB 1.
GTC 96, Flexible T5.4 Thermocouple Harness	To incorporate and improved T5.4 thermocouple harness with detachable probes. Includes replacement of current four "hard lead" harnesses with four flexible harness pieces. The flexible leads also incorporate detachable thermocouple probes, which may be disconnected from the harnesses without removal of the probes, for a higher degree of maneuverability during maintenance.	O, I and D level change. D will install on all GGs processed for repair. Order kits IAW GGTB 1.
GTC 97, Power Turbine Speed Sensor Improvement	Installs an improved Power Turbine (PT) speed sensor. The new design requires no gap measurements or shimming and is more reliable. Not applicable to FFG 7 Class ships.	O and D level change. D on all GGs processed for repair. Order kits IAW GGTB 1.
GTC 98, Air/Oil Separator Flexible Coupling Tube and Hose	Installs an improved Air/Oil Separator Flexible Coupling Tube and Hose.	O and D level change. D on all GGs processed for repair. Order kits IAW GGTB 1.
GTC 100, Engine Control System Change from Hydro mechanical to Digital Fuel Control	The current MFC and PLA are removed and a deck mounted Digital Fuel Metering Valve is installed. New VSV actuators with Linear Variable Differential Transformers (LVDTs) are installed to track movement. An engine mounted hydraulic pump and off engine-mounted accumulator provide coast-down capability. A Micronet Engine Control Unit (ECU) is installed to replace the FSEE on CGs. The requirement for rigging the PLA is eliminated and VSVs can be opened or closed for maintenance using the control console during a motor. All control functions are conducted in the Micronet processor. The module maintenance platform requires a modification to cover the deck mounted Fuel Metering Valve Actuator (FMVA). Installation is planned with CG SMART ship SHIPALTs.	Off Ship Team in conjunction with CG SMART ship SHIPALT.

Table 6-1. Recent LM2500 TDs - Continued

TD	Purpose and Description	Compliance
GTC 101 and AYC 39, R2 Improved Drain System for the Fuel Shut-Off Valves	To modify the Gas Turbine Fuel Drain System by replacing the single drain manifold with two tubes, each dedicated to a Fuel Shut-Off Valve (FSOV) drain port. This TD was originally issued as AYC 39. GTC 101 was issued to incorporate the Gas Turbine Change portion of AYC 39 into a GTC. This allows for depot level compliance of Improved FSOV drain system for all GGs processed. Comply with GTC 101 and AYC 39, R2 concurrently.	O, I and D level change. D will install on all GGs processed for repair. Order kits IAW GGTB 1. Comply with GTC 101 and AYC 39 concurrently at the shipboard level.
AYC 35, R1 Improved Base/Enclosure Vent Damper Sealing	To improve vent damper sealing with an improved blade design and with Viton seals on the blade edges.	O and I level change. I level will complete the change on a ship to shop basis. Order kits IAW GGTB 1.
AYC 36 Base/Enclosure Assembly Inlet Barrier Wall Sealing	To improve the sealing of the Enclosure Inlet Barrier Wall by replacing the four vertical angles securing the barrier wall to the enclosure sidewalls, with two continuous angles, and by adding eight seals to reduce the flow area between the inlet and engine side of the module.	I level change. Order kits IAW GGTB 1.
AYC 38 Exhaust Splitter	To add an Exhaust Splitter to eliminate an aerodynamic instability within the exhaust collector that contributes to exhaust system distress and excites the 26 Hz power turbine and engine system non-synchronous modes.	I level change. Order kits IAW GGTB 1.
AYC 46, R1 Forward Exhaust Collector Insulation Blanket Installation	To install a Forward Exhaust Collector Blanket to significantly reduce the temperature gradient, prevent rapid and uneven cooling of the exhaust collector and prevent the cracking of welds.	O and I level change. Order kits IAW GGTB 1.

6.2 ENGINEERING OPERATIONAL SEQUENCING SYSTEM (EOSS)

(Ref: EOSS Users Guide)

Engineering Operational Sequencing System (EOSS) provides safe, technically accurate and standardized operational and casualty control procedures tailored to the individual ship's configuration. Use of EOSS increases equipment service life and minimizes casualty occurrence by ensuring that each system or component is properly aligned, operated and secured. EOSS also ensures that shipboard training for machinery operation is standardized.

In situations where a ship requires an operational or casualty control procedure, which is not included in the current EOSS package, a local procedure should be developed. These locally developed procedures must be approved by the Commanding Officer and should state or be stamped "Locally Prepared".

6.2.1 Description of EOSS

a. EOSS consists of procedures, charts and diagrams required for operation of a ship's propulsion plant. It consists of two parts.

   (1) Engineering Operational Procedures (EOP).

   (2) Engineering Operational Casualty Control (EOCC).

b. EOSS coverage is provided for the normal transition between steady state operating conditions, casualty restoration and the most commonly occurring casualties. Ships are encouraged to write procedures for evolutions for which EOSS has not been installed. However, when installed, EOSS use is mandatory.

