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NAVAL SHIPS' TECHNICAL MANUAL

CHAPTER 234

MARINE GAS TURBINES

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CHAPTER 234

MARINE GAS TURBINES

SECTION 1

INTRODUCTION

234-1.1 GENERAL

234-1.1.1 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 this chapter.

234-1.1.2 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 Systems Command (NAVSEA) technical manuals and manufacturer technical manuals should be used for specific information about each engine.

234-1.1.3 Before operating a gas turbine engine or performing routine maintenance or overhaul, detailed personnel should be thoroughly familiar with the information available from:

a. Manufacturer's installation, operation, and maintenance technical manuals and instructions for the model of engine to which assigned

NOTE

A manufacturer's technical manual with a NAVSEA number assigned has the full authority of a NAVSEA technical manual.

b. Class advisories, circular letters, and force, squadron, and division engineering directives pertaining to a specific gas turbine engine and accessories

c. Relevant NSTM Chapters

d. NAVSEA Planned Maintenance System (PMS) documentation, Maintenance Requirement Cards (MRCs), and Maintenance Index Pages (MIPs)

e. NAVSEA Engineering Operational Sequencing System (EOSS)

f. Engine allowance lists and the Consolidated Onboard Ship's Allowance Lists (COSAL) for the ship

g. NAVSEA technical directives and technical bulletins covering the particular engine.

234-1.1.4 In addition, personnel working on gas turbines should be familiar with the following training manuals:

a. **Tools and Their Uses,** NAVEDTRA 10085

b. **Fireman,** NAVEDTRA 10520

c. **Gas Turbine Systems Technician (Electrical) 3/ Gas Turbine System Technician (Mechanical) 3** , Volume 1, NAVEDTRA 80563 and Volume 2, NAVEDTRA 80564

d. **Gas Turbine Systems Technician (Electrical) 2** , NAVEDTRA 82157.

e. **Gas Turbine Systems Technician (Mechanical) 2** , NAVEDTRA 82153.

f. **Gas Turbine Supervisor** , NAVEDTRA 82158.

g. **Diesel Engines,** NAVEDTRA 10625

h. **Principles of Naval Engineering,** NAVEDTRA 10788

i. **Engineering Administration,** NAVEDTRA 10858

j. **Fundamentals of Petroleum,** NAVEDTRA 10883

k. **Navy Safety Precautions for Forces Afloat,** OPNAVINST 5100.19.

234-1.2 ENGINE OPERATING DESCRIPTION

234-1.2.1 A gas turbine engine in its simplest and most common form is a heat engine where heat in the form of burning fuel is added, and useful work is extracted. The gas turbine engine operates by a series of processes consisting of:

a. The compression of a working gas (air) taken from an external reservoir (the atmosphere)

b. The addition of heat to the air (by burning fuel)

c. The flow of the high-temperature, high-pressure gas through a turbine where work is extracted

d. The discharge of gas back to the atmosphere

234-1.2.2 Since the operating process is open on both ends - that is, the exhaust gas is not sent back to the inlet - the engine is called the open cycle gas turbine. Since the open cycle gas turbine engine is the only type of gas turbine currently in use in the Navy, all discussion in this chapter is confined to the open cycle engine. Figure 234-1-1 is a simple schematic of an open cycle gas turbine engine.

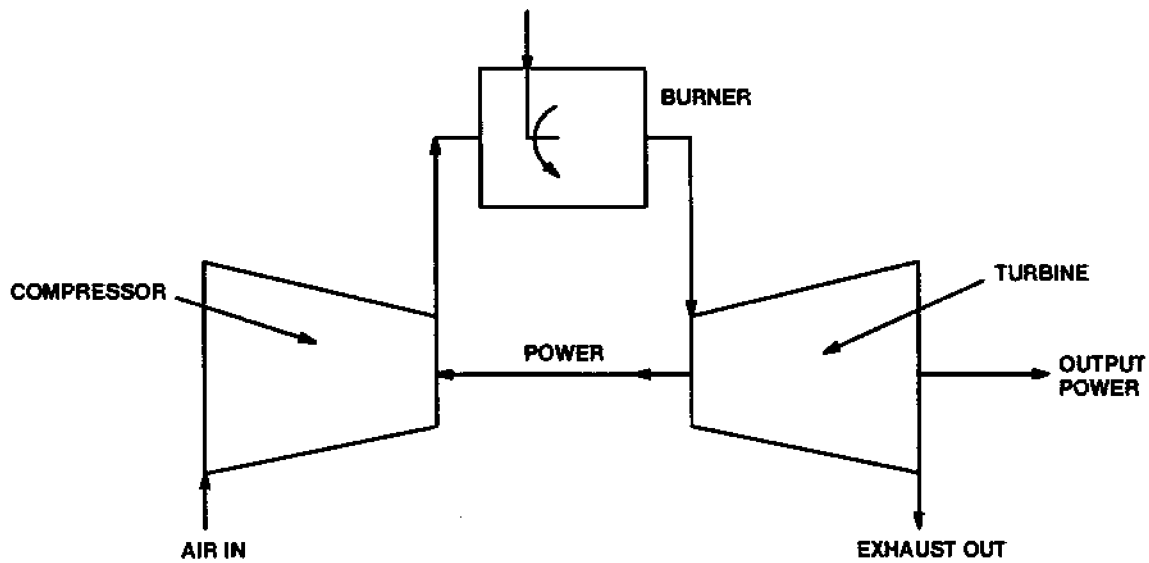

Figure 234-1-1. Schematic of Open Cycle Gas Turbine Engine

234-1.2.3 The gas turbine engine is roughly similar to the gasoline and diesel engines in its use of air and internal combustion to perform useful work. It is also like the steam turbine because it has continuous flow of the working gas.

234-1.2.4 The continuous flow allows the compression and power production (expansion) processes to be performed by rotating elements. Energy is transferred directly to the rotating elements rather than through the motion of pistons and connecting rods as is the case for reciprocating engines.

234-1.2.5 A typical U.S. Navy gas turbine engine is constructed in four principal sections, or modules, each section containing components necessary to perform a specific function in the cycle. In some instances a section is modularized to the extent that a module can be replaced without disassembling the remaining modules.

234-1.3 INLET SECTION

234-1.3.1 The inlet section of a gas turbine engine directs air into the compressor. Inlet sections are designed to provide at the compressor inlet the most uniform velocity and total pressure distribution possible. Without smooth, nonturbulent airflow, compressor blade life, output horsepower, and engine fuel consumption will be adversely affected.

234-1.3.2 The inlet section provides important secondary functions. It usually contains the wash manifold and injection nozzle for spraying a liquid cleaning solution into the engine. This wash system is important because it removes salt and other fouling residues that accelerate vane and blade corrosion, decrease compressor efficiency, shorten engine life, and increase engine fuel consumption.

234-1.3.3 Since a ship may need to serve in extremely cold environments, the inlet section may also contain anti-icing piping and injection nozzles used to introduce hot air into the compressor inlet. This hot air, usually extracted from the engine compressor discharge bleed air port, inhibits the formation of ice on engine components such as variable pitch compressor vanes, and other items such as bellmouth and inlet screens.

234-1.4 GAS GENERATOR

234-1.4.1 GENERAL. The gas generator consists of the compressor(s), the combustion system(s), and the high-pressure turbine(s).

234-1.4.1.1 During engine operation, air from the inlet section enters the compressor where its pressure is increased. The high-pressure air is then directed into the combustion section where it is mixed with fuel and ignited, raising its temperature.

234-1.4.1.2 The hot gases from the combustor are directed into the high-pressure turbine, where power is extracted from the gas stream to drive the compressor rotor. From the high-pressure turbine, the gases, now at reduced pressure and temperature, are ducted into the power (or low-pressure) turbine and into the exhaust collector.

234-1.4.2 COMPRESSOR. The compressor consists of a rotor and stator within a casing. Its function is to pressurize intake air. Gas turbine compressors are either axial flow or radial flow, dependent on the direction of the air leaving the compressor rotor.

234-1.4.2.1 Axial Flow Compressor. The only compressor type in large marine gas turbine engines is the multistage axial flow compressor, a cutaway view of which is illustrated in Figure 234-1-2.

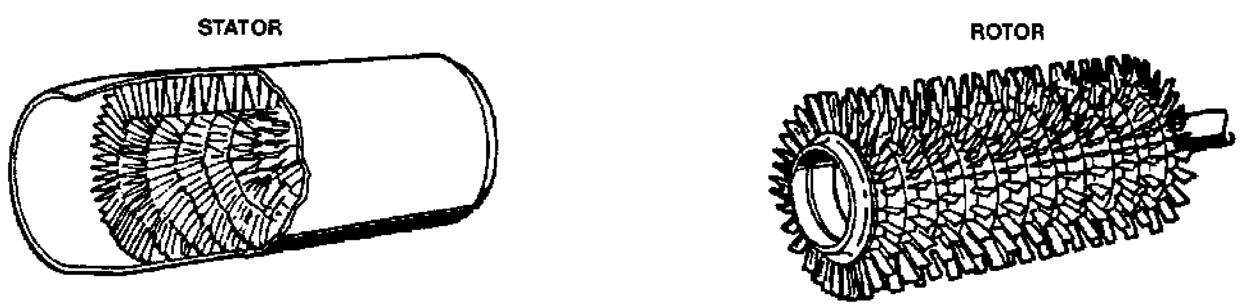

Figure 234-1-2. Rotor and Stator (Cutaway View) of Multistage Axial Compressor

234-1.4.2.1.1 In the axial flow compressor, exit flow is discharged from the compressor in the same direction as the input flow enters. This allows higher efficiency, and the production of a high pressure ratio on a single shaft. The axial compressor stage consists of a rotating row of blades followed by a stationary vane row. The rotating blades increase the kinetic energy of the air. The increased kinetic energy is then converted to pressure by the stator vanes. By combining several stages in series it is possible to increase the pressure of the air in successive steps.

234-1.4.2.2 Radial Flow Compressor. The radial flow compressor, used in several small gas turbine engines, is best suited to low pressure ratios where overall engine diameter is not important. The radial flow compressor imparts centrifugal energy (increased velocity) to the air by rotating the air out from the compressor inlet flow axis; that is, most gas turbine radial flow compressors discharge air radially outward at an angle 90° to the input axis. The exhaust flow then passes through a diffuser, increasing the air pressure.

234-1.4.2.2.1 Figure 234-1-3 shows an exploded view of a radial flow compressor.

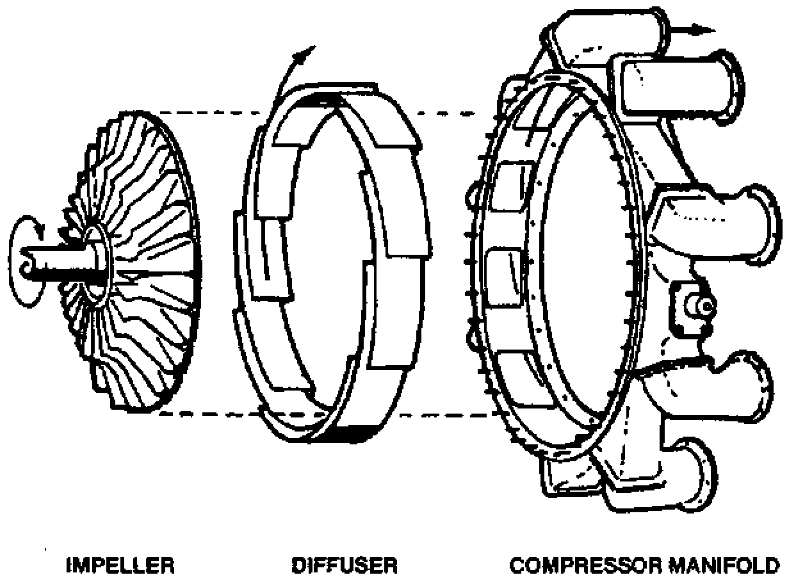

Figure 234-1-3. Exploded View of Radial Flow Compressor

234-1.4.2.3 Combination Axial-Radial Compressors. Although the majority of compressors currently in use are either axial or radial flow, it is possible to have compressors in which both types are used in combination. A typical example of such an application is illustrated in Figure 234-1-4.

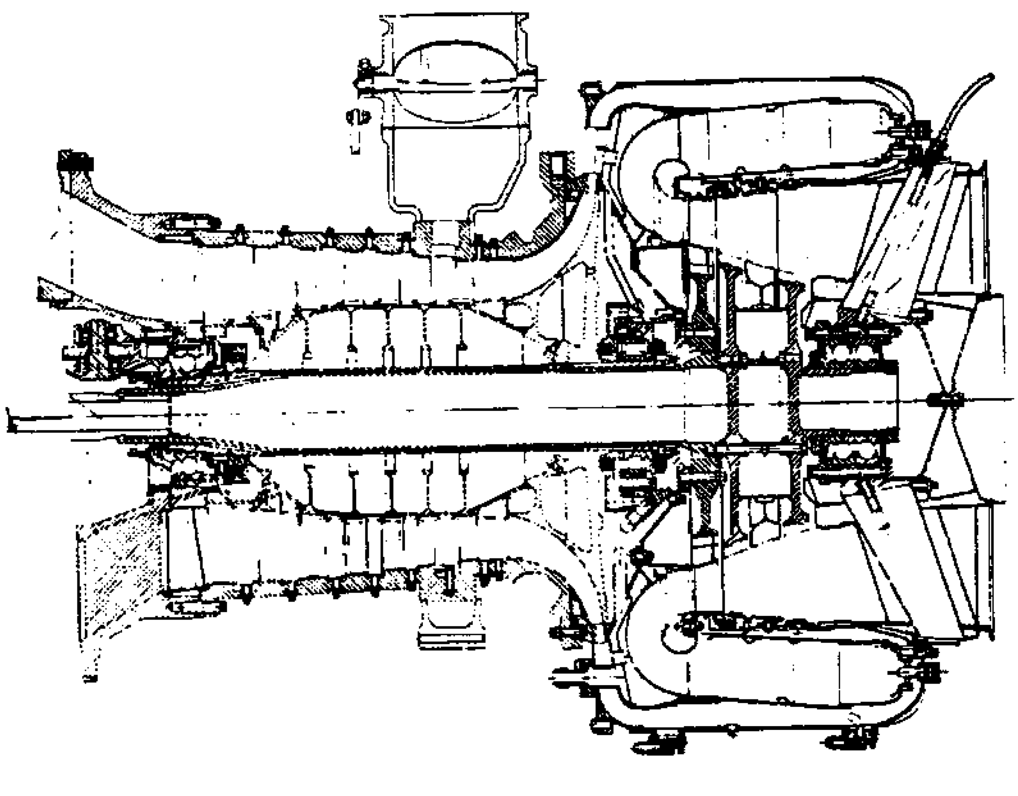

Figure 234-1-4. Cross Section of LCAC TF40B Gas Turbine Engine

234-1.4.3 COMBUSTION SECTION. The combustion section of the gas turbine accepts air from the compressor and delivers it to the high-pressure turbine at increased temperature, with little loss of pressure; this is accomplished by the internal combustion of fuel.

234-1.4.3.1 General. Fuel preparation, mixing, and burning takes place in the combustion section which consists of the combustor, the fuel manifold, fuel nozzles, the igniter, and leads.

234-1.4.3.1.1 Marine gas turbine combustors are of three types - can, annular, or can-annular.

234-1.4.3.2 Can Type Combustor. A can burner combustor is most frequently employed in centrifugal compressor engines. Air leaving the diffuser is ducted to individual combustion cans, or cylinders, arranged around the axis of the engine. Each can contains its own fuel nozzle located in the center of the burner. Primary air delivered from the compressor is introduced at the nozzle, mixes with the fuel, and supports combustion. Additional air, which bypassed the fuel nozzles, mixes with the products of primary combustion to cool the combustor, dilute and cool the hot gases, and distribute the heat energy evenly. The hot gas from the combustion can(s) then flows into the turbine section. The can type combustor is illustrated in Figure 234-1-5.

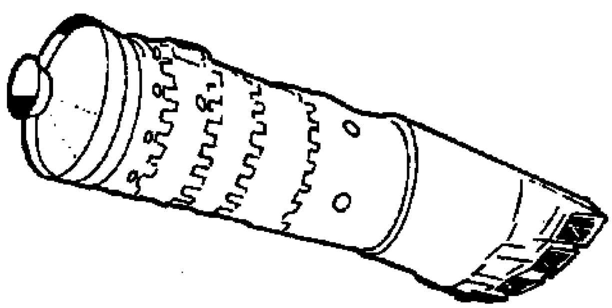

Figure 234-1-5. Can Type Combustor

234-1.4.3.2.1 One advantage of the can type combustor is that serviceability is enhanced since individual cans may be removed for inspection and replacement without disturbing the engine installation. One disadvantage of the can type combustor is that if any one fuel nozzle malfunctions, the turbine nozzle guide vanes are subjected to severe temperature differentials that can cause vane distortion or burnout.