6.2.2 Mandatory Use of EOSS

a. When EOSS has been approved and installed on your ship, it will be strictly adhered to as written. This means that, when shifting between the various steady state operating conditions (EOP), responding to a casualty (EOCC) or restoring from a casualty (EOP), the action steps in the procedure must be accomplished, as written and in the stated sequence, without deviation.

b. The level of proficiency of the watchstander will determine how a particular EOP procedure will be "Strictly adhered to as written". After being ordered to carry out a section of a procedure (aligning for operation, starting, stopping etc.) the inexperienced watchstander shall read the entire section before accomplishing any action step in the section immediately before it is accomplished. After all required steps in the section are accomplished, the section should be re-read to ensure all required actions have been accomplished in the proper order.

c. Repeated use of EOP to operate the propulsion plant will increase the watchstander's level of proficiency. As a result, the manner in which the watchstander strictly adheres to the EOP will change. The more proficient watchstander is still required to review each section before any actions are carried out. However, several action steps (in the case of short procedures, the entire section) may be accomplished before referring to the procedure. The section should be re-read after it is accomplished.

d. At the highest level of proficiency, the watchstander will utilize the procedure as a checkoff sheet, ensuring that all required actions are accomplished in the correct sequence. However, no matter how experienced or knowledgeable the watchstander becomes, the EOP should be reviewed prior to accomplishing the required procedure and it should be re-read again after the procedure is accomplished to ensure that all required actions have been completed.

e. The philosophy for “strictly adhering to EOCC is different because of the following:

(1) The Symptoms/Indications, Possible Causes and Possible Effects of a casualty must be know and understood.

(2) The Controlling and Immediate Actions sections of EOCC must be memorized.

(3) The Stopping during a Casualty sections of designated EOP procedures must be memorized.

(4) The location and operation of designated valves and components must be fully understood. After Controlling and Immediate Actions are taken, these sections of the procedures should be read as soon as feasible to ensure that all required actions have been accomplished. The procedure should then be used to accomplish the Supplementary Actions and Restore Casualty sections. As in the case of EOP procedures, the watchstander should review Supplementary Actions and Restore Casualty sections before these actions are carried out. However, as watchstanders proficiency increases, several action steps can be accomplished before referring to the procedure. The sections should be re-read after they are accomplished. At the highest level of proficiency, the watchstander will utilize these sections as a checkoff sheet, ensuring that all required actions are accomplished in the correct sequence.

6.2.3 <u>Conditions That Warrant Deviation From EOSS</u>

a. There are conditions, which warrant deviation from strict adherence to EOSS. Each change to EOSS must be authorized by the Commanding Officer with either a signature on the bottom of each procedure or a cover letter explaining the authorized change. It is recommended that the ship keep track of these deviations.

(1) Deviation is authorized when it is determined that adherence to EOSS may endanger personnel or damage equipment. In these cases, the EOSS shall be marked-up to reflect the necessary changes. These changes shall be reported via priority Naval Message to NAVSURFWARCEN SHIPSYSENGSTA PHILADELPHIA PA as indicated in the EOSS Users Guide. The user should continue to use the marked-up EOSS until the feedback is resolved by NSWCCD.

(2) Deviation is authorized when EOSS does not match the actual configuration or the propulsion plant is modified. These modifications include such things as SHIPALTs, MACHALTs, or AERs. EOSS diagrams and procedures shall be marked-up to reflect these configuration changes. These changes shall be reported to NSWCCD using the routine EOSS feedback form. Include a copy of all marked-up diagrams and procedures.

(3) Deviation is authorized when a component or system becomes inoperative or a TYCOM deviation from specifications is issued. Under such conditions, the following actions shall be performed:

(a) The Commanding Officer and OOD shall be notified as required by Navy regulations. At that time, they shall be briefed fully on the guidance necessary to deviate from the installed EOSS.

(b) Changes shall then be made and pasted into each watchstander's book with the Commanding Officer's signature appearing at the bottom of each procedure. It should be noted that each watch supervisor and watchstander must be fully knowledgeable of all deviations prior to a watch turnover.

(c) All Changes shall be removed from the EOSS books upon repair of the equipment or component.

(d) It is assumed that these actions will only be taken for a condition, which is temporary in nature. For conditions, which will persist for longer than 6 months, an EOSS routing feedback shall be submitted.

(e) For deficiencies, which are expected to be resolved within six months, it is recommended that temporary Engineer Officer Standing Orders be prepared to ensure safe operation of degraded equipment.

(4) Deviation is authorized to adhere to provisions of ISE & class advisory messages.

(5) Deviation is authorized when the ship is operating in a restricted maneuvering situation. A complete description of the restricted maneuvering casualty control procedures in effect is required. In all cases, the procedures for normal casualty control are mandatory unless expressly modified in writing by the Commanding Officer.

b. No other deviations or local changes to EOSS are authorized. Only NSWCCD can approve and issue permanent changes to the NAVSEA installed EOSS.

6.2.4 Engineering Operational Procedures (EOP)

a. The EOP consists of several types of procedures. They are listed below.

(1) Master Prelightoff Checklist (MLOC).

(2) Master Plant Procedures (MPs).

(3) Operational Procedures (OPs) for the EOOW.

(4) System Procedures (SPs).

(5) Component Procedures (CPs).

(6) Status Charts (SCs).

(7) System Diagrams (SDs).

(8) Standard Notes For The Oil King (SNOK).

(9) Tank Tables (TTs).

(10) Tank Status Diagrams (TSDs).

(11) Sewage Disposal Procedures (SDOSS).

6.2.5 Engineering Operational Casualty Control (EOCC)

a. EOCC consists of several procedural formats. They are listed below.

(1) Master Casualty Response Procedures.

(2) Casualty Response Procedures.

(3) Master Emergency Procedures.

(4) Emergency Procedures.

6.3 NAVAL SHIPS TECHNICAL MANUAL (NSTM) CHAPTER 234, MARINE GAS TURBINES

(Ref: S9086-HC-STM-010/ 234)

a. Gas turbine engine applications as shipboard auxiliary and propulsion units are increasing in the fleet. Many different engine makes, models and power ratings are used to meet these applications. Because the engines differ, only general guidelines and useful gas turbine information are discussed in NSTM chapter 234.

b. All personnel assigned to operation and maintenance of gas turbine engines should become thoroughly familiar with the construction features, installation, operation, adjustment, safety precautions and maintenance requirements of the engines. Appropriate Naval Sea System Command (NAVSEA) technical manuals and manufacturer technical manuals should be used for specific information about each engine.

c. Before operating a gas turbine engine or performing routine maintenance or overhaul, detailed personnel should be thoroughly familiar with the information available from:

(1) Manufacturer's installation, operation and maintenance technical manuals and instructions for the model of engine to which assigned.

(2) Class advisories, force, squadron and division engineering directives pertaining to a specific gas turbine engine and accessories.

(3) Relevant NSTM chapters.

(4) NAVSEA Planned Maintenance System (PMS) documentation, Maintenance Requirement Cards (MRCs) and Maintenance Index Pages (MIPs).

(5) NAVSEA Engineering Operational Sequencing System (EOSS).

(6) Engine allowance lists and the Consolidated Onboard Ship's Allowance Lists (COSAL) for the ship.

(7) NAVSEA technical directives and technical bulletins covering the particular engine.

d. There are 10 sections of NSTM Chapter 234. They are listed below.

(1) Section 1, Introduction.

(2) Section 2, Operation.

(3) Section 3, Support Systems.

(4) Section 4, Maintenance and Configuration Management.

(5) Section 5, General Maintenance Actions.

(6) Section 6, Removal and Replacement.

(7) Section 7, Spare Parts and Allowance Lists.

(8) Section 8, Marine Gas Turbine Equipment Logbooks and Service Records.

(9) Section 8A, Marine Gas Turbine Equipment Logbooks and Service Record (Automated).

(10) Section 9, Safety Precautions.

6.4 MARINE GAS TURBINE EQUIPMENT LOGBOOKS AND SERVICE RECORD (AUTOMATED)

(Ref: S9086-HC-STM-010/ 234 (NSTM Chapter 234, Section 8A) and www.navygasturbines.org)

NSTM Chapter 234, Section 8A establishes policy and procedures for use of the automated marine gas turbine equipment service records (Autolog) and the Marine Gas Turbine Information System (MGTIS).

6.4.1 Background

a. The Navy extensively deploys gas turbine equipment in propulsion and ship-services systems in its fleet. Selection of gas turbine equipment for these systems reflects a desire to increase ship availability through reduction in system downtime.

b. Acceptable reliability and on-board maintenance features combined with ease of removal and replacement for internal repairs, made possible by the high power-to-weight and size ratios of the major equipment assemblies, have resulted in less system downtime. Lower shipboard manning levels have also been achieved.

c. System downtime and lower shipboard manning levels have been realized through properly directed maintenance, logistic support, and reliability and maintainability improvement efforts.

d. Use of automated service records, to retain significant historical operating and maintenance data with gas turbine equipment transferred between shipboard installations and repair or rework facilities, shall provide a consolidated source of background information available to personnel conducting and analyzing maintenance activity.

6.4.2 Objectives Of NSTM Chapter 234, Section 8A, is to Describe the Policy and Procedures:

a. Maintaining and updating the Marine Gas Turbine Automated Service Records for inputting data related to complete equipment assemblies or associated components and accessories.

b. Maintaining and updating the Marine Gas Turbine Automated Service Records for inputting data related to Ancillary Equipment.

c. The Automated Marine Gas Turbine Equipment Service Record is a sectioned data input format for a complete equipment assembly, including a section providing assembly- designation and installation-history information.

d. The Automated Marine Gas Turbine Equipment Logbook (Autolog), which is onboard ship, is the application containing the sectioned data input format for each installed equipment assembly. One Autolog contains complete data for each installed equipment. It is arranged by engine type and position, and incorporates each engine's respective logbook sections.

e. The Marine Gas Turbine Information System (MGTIS) is the main database repository for all Autolog data. There is an Internet interface between the Autolog and MGTIS.

6.4.3 Policy

a. All activities having custody of marine gas turbine equipment and associated components and accessories, shall maintain automated service records in a proper and up-to-date status in accordance with the procedures described in NSTM Chapter 234, Section 8A.

6.4.4 Procedures

a. Equipment data is an essential element of the gas turbine technical discipline; it provides a history of maintenance and operation, and configuration changes of the equipment. A means of accomplishing maintenance planning for scheduled removal is provided. Incomplete or inaccurate data can cause unnecessary maintenance of equipment. Activities receiving questionable or incomplete data should request immediate corrective action by the delinquent activity. Obvious mistakes may be corrected by the current custodian after receipt of the data providing necessary information.