234-1.4.3.3 Annular Type Combustor. The annular combustion chamber consists of combustion space formed by concentric cylinders around the engine axis. Fuel is introduced through a ring of nozzles at the upstream end of the annulus.

234-1.4.3.3.1 This type of burner uses all of the space available, which permits more time for fuel and air mixing within a relatively simple structure and low pressure loss.

234-1.4.3.3.2 The principal objections to an annular combustion chamber are:

a. The annular chamber is subject to heat and stress buckling.

b. Removal of the chamber requires significant disassembly of the engine.

234-1.4.3.3.3 Two views of the annular combustor are illustrated in Figure 234-1-6.

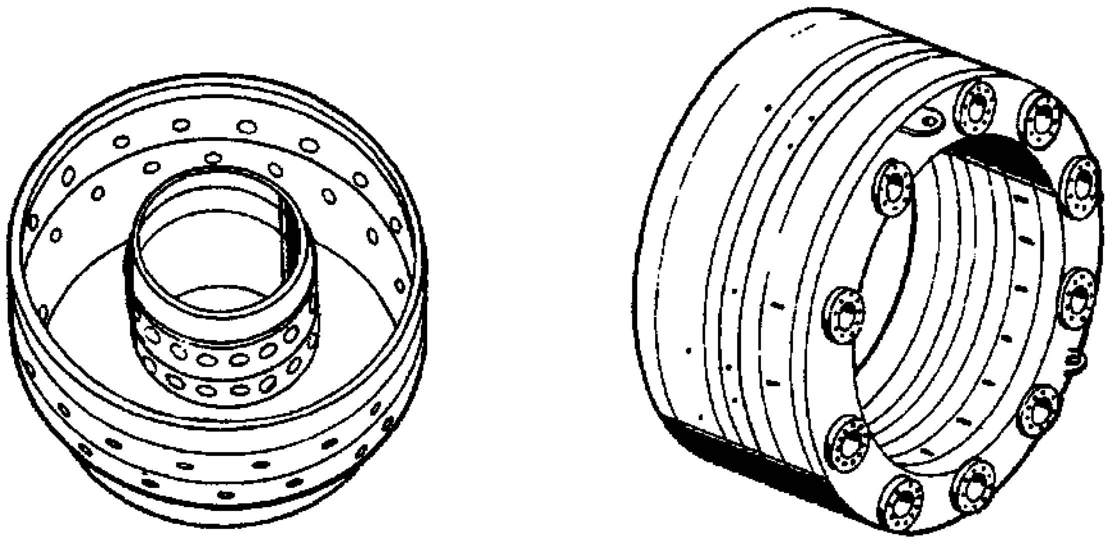

Figure 234-1-6. Annular Type Combustor

234-1.4.3.4 Can-Annular Type Combustor. The can-annular combustor chamber arrangement consists of individual cans placed side by side in an annular chamber. The cans are essentially individual annular burners. Each is provided with a concentric tube which increases the effective burner length by increasing the fuel air mixing, without adding to the overall size. A cluster of several fuel nozzles is placed around the perimeter of the forward end of the can. The cans are interconnected by means of crossover or fire tubes which propagate the flame from can to can after initial combustion.

234-1.4.3.4.1 In the can-annular type of arrangement, only one or two igniter plugs (see paragraph 234-1.4.3.6) are used and the flame traveling crossover tubes provide combustion to other cans.

NOTE

In comparison, a can burner has one igniter plug for each can when not connected through crossover tubes.

234-1.4.3.4.2 The can-annular combustion chamber, like the can burner arrangement, allows removal and replacement of individual cans without disassembly of the engine. It does not provide as even a temperature distribution at the turbine inlet as the annular combustor.

234-1.4.3.5 Fuel Nozzles. The function of the fuel nozzle is to spray highly atomized fuel into the combustion areas so burning is completed in the shortest space and time. The fuel must be sprayed evenly to prevent formation of any hot spots on the combustion chamber liner.

234-1.4.3.5.1 The rate flow through a given nozzle will depend on the viscosity of the fuel and the pressure drop across the nozzle. Too low a fuel pressure will result in poor atomization, with incomplete combustion and the formation of carbon deposits.

234-1.4.3.5.2 One method of avoiding the problem of low fuel pressures and resultant poor combustion is use of a dual (or duplex) nozzle which has both a primary and secondary orifice. The dual nozzle requires a pressure-operated valve to divide the fuel flow into primary and secondary manifolds.

234-1.4.3.5.3 At low fuel flows, all of the fuel passes through the primary manifold. The primary orifice permits a higher degree of atomization under these conditions. When the fuel pressure is sufficient to open the main line, the secondary orifice sprays the greater amount of fuel in a satisfactory pattern.

234-1.4.3.6 Igniters. Usually, gas turbine engines are provided with two igniter plugs, sometimes referred to as spark igniters. In the case of can type and can-annular type burner chambers, the igniter plugs are located in separate chambers.

234-1.4.3.6.1 Igniter plugs serve a purpose similar to spark plugs in a reciprocating type engine. Unlike the ignition system of a reciprocating engine, the operation of the gas turbine engine ignition system is necessary, usually, only for a short time during engine starting.

234-1.4.3.6.2 The typical dual ignition system consists of an electrical power source, two igniter plugs, separate exciters for each igniter plug, and the associated wiring harnesses and high-tension leads. The exciter converts a low voltage power to a high-voltage potential for delivery to the igniter plug.

234-1.4.4 GAS GENERATOR TURBINE. The gas generator turbine, which is the high-pressure turbine, extracts energy from the expanding gases flowing from the combustion chamber and converts this energy into torque to drive the compressor and various engine accessories.

234-1.4.4.1 General. The high-pressure turbine is mounted on the same shaft as the compressor, and the energy extracted by the turbine is used to drive the compressor. As much as 3/4 of all energy available from the combustion process is used to drive the compressor. The remaining energy is available for useful work.

234-1.4.4.1.1 Turbines, like compressors, are either axial flow or radial flow type although only axial flow turbines are currently in Navy marine use. The axial flow turbine extracts energy from the expanding gas flow and exerts a force on the blades. The expansion of the gas flow across the turbine blades causes a change in velocity. This force is translated into torque which is applied to the shaft. Figure 234-1-7 illustrates the stator and rotor components of the single-stage high-pressure turbine.

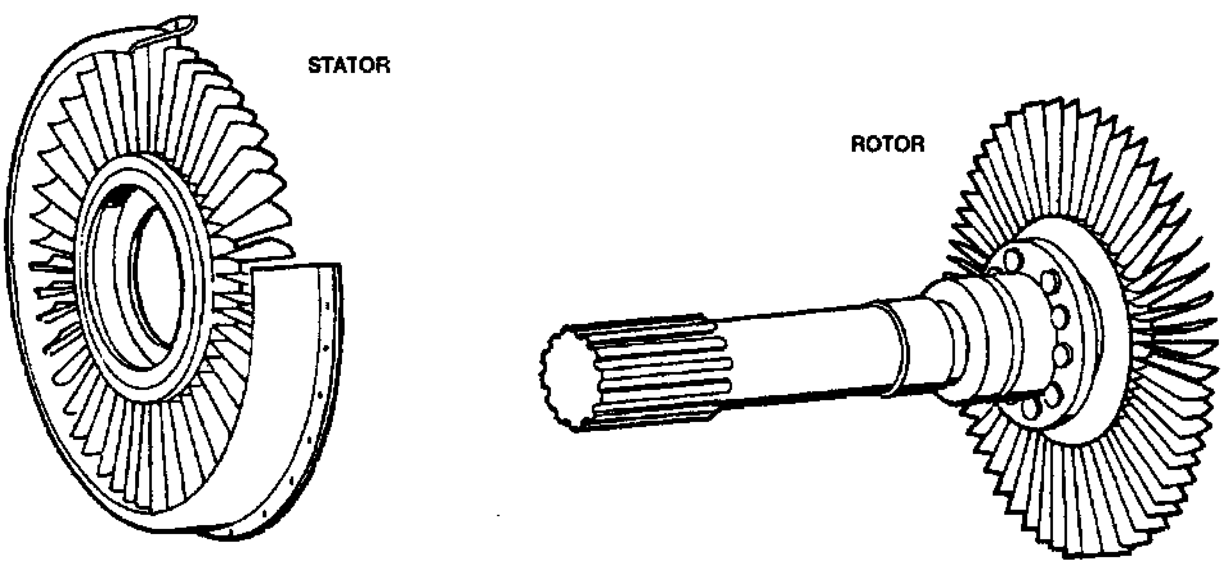

Figure 234-1-7. Single Stage High Pressure Turbine Components

234-1.4.4.1.2 An axial flow turbine is comprised of two main elements, a set of stationary vanes, and a turbine wheel or rotor. The stationary section consists of a plane of contoured vanes concentric with the turbine axis. The vanes are angled to form a series of small nozzles which discharge the gases onto the blades of the turbine wheel. The stationary vane assembly is usually referred to as the turbine nozzle and the vanes are called nozzle guide vanes.