6.4.5 Autolog and Operating Requirements

a. The Autolog is part of the Marine Gas Turbine Information System (MGTIS). It is a stand alone, automated, MGT equipment record keeping run time application with an Internet interface for data and operating system transfers.

b. MGTIS is the main database repository for all Autolog data herein described. Interfacing with this database will be different for the various activities supplying/updating pertinent Autolog data. Ships will use the Autolog platform to upload data updates and/or download system upgrades monthly to/from MGTIS, superseding GGTB 4 (GGTB 4, Revision 6, requires 6 month reporting). The requirements and guidelines to do so are detailed in (NSTM 234) and in the Autolog Users' Guide. However, note that MGTIS database updates via the Autolog allows for four alternate data transmission options; the higher the level of transmission option, the more complete the transmission through Autolog. Ships seeking data outside the Autolog operating environment should contact NSWCCD-NAVSSES, Code 9354, for instructions. Other activities supplying needed MGTIS updates will do so directly via the web, as outlined in separate instructions. If feasible and preferred, some of these activities may elect to use the Autolog application, enter the data, and then use it as the database update application. As required, said activities will create portable, hard format, Autolog database applications (CDs or Disks) at the time of equipment transfer as a spare or to a ship for installation. Procedures for doing so are outlined in separate instructions. Ships receiving equipment without data should contact NSWCCD-NAVSSES, Code 9354 for instructions.

c. During construction of a ship, which uses gas turbine equipment, the shipbuilding contractor updates the MGTIS database and Autolog under the direction of the supervising authority (SUPSHIP), until the ship is delivered. At that time, the contractor or NSWCCD-NAVSSES will generate an Autolog for the ship on CD-ROM or disks.

d. The Autolog shall be maintained on a ship designated secure PC and/or a secure work area. Internet capability is strongly recommended to allow easier and faster data and operating system transfers.

e. The Autolog shall be updated and maintained for each installed marine gas turbine from the time custody of the equipment is accepted until time of equipment transfer. Navy personnel will be trained on the maintenance of the Autolog and will be provided a users' guide.

f. The Autolog is created by the manufacturer, the activity originally accepting the equipment for the Navy, repair/rework facility, or NSWCCD-NAVSSES. The Autolog is subsequently maintained by the ship having custody of the equipment.

g. When marine gas turbine equipment is installed onboard ship as an engine or modular section of an engine, the associated automated record accompanies the equipment on CD or disks and becomes a part of the Autolog. Instructions for uploading the data from the CD are outlined in the Autolog User's Guide.

h. When complete equipment assemblies or removable accessories, or components for which Autolog is maintained are transferred (for example, from a ship installation to a depot repair facility), the last database updates will be transmitted to NSWCCD-NAVSSES.

i. The types of equipment assemblies which currently require an Autolog section are:

   (1) Gas turbine (single-shaft or single unit engine assembly).

   (2) Modular engine (gas turbine with major sections of engine that are replaceable).

   (3) Ancillary Equipment (LM2500 and 501-K series).

j. The requirement for maintaining an Autolog for a specific type of equipment is promulgated in General Gas Turbine Bulletin Number 3. The bulletin shall include a listing of the appropriate data to be tracked in the subject Autolog.

NOTE

Refer to General Gas Turbine Bulletin Number 0 (GGTB Nr. Zero) the index for current amendments/revisions to GGTB Nr. 3 and/or all other TDs.

k. For new ship construction, the Autolog shall be closed out at the time of acceptance/custody transfer of the ship to the Navy. Serial numbers recorded in the Autolog shall be verified before acceptance.

l. After the ship is delivered, all necessary Autolog entries for installed equipment shall be made under the direction of the ship's designated Autolog custodian.

m. Any ²verified by² field in the Autolog is the name of the individual(s) designated as responsible for the data entered.

n. The Autolog is comprised of different engine types, each with several automated NAVSEA service record forms. Custodial activities (ships, shipyards, overhaul facilities, or manufacturers) of marine gas turbine equipment assemblies will update both the Autolog and the MGTIS database. The MGTIS database can be updated through the Autolog or directly. The manufacturer, shipyards and overhaul facilities will create an Autolog application CD to accompany marine gas turbine equipment assemblies.

6.4.6 Automated Marine Gas Turbine Equipment (MGTE) Records

a. MGTE SERVICE RECORD. The Automated Marine Gas Turbine Equipment Service Record, NAVSEA 9400/1, page is used for equipment identification and installation data.

b. MGTE CUSTODY AND TRANSFER RECORD. The Automated MGTE Custody and Transfer Record, NAVSEA 9400/2, is updated when there is an equipment transfer.

c. MGTE OPERATING LOG. The Automated MGTE Operating Log, NAVSEA 9400/3 provides for the logging of all operating hours and starts on the equipment by month.

d. MGTE INSPECTION RECORD. The Automated MGTE Inspection Record, NAVSEA 9400/4, provides for logging and authenticating the performance of all special and conditional inspections performed on the equipment during the period of custody by a ship. Accurate inspection records are a primary requirement and prevent unnecessary reinspection by a new custodian upon transfer of the equipment.

e. MGTE RECORD OF REWORK. The MGTIS database and Autolog (9400/5) shall be updated with a complete record of all repair, reconditioning, conversion, modification, modernization, or rework performed on the equipment at a designated repair point, naval rework facility, or contractor. Ship's force will not update this page.

f. MGTE TECHNICAL DIRECTIVES. A Record of Technical Directive (TDs) affecting the equipment and accessories is entered on the automated MGTE Technical Directive page NAVSEA 9400/6.

g. MGTE MISCELLANEOUS HISTORY. The Automated Miscellaneous History, NAVSEA 9400/7, is used in the Autolog to record pertinent information for which no other place has been provided. This information would include significant information, which might be of assistance to personnel/activities involved in subsequent diagnoses of problems with the equipment, special test data, abnormal characteristics of equipment, significant damage or repair, yard periods, engine lay-up procedures, and authorization for extension of operating intervals. The MGTIS database shall be updated, either directly or through Autolog, with Miscellaneous History data.

h. MGTE SELECTED COMPONENT RECORD. The Automated Selected Component Record, NAVSEA 9400/8, is used to maintain a current inventory and installation and removal data for all equipment accessories and components that are tracked.

i. SUPPLEMENTAL RECORDS. The Automated MGTE Turbine Rotor Disc Assembly Service Record, NAVSEA 9400/10, and Automated Compressor Rotor Assembly Service Record, NAVSEA 9400/11, are the supplemental records presently required to be included in the Autolog.

j. Refer to NSTM Chapter 234, Section 8 for detailed information on Automated Marine Gas Turbine Equipment (MGTE) Records. Refer to www.navygasturbines.org for further AUTOLOG information.

6.5 LM2500 TECHNICAL MANUALS

Prior to using a Technical Manual, verify you are using the latest version. LM2500 Technical Manuals are issued in electronic format. Contact your local Technical Publication Officer for assistance obtaining and verifying the latest references. If required Contact your local MGTI for assistance.

Table 6-2. LM2500 Technical Manuals

SERIES	TITLE
S9234-AD-MMO-010	Description And Operation, Volume 1, Part 1, Revision 4
S9234-AD-MMO-020	Installation And Scheduled Maintenance, Volume 1, Part 2, Revision 4
S9234-AD-MMO-030	Troubleshooting, Volume 2, Part 1, Revision 4
S9234-AD-MMO-040	Reference Diagrams, Volume 2, Part 2, Revision 4
S9234-AD-MMO-050	Corrective Maintenance, Volume 2, Part 3, Revision 4
S9234-AD-MMO-060	Corrective Maintenance, Volume 2, Part 4, Revision 7
S9234-AD-MMO-070	Gas Turbine Assembly Illustrated Parts Breakdown, Volume 3, Part 1, Revision 6
S9234-AD-MMO-080	Lube Oil Storage And Conditioning Assembly Illustrated Parts Breakdown, Volume 3, Part 2, Revision 6
S9234-AD-MMO-090	Controls And Accessories Illustrated Parts Breakdown, Volume 3, Part 3, Revision 6
S9234-AD-MMO-100	Free Standing Electronic Enclosure Assembly Illustrated Parts Breakdown, Volume 3, Part 4, Revision 2
S9234-BF-MMI-010	LM2500 Gas Turbines Special Shipboard Maintenance, Volume 1, Revision 2
S9234-BF-MMI-020	LM2500 GG, PT, HSFCS Removal & Replacement, Volume 2
S9234-AB-MMD-010	Depot Level Gas Turbine Overhaul And Repair Instructions, Volume 1, Revision 2
S9234-AB-MMD-020	Depot Level Gas Generator Overhaul And Repair Instructions, Volume 2, Part 1, Revision 2
S9234-AB-MMD-030	Depot Level Gas Generator Overhaul And Repair Instructions, Volume 2, Part 2, Revision 2
S9234-AB-MMD-040	Depot Level Power Turbine Overhaul And Repair Instructions, Volume 3, Revision 2
S9234-AB-MMD-050	Depot Level Accessories Overhaul And Repair Instructions, Volume 4, Part 1, Revision 2
S9234-AB-MMD-060	Depot Level Electronic Enclosure Overhaul And Repair Instructions, Volume 4, Part 2, Revision 2
S9234-DI-GTP-010	Internal Inspection and Evaluation of Marine Gas Turbine Engines

CHAPTER 7

LM2500 CONTACT AND SUPPORT INFORMATION

The Chain of Command (COC) should always be followed when requesting outside assistance. After you have exhausted your internal COC onboard ship. Contact your ISIC MGTI, local SIMA and FTSC prior to contacting NAVSEA or NSWC.

POC	Number
FTSC-LANT, Norfolk, VA	757-443-3872
FTSC-LANT, Mayport, FL	904-270-6323
FTSC-PAC, San Diego, CA	619-556-2645
FTSC-PAC, Everett, WA	425-304-5411
FTSC-PAC, Pearl Harbor, HI	808-473-0645
SIMA 31T, Norfolk, VA	757-444-1954
SIMA 31T, Mayport,FL	904-270-5126
SIMA 31T, Pascagoula,MS	228-761-2189
SIMA 31T, San Diego, CA	619-556-1500
SIMA 31T, Everett, WA	425-304-5502
SRF 31T, Pearl Harbor, HI	808-473-8000
NAVSEA 03Z3	800-526-1234
NSWC 933	215-897-7618
NSWC 933 Tech Watch Pager	888-995-8380

*The FTSCPAC # will change in the spring of 04 due to reorganization under the umbrella of South West Regional Maintenance Center (SWRMC).