234-1.4.4.1.3 Axial flow turbines may consist of either a single stage or of multiple stages. In multiple stage arrangements, stationary vanes are inserted before each rotor wheel. Each set of stationary vanes forms a nozzle vane assembly that conditions and aligns the gas flow for entry into the next stage of turbine blades.

234-1.4.4.2 Power Turbine. The power turbine or the low-pressure turbine is the component of the gas turbine engine that produces useful work. The operating principles are the same as for the high-pressure turbine but since the power turbine is downstream of the high-pressure turbine, it operates with lower temperature and pressure gases.

234-1.4.4.2.1 The power turbine rotor is directly mounted on the output power shaft which can drive aft through the exhaust collector or forward concentrically through the compressor shaft. Figure 234-1-8 is a schematic showing the gas turbine with free power turbine driving through the exhaust and Figure 234-1-9 is a schematic of the gas turbine with free power turbine driving through the inlet.

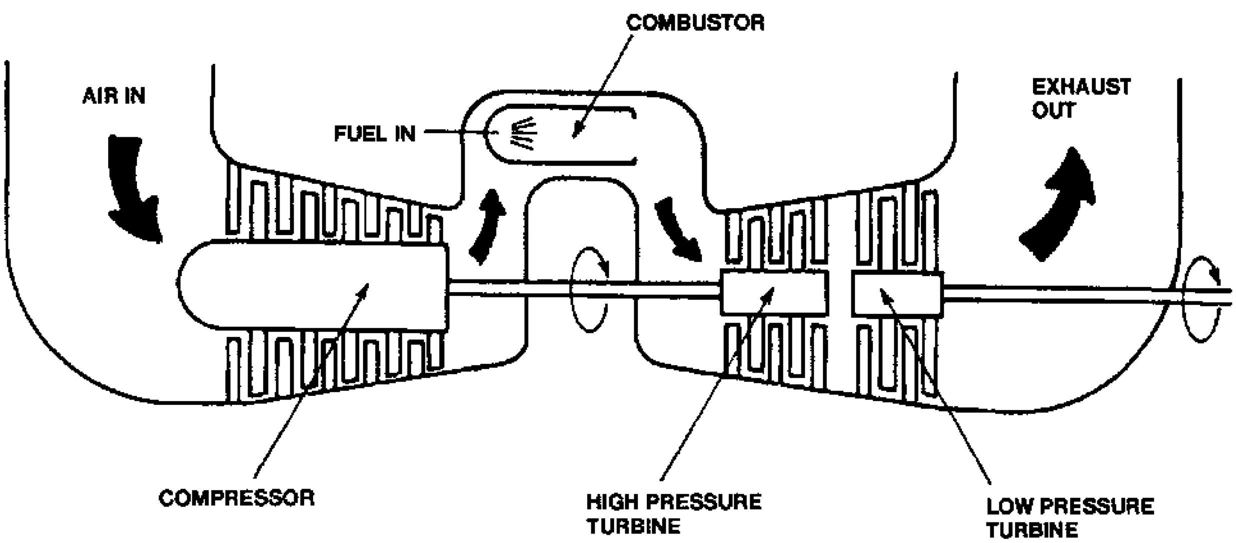

Figure 234-1-8. Schematic of Gas Turbine With Free Power Turbine Driving Through Exhaust

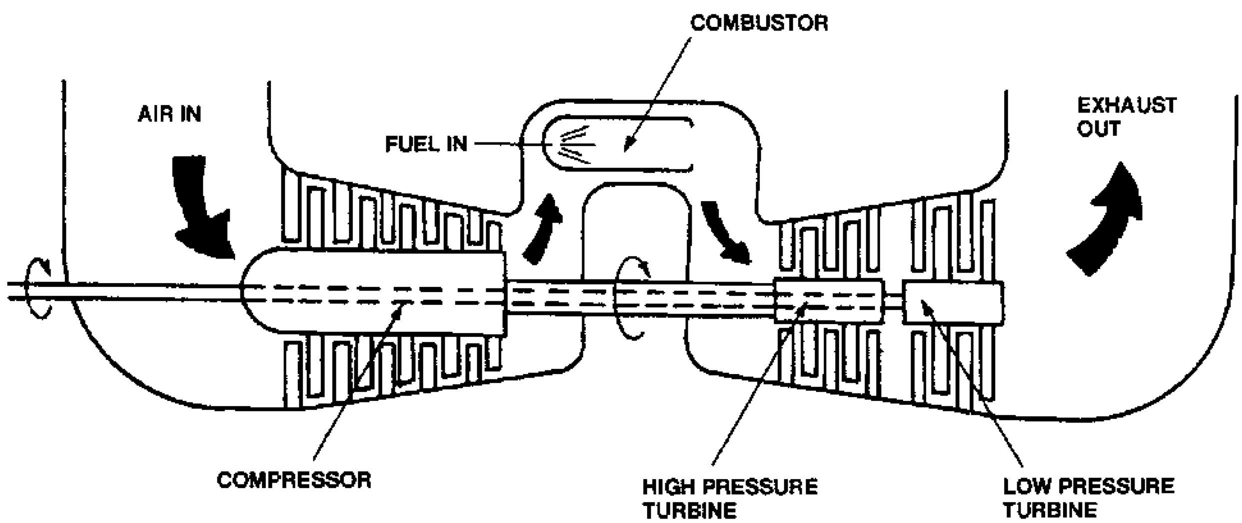

Figure 234-1-9. Schematic of Gas Turbine With Free Power Turbine Driving Through Inlet

234-1.4.4.3 Exhaust Section. The exhaust section consists of the inner and outer duct forming the diffusing passage from the power turbine rear frame into the exhaust collector.

234-1.4.5 DESIGNATION OF GAS TURBINE ENGINES

234-1.4.5.1 General. Gas turbines are either a free turbine or coupled turbine depending on whether or not the power turbine is connected to the gas generator shaft.

The gas generators are either single-spool or multispool. Coupled and free turbines and single-spool and multispool gas generators are discussed in paragraphs 234-1.4.5.2 through 234-1.4.5.5.

234-1.4.5.2 Coupled Turbine. The primary characteristic of the coupled or single-shaft gas turbine is that the power turbine shaft is directly connected to the gas generator shaft so the power turbine, high-pressure turbine, and compressor are essentially mounted on a single shaft. In turn, the single shaft or combined shafts are linked to the driven load.

234-1.4.5.2.1 With this arrangement, the power turbine cannot be run at low speeds because the gas generator would be at the same speed and would not develop sufficient power. Consequently, the coupled turbine engine is best suited to applications exhibiting constant speed and power requirements such as electric generator sets. Figure 234-1-10 illustrates a coupled gas turbine engine.