7.1 FUNDAMENTAL SECTION REVIEW QUESTIONS AND ANSWERS

1. What are the major components of the Compressor? **Compressor Front Frame, Compressor Rotor, Compressor Stator and Compressor Rear Frame**
2. What stages of Compressor Stator Vanes are variable? **Inlet Guide Vanes and the first six stages of Stator Vanes**
3. What stages of blades in the Compressor are titanium? **1-14**
4. Bleed air extracted from the ninth stage of the Compressor is used for what purposes? **PT cooling, PT Fwd Seal Pressurization and PT Balance Piston Cavity pressurization**
5. What are the four major parts of the Combustor? **Cowl (Diffuser Assembly), Dome, Inner Liner and Outer Liner**
6. What number bearings support the front and rear end of the HP Turbine Rotor? **The front end of the Turbine Rotor is supported at the Compressor Rotor Rear Shaft by the No. 4 Bearings and the rear of the Rotor is supported by the No. 5 Bearing in the TMF**
7. What is the primary configuration difference between paired blade and single shank HP Turbine Blades? **Blades are brazed together in pairs on paired blade configuration and the blades are one-piece castings on Single Shank configurations**

8. How are the HP Turbine Blades cooled? **Cooled by CDP Air which flows through the dovetail and through Blade Shanks into the Blades**
9. What are the major parts of the Second Stage Nozzle Assembly? **Nozzles, Nozzle Support, First and Second Stage Turbine Shrouds and Interstage Seal**
10. Where are the PT First-Stage Turbine Nozzles located? **Turbine Mid-Frame**
11. What components are mounted on the Transfer Gearbox? **The Fuel Pump and MFC, the Pneumatic Starter and the Lube & Scavenge Pump are mounted on the aft side of the TGB; the Air-Oil Separator is mounted on the front**
12. Why do all six stages of PT Blades contain interlocking tip shrouds? **To reduce vibration**
13. What bearing is housed in the Turbine Rear Frame? **No. 7 Ball and No. 7 Roller Bearings**
14. What is the purpose of the High-Speed Coupling Shaft Anti-Deflection Rings? **They restrict radial deflection of the couplings during shock loads**
15. What are the types of Oil Seals used in the LM2500? **Labyrinth/Windback in sumps areas and carbon used in TGB**
16. What are the types of Air Seals used in the LM2500? **Labyrinth/Honeycomb in the sumps and Turbine areas and Fishmouth in the Combustor and TMF**
17. How many Resilient Mounts are located under the GTM Module? **32**
18. What is the purpose of the Pressurizing Valve mounted on the Fuel Control outlet port? **Maintains backpressure to ensure adequate fuel pressure for Fuel Control Servo Operation and Variable Vane Actuation pressure at low F/O levels**
19. What are the two types of fuel flow within the Main Fuel Control? **Metered Flow and Bypass Flow**
20. What fuel manifold pressure does the Fuel Nozzle Flow Divider open at? **330-350 PSIG**
21. What are the primary inputs to the Main Fuel Control for Fuel Scheduling? **NGG, CIT, CDP and PLA**
22. Name the three LM2500 Lube Oil Sub Systems? **Lube Oil Supply, Lube Oil Scavenge and Sump Vent**
23. What Technical Directive adds magnetic drain plugs to the Lube and Scavenge Pump Inlet Screens? **LM2500 Gas Turbine Change (GTC) No. 81**
24. What is the purpose of the Lube Oil Scavenge Check Valve? **Prevents oil in the scavenge lines from draining back into the sumps and gearbox when the GTE is shutdown**
25. How are the LM2500 Gas Turbine Engine Sumps pressurized? **Pressurized by 8th Stage Compressor Air**
26. How are the Air-Oil Separator Labyrinth Seals pressurized? **Pressurized by 8th Stage Compressor Air**
27. The Ignition Exciter operates on what input power? **115 VAC 60 HZ**
28. What prevents accumulation of carbon in interior passages of the Spark Igniters? **Air Cooling and Air Vents**
29. What conditions will cause an Icing condition? **Temperature below 41 degrees F and humidity above 70%**
30. What are the two types of Vibration Detection Systems used on LM2500 engines? **Accelerometers (installed by GTC No. 77 and AYC No. 31) and Velocity Transducer System (original configuration)**
31. Where is the Flame Detector Signal Conditioner located? **In a metal box which is attached to the underside of the BEA**

32. How many Flame Detectors and Temperature Switches are used in the LM2500 Fire Detection System? **3 Flame Detectors and 2 Temperature Switches**
33. What class ships use Halon as a LM2500 Module Fire Extinguishing agent? **FFG and DDG**
34. Where are the LM2500 Water Wash System Manifold and Outlet Spray Orifices located? **Inlet Duct**
35. What is the primary purpose of the Enclosure Heater? **Maintains the enclosure air temperature above 60 degrees F so that a suitable fuel viscosity is maintained for GT start**
36. What are the two types of temperature sensors used in the LM2500 Module? **RTD and Thermocouples**
37. Describe the flow of Thirteenth Stage Air? **13th Stage bleed air is bled from the Compressor through holes in the 13th Stage vane bases and Compressor Casing to an external manifold. The air is piped through the Compressor Rear Frame casing and into the High Pressure Turbine Shrouds. The air then flows through and cools the second stage Turbine Nozzle. Some of the air exits through the trailing edge holes. The remaining air is used for cooling the Interstage Seal, the aft side of the First Stage Blade Shanks and the front side of the Second Stage Shanks.**
38. What is the primary purpose of the Eighth Stage Air Ejectors? **Give a high volume output of low pressure and low temperature air**
39. What are the two major components of the Electronic Power Control System? **FSEE or ECM and PLA Rotary Actuator**
40. What are the signals that modify the command directed to the PLA Actuator? **Rate and Position Feedback Signals from the PLA Actuator, Torque Limiting Signal, Speed Limiting Signal and Acceleration Limiting Signal**
41. During a LM2500 start what is the maximum time allowed to reach 4500 NGG? **90 seconds**
42. What is the maximum T5.4 allowable during LM2500 start? **1350 degrees F**
43. What is the maximum allowable LM2500 T5.4 at idle? **1000 degrees F**
44. What are the LM2500 GG and PT vibration alarm limits? **GG 4 mils, PT 7 mils**
45. What is the L/O pressure low alarm set point? **15 PSIG**

7.2 PLANNED MAINTENANCE SYSTEM AND INSPECTION PROCEDURES REVIEW QUESTIONS AND ANSWERS

1. True/False. During inspections and assessments, inspectors will down equipment when ships force cannot demonstrate that they are tracking hours and performing hour base and conditional maintenance? **True**
2. What is the definition of Coking? **An accumulation of Carbon**
3. What is the definition of Tip Clang? **Contact between tips of adjacent Compressor Blades. Blade deflection causes contact between the leading edge tip of one blade and the Convex side of the adjacent blade. It indicates a severe Stall.**
4. What is the definition of a Radial Crack? **A Radial Crack extends in the general Direction perpendicular to the centerline of the GT or part.**
5. What is the definition of Not Serviceable? **The observed condition discrepancy is judged not acceptable for continued operation of the equipment without proper corrective action.**

6. What conditions warrant the accomplishment of MIP 2340, MRC R-13, Borescope Inspection? **750+/- hours since last inspection, 90 days prior to deployment, GT Overtemperature, GT Overspeed, GT Stall above 7500 RPM, High GT Vibration and Post Shutdown Fire**
7. What position should the Variable Stator Vanes be in during Borescope Inspection? **Full Open Position**
8. How are Compressor Rotor Blades Indexed during Borescope Inspection? **The first Rotor Blade CCW from the Second Locking Lug is Blade number 1**
9. During Borescope Inspection you note a missing Platform corner on the concave locking blade in Stage 7, is this damage? **No, it is Gas Turbine Change No. 46**
10. Which direction do you rotate the Compressor Rotor during Borescope Inspection? **CCW, disregard the fact that the GG runs clockwise**
11. How many Compressor Blades are located in the 16th stage? **76**
12. How many Double Shank HP Turbine Blades are located in the First Stage? **108**
13. How do you Index the HP Turbine Rotor? **Use Stage 10 Compressor Rotor**
14. How many Single Shank HP Turbine Blades are located in First Stage? **88**
15. During Combustor Borescope Inspection you note Burn Through and Missing Material in the Trumpet Area. What is the maximum Serviceable Limits for Trumpet Burn Through and Missing Metal? **Any amount less than 180 degrees of Burn Through the Trumpet and/or Dome Plate around any one Swirl Cup.**
16. While conducting MIP 2340, MRC R-18, MFC VSV Feedback Lever and Actuation System Inspection, you note a VSV System discrepancy. What is your course of action? **Report any VSV System discrepancies to Work Center Supervisor and if an Out Of Limit condition is found, contact local MGTI or FTSC Gas Turbine Rep for further evaluation**
17. During Compressor VSV Inspection you note side-to-side movement by hand. How do you properly measure the side-to-side movement? **A Dial Indicator**
18. What is the Serviceable Limit for Compressor VSV side-to-side movement? **0.000” − 0.019” side-to-side movement**
19. What level is the level of repair for Compressor VSV Bushing and Spacer Wear? **IMA**
20. What is the proper installation direction for the VSV Feedback Cable Rod-End Bearing attaching bolts? **Bolt Heads toward GT**
21. From what position should you view Feedback Cable Rig Marks? **The rig marks must be viewed directly behind the MFC. Viewing marks on an angle will not allow an accurate reading**
22. What instrumentation lines are disconnected prior to performing MIP 2340, MRC R-1, Detergent Wash of Gas Turbine Internal? **PS3, PT2 and PT5.4**
23. How many wrenches should be used when loosening or tightening Swivel Coupling Nuts, Hoses, Tubes or Fittings? **2, Hold stationary part with one wrench while applying torque with second wrench**
24. After completion of Propulsion Air Inlet System Inspection, how long do you operate the Gas Turbine with the nylon screen placed over the Bellmouth Screen? **30 minutes, if screen has collected debris, remove debris, reinspect nylon screen and repeat engine run, repeat until nylon screen collects no debris**