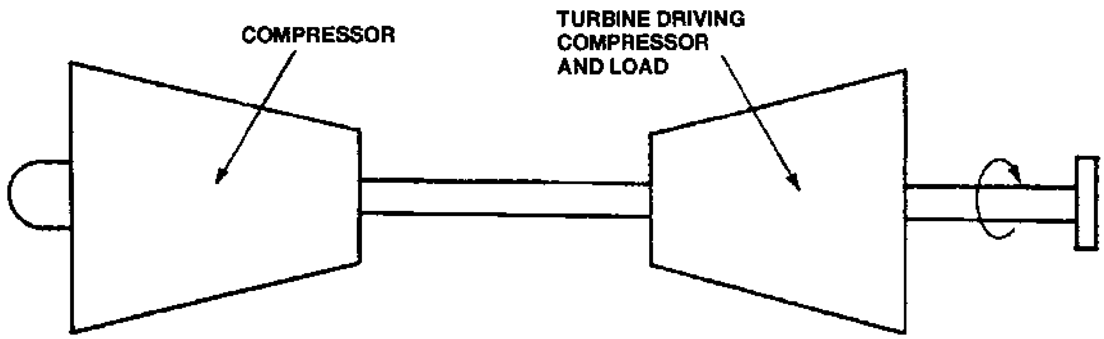

Figure 234-1-10. Coupled Gas Turbine Engine

234-1.4.5.3 Free Turbine. In the free turbine engine, there is no mechanical connection between the gas generator and power turbine shafts. Each shaft is independent of the other, allowing the rotational speed of one to vary independently of the other.

NOTE

Independent shaft operation is especially important for applications where frequent driven unit load or speed changes are required because the independent action allows the gas generator to be operated at its most efficient operating point for any given load.

234-1.4.5.4 Single-spool Gas Generator. The single-spool gas generator consists of a single-compressor high-pressure turbine combination. The compressor and turbine may contain multiple stages but all of the stages are on a single shaft. Figure 234-1-11 illustrates the single-spool free power turbine engine. The numbers in the illustration refer to station designations indicating the gas flow path. The station designations are discussed in paragraphs 234-1.5 through 234-1.5.1.3.

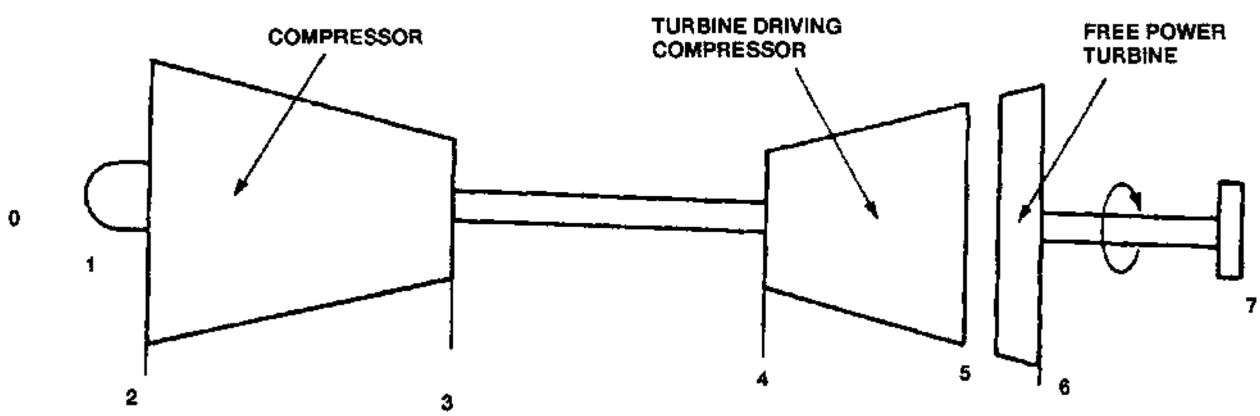

Figure 234-1-11. Single Spool Free Power Turbine Engine

234-1.4.5.5 Multispool Gas Generator. The multi-spool gas generator configuration combines more than one compressor turbine combination, each mounted on independent shafts. The two, or double-spool, gas generator has two mechanically independent compressors, each driven by a separate turbine. The first, or low-pressure compressor, is driven by the second, or low-pressure turbine. The second, or high-pressure compressor, is driven by the first, or high-pressure turbine. In the multi-spool configuration, the low-pressure compressor turbine shaft is located concentrically within the high-pressure shaft. Figure 234-1-12 illustrates the two spool free power turbine engine.

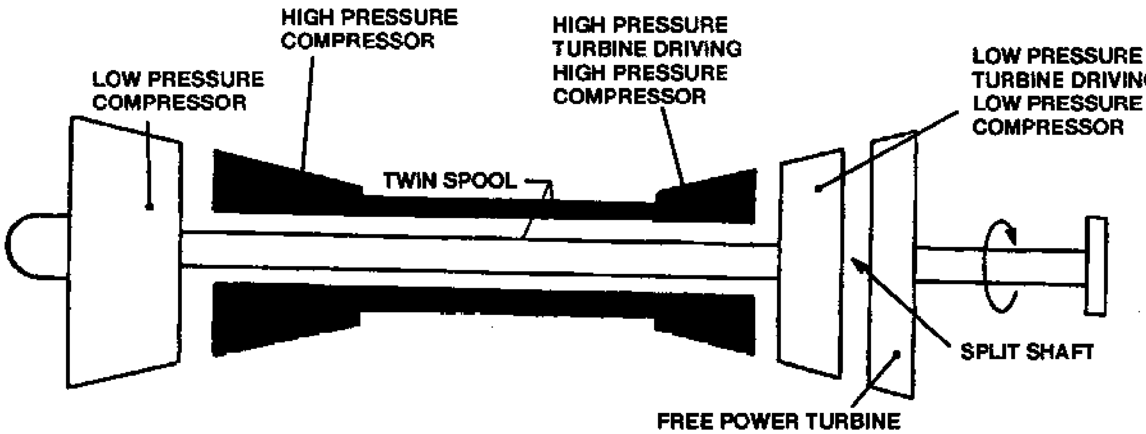

Figure 234-1-12. Two-Spool Free Power Turbine Engine

234-1.5 STATION DESIGNATIONS

234-1.5.1 GENERAL. Station designations are used in gas turbine engine descriptions or calculations to provide a uniform method of identifying specific locations in the gas flow path that are significant to engine performance. The system of station designations provides for the consistent definition of the process being undergone by the gas, regardless of the type of engine cycle. The five main processes isolated are:

a. Air intake

b. Compression in engine compressors

c. Heat addition

d. Expansion in turbines

e. Exhaust

234-1.5.1.1 Assignment of station designators for any specific engine is the sole prerogative of the engine manufacturer.

NOTE

Gas turbine operators should refer to the technical manuals supplied with the engine under their cognizance for the proper station designators.

234-1.5.1.2 For consistency, the station numbers established in **Gas Turbine Engine Performance Station Identification and Nomenclature, Society of Automotive Engineers, Inc., Aerospace Recommended Practice 755A,** are used in this chapter to identify the primary processes for gas flow. The station numbers are:

a. 0 - Free stream air conditions

b. 1 - Inlet or engine interface

c. 2 - First compressor discharge

d. 3 - Last compressor discharge

e. 4 - Burner discharge

f. 5 - High-pressure turbine discharge

g. 6 - Power turbine discharge

h. 7 - Engine to exhaust interface.

234-1.5.1.3 Identification of intermediate stations within a designated primary process is accomplished by the addition of a numeric or alphabetic subdivision. Numbering of stations intermediate to those indicated in paragraph 234-1.5.1.2 are usually limited to two digits which can be chosen to prevent duplication. Intermediate station designators are assigned in an ascending or alphabetic sequence which corresponds to the direction of flow. Figure 234-1-11, discussed in paragraph 234-1.4.5.4, shows application of station numbers to a theoretical engine. Figure 234-1-13 and Figure 234-1-14 are examples of the applications of the station designation system to typical Navy engine configurations.