25. While conducting MIP 2340, MRC R-20, Inspection of Gas Turbine Base Enclosure Interior and Base Enclosure Exterior, you note discrepancies. Where do you locate Inspection Criteria? **S9234-AD-MMO-060/LM2500**
26. What is the maximum allowable span of Safety Wire between two tension points? **Six inches, unless otherwise specified**
27. How many twists per inch are allowable for .032 inch and .020 inch diameter Safety wire? **7-10 twists per inch for .032 inch diameter and 9-12 twists per inch for .020 inch diameter wire**
28. What is the maximum allowable flexing at the center of a 6-inch length of Safety Wire? **3/4"**
29. What is the maximum number of bolts you can Safety Cable together with on Safety Cable? **3 Bolts**
30. How do you determine Breakaway (Running) Torque on Self-locking Nuts? **Screw the nut onto a bolt until two to five threads are exposed beyond the nut, measure the amount of torque required to turn the nut on or off the bolt**
31. What is the proper method for installing a V-Band Clamp? **Tighten nut to half of required torque value, check around clamp for even seating over flanges, using a non metallic mallet, lightly tap around clamp to distribute band tension while increasing torque to required value, continue tapping around clamp, after reaching required torque tap around clamp again and recheck torque**
32. What is the proper method for tightening electrical connectors? **Tighten with Teflon Pliers**
33. What Technical Directive is required to be accomplished concurrently with GTB 12? **GTB 24**
34. What actions are required if during deployment of over 90 days GTB 12 and 24 inspection interval time occurs? **Ship is to notify their ISIC/TYCOM and follow current TYCOM Departure From Specification (DFS) guidance, TYCOM will provide for accomplishing inspection as ship and inspection assets are available**
35. When is the initial inspection of GTB 22, Inspection of First Stage Compressor Carboloy Pads required? **Initial Inspection will be conducted at 10,000 +/- 1000 TSN/TSR**

7.3 <u>TROUBLESHOOTING PROCEDURES REVIEW QUESTIONS AND ANSWERS</u>

1. What is the definition of a Compressor Stall? **A stall is an aerodynamic disturbance of the normally smooth airflow throughout the GT**
2. What are the indications of a Stall? **Abnormal GT noises such as low frequency (40-50HZ) rumble, roar or banging noise, Higher than normal or fluctuating FMP, Sluggish or no GT response to throttle movements (Transient Stall), higher than normal T5.4, rapid rise or fluctuating T5.4 and/or high T5.4 alarm/automatic shutdown or higher than normal or fluctuating vibration levels**
3. What are the two General Classifications of Stalls? **Steady State and Transient**
4. What is the definition of a “High Speed Stall”? **A Steady State or Transient Stall occurring above 7500 RPM**
5. What are the two categories of Torque Splits? **Real and Calculated**
6. What is considered an excessive Torque Split? **Torque Split of more than 6,000 FTLBs**
7. What is the definition of CIT Sensor Hot Shift? **When the CIT Sensor internally malfunctions (or**

inlet screen is clogged) and projects an inlet temperature much higher than the actual. The MFC schedules the Stator Vanes more closed, may cause a loss of power

8. How many FT LBS will torque change for every 1.0 PSIA change in PT5.4? **1230 FTLBs**
9. What could a VSV Feedback Lever Rig Mark, rigged above the Stationary Rig Mark lead to? **Too much power for a given speed and depending on outside air temperature could lead to a stall**
10. Does a Gas Turbine Engine run more efficient on a hot or cold day? **Cold day**
11. What is the maximum allowable LM2500 oil consumption per hour? 24 hour operating period? **946 CCs per hour (6 gallons per 24 hour operating period, the 6 gallon per 24 hr operating limit is considered the maximum safe operating limit for the engine until the consumption problem can be identified and corrected.**
12. What is the maximum allowable leakage from the Starter Accessory Gearbox Drain line in a one hour period? **5CCs per hour (approximately 0.2 oz)**
13. What is the common cause for smoke in module after extended low power operation? **Insufficient sealing air pressure. Full power operation for 30-90 minutes should clear the seals and restore normal operation**
14. What is the common cause for a LOSCA level drop when the engine is secured? **A faulty L/O Supply Check Valve**
15. What course of action is required if chaffing of the C-Sump Oil Supply Tube at the TMF Strut is found? **Contact FTSC to determine serviceability of the tube and investigate cause, Install GTC 79 Vibration dampening bracket and clamps to prevent further wear**

7.4 CORRECTIVE MAINTENANCE REVIEW QUESTIONS AND ANSWERS

1. In what maintenance manual would you find the corrective maintenance procedure for the MFC? **S9234-AD-MMO-050/LM2500**
2. When replacing a LM2500 Power Turbine, what alignment check is required to be accomplished prior to and after replacement? **Gas Turbine Assembly to Ships Main Reduction Gear Assembly Alignment Check**
3. When is General Gas Turbine Bulletin 23 required to be adhered to? **For Any Gas Turbine removal and replacement onboard ship for both the MGT Assembly being received and for the failed MGT Assembly being removed**
4. What is the installed life for DDG FWD/MER LM2500 Shock (Resilient) Mounts? **14 years**
5. What liquid load is required prior to performing H & J Alignment? **Between 75 and 85 percent of total liquid load**