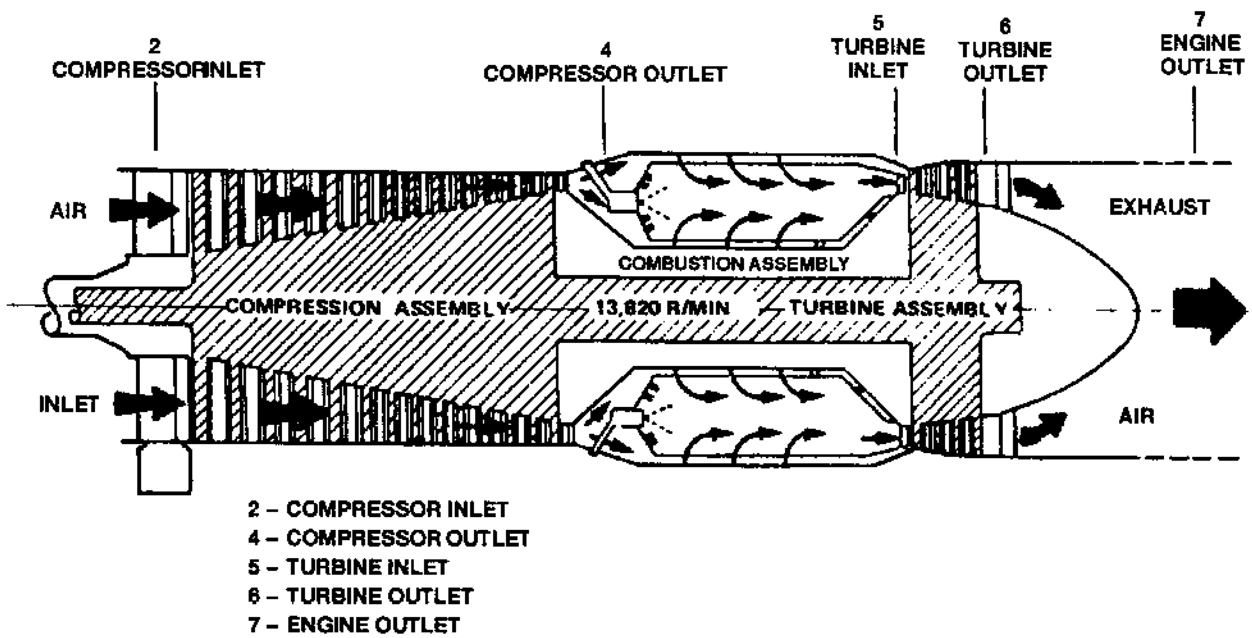

Figure 234-1-13. Schematic of 501-K17 Showing Station Designations

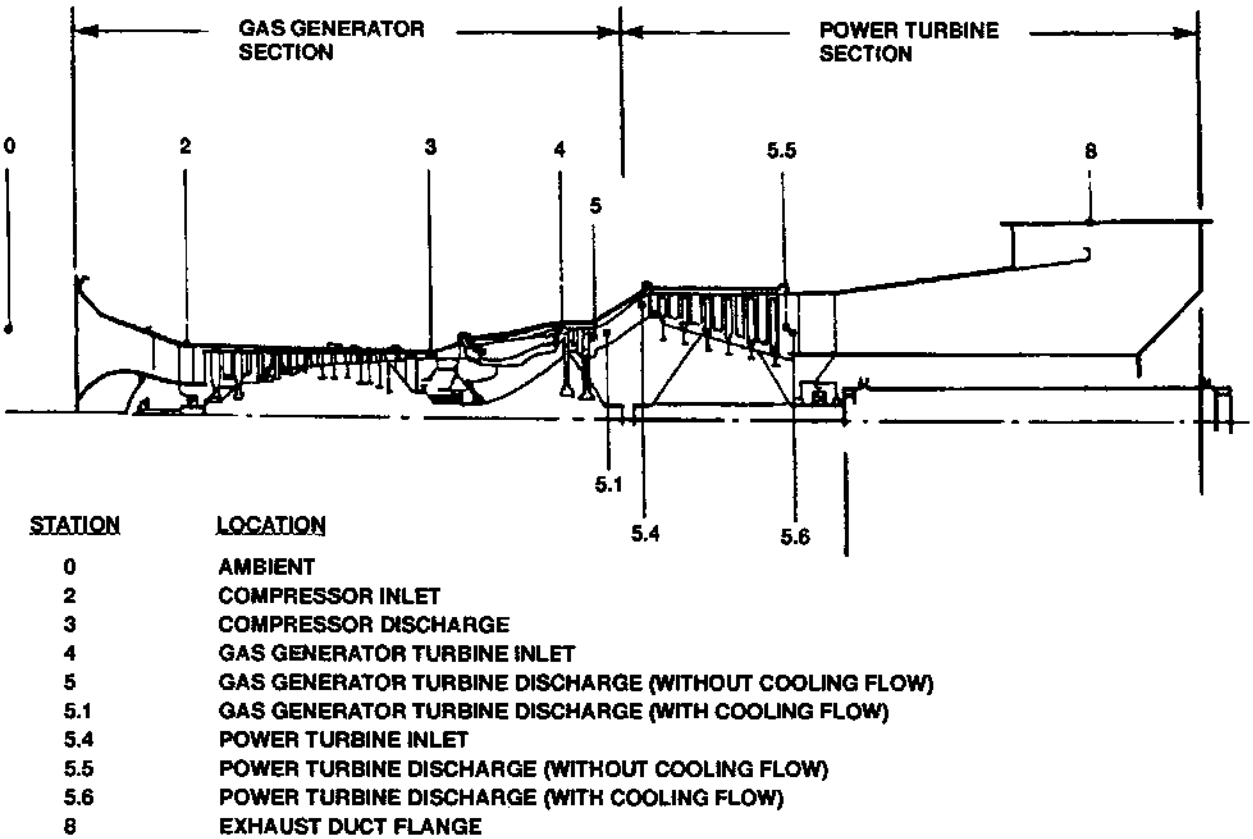

Figure 234-1-14. Schematic of LM 2500 Engine Showing Station Designations

234-1.6 PERFORMANCE PARAMETERS

234-1.6.1 NOMENCLATURE. Table 234-1-1 introduces the nomenclature associated with the gas turbine engine. The intent is to provide a common language for oral and written communications that identify to all concerned the specific item or parameter being discussed. Examples of parameters and their definitions, given to illustrate the need for a common communications language, are listed in Table 234-1-2.

Table 234-1-1. NOMENCLATURE

ABBREVIATION	
Abbreviation	**Definition**
B	Burner
BHP	Brake horsepower (horsepower available to power turbine shaft output flange)
C	Compressor
FAR (W_f /W_a)	Fuel-to-Air Ratio
GG	Gas Generator
HHV	Higher Heating Value (of fuel)
IGV	Inlet Guide Vane
LHV	Lower Heating Valve (of fuel)
N	Rotational Speed
P	Pressure - Absolute
p	Pressure

Table 234-1-1. NOMENCLATURE - Continued

ABBREVIATION	
Abbreviation	**Definition**
PR	Pressure Ratio
PT	Power Turbine
RH	Relative Humidity
SFC	Specific Fuel Consumption
T	Temperature - Absolute
t	Temperature
W	Flow Rate
SUBSCRIPTS	
Subscript	**Definition**
a	Air (gas)
amb	Ambient condition
b	Burner
bl	Bleed
c	Compressor
f	Fuel
g	Gas
h	High-pressure component or rotor
i	Intermediate-pressure component or rotor
l	Low-pressure component or rotor
pt	Power turbine
s	Static
t	Total
SYMBOLS	
Symbol	**Definition**
δ	Delta (ambient pressure to standard sea level pressure)
η	ETA (efficiency)
ϕ	Theta (ambient temperature to standard sea level temperature)
$\surd$	Square root

Table 234-1-2. EXAMPLES OF PARAMETERS

Parameter	Definition
W_f	Fuel mass flow rate
N_{gg}	Rotational speed of the high-pressure gas generator (single-spool engine)
T_4	Burner discharge total temperature (total temperature at engine station 4)
T_5	High-pressure turbine discharge temperature
W_g 7	Gas flow rate at the engine exhaust
C_{pr}	Compressor overall pressure ratio

234-1.6.2 PERFORMANCE TREND ANALYSIS. Performance trend analysis takes into consideration both gas turbine ratings and standard day conditions. Ratings and day conditions are discussed in paragraphs 234-1.6.3 through 234-1.6.4.1.

234-1.6.3 RATINGS. Gas turbine engines are rated at certain power levels associated usually with time-at-temperature or output shaft torque limitations. The exact names assigned to a given rating and the time-at-rating limitations vary from engine to engine. Manufacturer's technical manuals should be consulted for exact rating names and time-at-rating or torque limitations for the specific model of engine to which assigned.

234-1.6.3.1 Table 234-1-3 gives examples of common rating points for gas turbines. The normal rating for auxiliary drive gas turbines would correspond to the normal continuous rating defined in this table and the emergency rating would correspond to the maximum continuous rating defined in the table.

Table 234-1-3. TYPICAL GAS TURBINE RATINGS

Rating	Definition
Normal Continuous[1]	Normal continuous is the rating at which the engine can be operated continuously while providing long life and high reliability.
Maximum Continuous[2]	Maximum continuous is the boost rating. Continuous use is permitted (up to several hours daily) but the expected life is reduced to 2/3 to 4/5 of that anticipated with the normal continuous rating.
Maximum Intermittent[2]	Maximum Intermittent is a burst rating permissible only for short periods of time. Engine life should not be seriously reduced if operation at this rating is limited to no more than 5 percent of the time.

234-1.6.4 STANDARD CONDITION. To permit comparison of gas turbine performance with baseline data and with other engines, specific standard rating conditions have been established. The manufacturer's technical manuals should be consulted to define the condition at which an engine is rated before attempting to calculate or compare the performance of that engine.

234-1.6.4.1 The International Standards Atmosphere (ISA) Standard Day is used for commercial and aircraft applications, and the Navy Standard Day is used for Navy marine engines. Navy Standard Day conditions are listed in Table 234-1-4.

NOTE

Note: The abbreviations, symbols, and subscripts listed in this table, and station designations discussed in paragraphs 234-1.5 through 234-1.5.1.3 are used in combination to define specific parameters associated with gas turbine engines. The combinations used designate a specific parameter in the engine cycle.

NOTE

Note: The abbreviations, symbols, and subscripts listed in this table, and station designations discussed in paragraphs 234-1.5 through 234-1.5.1.3 are used in combination to define specific parameters associated with gas turbine engines. The combinations used designate a specific parameter in the engine cycle.

Table 234-1-4. NAVY STANDARD DAY CONDITIONS

(1) Altitude	Sea Level
(2) Ambient Pressure (absolute)	(14.7 lb/in^2 a) 29.92 Hg absolute
(3) Ambient Temperature	37.8°C (100°F)
(4) Relative Humidity	Zero

Table 234-1-4. NAVY STANDARD DAY CONDITIONS - Continued

(5) Fuel Lower Heating Value	18,400 BTU/lb
(6) Installation Losses: (a) Inlet Pressure Loss (b) Exit Pressure Loss (c) Power Extraction	 4 in H_2 O 6 in H_2 O Zero

SECTION 2

OPERATION

234-2.1 STARTING PROCEDURE

WARNING

Do not operate any gas turbine engine without reading the appropriate manufacturer's and shipbuilder's operating manuals on the specific model of engine to be run.

234-2.1.1 General. Proper starting of any gas turbine engine is essential to ensure personal safety and effective engine performance. The procedural steps which are essential to proper starting are described in paragraphs 234-2.2 through 234-2.4.1.

234-2.2 AUXILIARY SYSTEM CHECKS.

The procedural steps for prestart, and starting gas turbines should periodically be performed for all installations. Accomplishment of the precautionary checks will ensure successful, safe starts.

234-2.2.1 Prior to starting a gas turbine, the prestart checklist should be used to ensure the engine is ready to be started. The checklist is:

a. Visually inspect engine inlet area for any foreign matter, lube oil, or fuel oil contaminations.

b. Check periodically, in compliance with appropriate Planned Maintenance System (PMS) documentation, the protective screening in the inlet plenum for any damaged areas that might jeopardize it.

c. For both the fuel and lube oil systems, check supply tank level, inspect filters and strainers, clean or replace elements as required, check leak integrity of the systems, and correct deficiencies where necessary. Align fuel and lube oil systems for engine operation.

d. Visually inspect all drains in inlet and exhaust ducting to ensure they are clear.

e. Check lube oil cooling system to determine proper operational condition.

f. Check charge status of batteries (used for engine starting or as the source of power for engine accessories).

g. If compressed air or hydraulic fluid is used as the starting media, ensure that an adequate supply is available. Align starting system for engine starts.

h. Check electrical connections for tightness, corrosion, and condition of insulation. Replace where required.

i. Verify that fuel oil, lube oil, and air systems are aligned and correct pressures are available for each system.

CAUTION

When starting a gas turbine, temperature gages shall be closely observed. Turbine exhaust temperature while starting may be higher than normal

operating temperatures. Starting temperature limits and maximum operating temperature limits given in the manufacturer's operating manuals must not be exceeded.

234-2.3 AUTOMATIC START SEQUENCES.

Many gas turbine installations are equipped with an automatic start sequencer. The automatic start sequencer is a small logic circuit, located in the engine circuitry, which systematically conducts the start procedures. The sequencer is provided with a feedback system that monitors engine operating parameters during the start attempt. The sequencer feedback system will abort the starting sequence if designated engine operating parameters should fall outside accepted limits.

234-2.4 MANUAL START SEQUENCE.

A condensed DDG 51 LM 2500 gas turbine starting procedure is listed in paragraph 234-2.4.1. While this is typical of starting procedures for marine engines, the manufacturer's manuals should be consulted for exact procedures.

CAUTION

When starting a gas turbine, the temperature gages shall be closely observed. The turbine exhaust temperature, while starting, may be higher than normal operating temperatures. Starting temperature limits and maximum operating temperature limits given in the manufacturer's operating manuals must not be exceeded.

234-2.4.1 The manual start sequence is:

1. Close enclosure door and hatch, if installed
2. Activate the fire extinguisher medium inhibit switch.
3. Turn on power to electronic enclosure.
4. Turn on electronic enclosure power switch.
5. Turn on fuel shutdown valve power switch.
6. Reset overspeed switch.
7. Turn off ignition.
8. Open ventilation damper, start cooling air.
9. Check ventilation exit air temperature limit.
10. Visually inspect oil tank level.
11. Check heat exchanger coolant inlet pressure and/or temperature.
12. Close fuel shutdown valves.
13. Close starter regulator/shutoff valve.

14. Check starter regulator/shutoff valve inlet medium pressure.
15. Position power level angle (PLA) actuator at idle.
16. Close bleed air valve.
17. Turn off ship water wash valve.
18. Check fuel inlet pressure and/or temperature.
19. Open start air shutoff valve.
20. At starting rpm - N_{gg}
    a. Turn on ignition.

CAUTION

If turbine inlet temperature (TIT) rapidly approaches or exceeds manufacturer's specified start temperature, abort start. A start may be aborted at any time by closing fuel shutdown valves, allowing gas generator to motor for 60 seconds, then closing starter shutoff valve.

    b. Open fuel shutdown valves.
    c. Note time to light-off. TIT will increase rapidly above 204°C (400°F). If engine does not light off or TIT exceeds limit, abort start.

CAUTION

Shut down engine and take appropriate corrective action if N_{gg} rpm stops accelerating or it takes longer than 60 seconds to reach idle speed.

21. At idle N_{gg} rpm
    a. Start shutoff valve should automatically close.
    b. Switch off ignition.
    c. Check oil pressure against limits.
22. At idle, use a checklist to ensure that engine is within normal operating limits. If not, shut down engine and refer to operating or maintenance manual for appropriate actions. Check:
    a. Oil pressure
    b. Fuel manifold pressure
    c. N_{gg}
    d. Power turbine inlet temperature
    e. N_{pt} with clutch and brake disengaged
    f. Gas generator vibration
    g. Power turbine vibration
    h. Lube oil heat exchanger outlet temperature
    i. Scavenge oil temperature
    j. Ventilation exit air temperature
    k. T_2

234-2.5 ABNORMAL STARTS.

Abnormal starts are defined as starts that do not result in smooth engine light-off and run-up, from starter initiation to compressor idle speed. Abnormal starts should be aborted. The two major abnormal starts, hot and hung starts, are described in paragraphs 234-2.6 through 234-2.7.

234-2.6 HOT START.

If combustion chambers are not completely drained following engine shutdown, fuel will collect in the bottom. Once the starter is engaged and air is forced through the combustion chamber, the accumulated fuel atomizes and ignites when ignition is turned on. Ignition causes an uncontrolled explosion in the combustion chamber which can damage the liner and nozzle.

234-2.6.1 In case of hot start, shut down engine operation completely until a comprehensive check of the engine combustion chamber and turbines can be accomplished.

234-2.7 HUNG START.

A hung start occurs when the gas generator rpm fails to accelerate following combustor light-off, or it takes longer than 60 seconds for the gas generator to accelerate from firing rpm to idle. In the event of a hung start, the start attempt should be aborted and appropriate corrective action taken.

234-2.8 STOP PROCEDURES

234-2.8.1 AUTOMATIC STOP SEQUENCES. The stop sequence is a continuation of the logic functions discussed in conjunction with the start sequence. The stop sequence uses the same engine parameter feedback system as in starting, monitoring and controlling selected performance parameters during the shutdown.

234-2.8.2 NORMAL MANUAL SHUTDOWN. A condensed form of the normal shutdown for the LM 2500 engines on the DDG 51 class is presented in paragraph 234-2.8.2.1. Not all of the steps will be applicable to every engine, but they are representative of at least one high population fleet engine. The manufacturer's technical manual should be consulted for the specific steps required for a particular engine.

234-2.8.2.1 The condensed normal shutdown sequence is:

1. Set gas turbine at idle power and ensure power turbine clutch (where installed) is disengaged.
2. Allow the engine to stabilize at idle for 5 minutes.
3. Close fuel shutdown valves.
4. Observe power turbine inlet temperature for manufacturer-designated time period after shutdown.

NOTE

If power turbine inlet temperature has not decreased below manufacturer's specified limit after designated time interval, motor engine on starter and continue motoring until temperature drops below limiting value.

5. If outside air temperature is below 10°C (50°F), shut off ventilation fan and close damper. If above 10°C (50°F), operate fan for a minimum of 10 additional minutes after stabilizing at idle for 5 minutes.

6. If gas turbine is to be shut down for an extended period, power switch in electronic enclosure may be turned off.

234-2.8.3 WATERWASH AFTER SHUTDOWN. Because of the salt laden air in which they operate, marine gas turbines must frequently be cleaned to prevent performance loss from salt or other contaminants deposited on the compressor blades. To prevent contaminant deposits, waterwashing of the compressor should be done at regular intervals in accordance with PMS requirements.

234-2.8.3.1 Distilled/Deionized water with the approved MIL-C-85704/QPL-85704–8 detergent should be used for normal cleaning. Operate the engine about 5 minutes after washing, to remove all liquid. Visually check all drains. The detailed waterwash procedure is discussed in paragraph 234-5.6.2.

234-2.9 EMERGENCY SHUTDOWN

234-2.9.1 MANUAL SHUTDOWN. Emergency shutdown procedures shall not be used except in case of emergency or catastrophic engine failure. Once an engine has been shut down under the emergency procedure, do not attempt to operate the engine until a thorough inspection of the engine has been made and cause of the failure has been identified and corrected. Components of the hot section should be examined and appropriate corrective action taken if metal distortion or heat stress cracks are identified.

234-2.9.1.1 Emergency shutdown procedures are the same as the normal shutdown procedures described in paragraphs 234-2.8 through 234-2.8.3.1 with the exception that steps 1 and 2, described in paragraph 234-2.8.2.1, are waived. If conditions permit, it is advisable to decrease the engine power level to idle prior to closing the fuel shutdown valves.

234-2.9.2 AUTOMATIC SHUTDOWNS. Most gas turbine engines are equipped with three primary automatic shutdown systems. These systems consist of sensors, feedback circuits, and electronic solenoids which activate shutoff valves in the engine fuel system. If the sensors detect variation in engine operation above predefined limits, the automatic shutdown system is activated, resulting in shutdown of fuel to the engine.

234-2.9.3 OVERSPEED TRIP. The power turbine shaft is equipped with an overspeed trip. In the event of power turbine overspeed, the overspeed governor will sense the shaft speed and activate the power turbine overspeed switch when the speed reaches a preset limit. The overspeed switch controls power to the fuel shutoff valve. Activation of the switch will deenergize the valve resulting in a shutdown of the fuel to the engine.

234-2.9.4 VIBRATION TRIP. In most applications both the gas generator and shafts are equipped with vibration sensors to detect vibrations above a preset level which will deenergize the fuel shutoff valve, and shut down fuel flow to the engine. On some engines, an alarm will sound before vibration levels reach the preset limit.

234-2.9.5 LOW LUBE OIL TRIP. Emergency shutdown will occur if lube oil pressure drops below a defined value. As with the other trips, this switch will deenergize the fuel shutoff valve and the engine will shut down.

234-2.10 NORMAL OPERATION

234-2.10.1 The mechanism by which command signals are transmitted from the ship to the engine is the throttle control lever (TCL) usually located both on the bridge and on the propulsion control console in the central control station.

234-2.10.2 The TCL is a hand-operated throttle usually graduated in increments of rpm or percents of normal rating. For normal cruising operations, the TCL is set and left in desired position. Internal engine controls will regulate fuel flow, and gas generator and power turbine speeds to comply with the TCL command signal. Procedures for low-power cruising vary according to the application (see paragraphs 234-2.11.6 and 234-2.11.6.1).

NOTE

Ship operation manuals should be consulted for low-power operating procedures.

234-2.10.3 No engine warmup time is required for most gas turbine engines prior to application of load. A check, however, should be made of instrumentation to determine if the engine is operating properly during starting and before application of load.

234-2.11 OPERATIONAL LIMITS AND OVERRIDES

234-2.11.1 GENERAL. To ensure maximum life and operational performance of a gas turbine, several mechanical and gas path parameters must be monitored so predefined limits are not exceeded. The manual start sequence described in paragraphs 234-2.4 and 234-2.4.1 summarizes the parameters that usually must be operator-monitored. Appropriate technical documentation should be consulted for the exact parameters to be monitored and for the limiting values (maximum and minimum) associated with each parameter. Under normal circumstances these limits should not be exceeded.

234-2.11.2 OPERATING LIMITS. The operating limits are described in paragraphs 234-2.11.3 through 234-2.11.8.

234-2.11.3 TEMPERATURE. Operating a gas turbine above the maximum allowable gas temperature can result in severe damage to the combustors and turbines, so temperature limits must be carefully observed. When temperatures in excess of the limits are observed, the manufacturer's instructional manual should be consulted for appropriate action. To ensure accuracy of temperature readings, it is mandatory that thermocouples and other temperature-sensing devices be kept clean and properly calibrated.

234-2.11.4 ROTATING SPEEDS. Care must be taken to maintain engine operating speeds within allowable limits. Tachometers should be calibrated periodically to ensure accuracy within specified limits. If speed limits have been exceeded, the manufacturer's instruction manual should be consulted for appropriate action.

234-2.11.5 NORMAL AND EMERGENCY RATINGS. Normal rating is the maximum permissible shaft horsepower for which the engine is designed to operate continuously. Some gas turbines have an emergency or intermittent rating. If the turbine is operated at these ratings, limitations and precautions specified in the technical manuals must be adhered to.

234-2.11.6 LOW-POWER OPERATION. Gas turbine engines are designed to achieve optimum fuel economy (lowest specific fuel consumption rate) at their full-power or cruise ratings. Below these levels, the engine fuel consumption and horsepower produced increases dramatically as the load is reduced. If two or more engines are coupled to a single gear and it is possible to declutch each engine, both engines should not be operated simultaneously if one engine at its normal rating or less could support the load.

234-2.11.6.1 In such an instance, a single engine should assume the load and the other engine should be declutched and shut down. This will provide the best operation and engine life because, in addition to improving fuel economy, it can help prevent excessive carbon buildup, resulting from low-power operation, in the combustion chambers.

NOTE

Single-engine operation, of course, is subject to ship operational and safety considerations that may dictate two-engine operation.

234-2.11.7 VIBRATION LIMITS. Vibration meters, where installed, must be monitored for signs of abnormal engine operation. Abnormal operation is an indication of engine malfunctioning and usually can be traced to an imbalance in the engine rotor system. Refer to manufacturers' technical manuals for maximum vibration limits and corrective actions.

234-2.11.7.1 If any vibration limit is exceeded, the engine shall be immediately shut down and the cause investigated.

234-2.11.8 TORQUE. Some engines are provided with a torque computer. The computer calculates the torque applied to the engine output shaft. This parameter is monitored and compared to a torque limit point. If the limit is exceeded, a signal varies the engine-mounted controls to reduce fuel flow to the engine. Table 234-2-1 summarizes normally limited gas turbine parameters.

Table 234-2-1. NORMALLY LIMITED GAS TURBINE PARAMETERS

Item	Limit
Starter	Maximum time limit for start cycle Maximum time limit for gas generator motoring
Ignition Cycle	Maximum time limit for activation
Starting Cycle (a) Light-off (b) N_{gg} Speed to idle	 Maximum time limit to light-off after initiation of ignition and fuel Maximum time limit following light-off for N_{gg} to reach idle rpm
Torque	Maximum steady state and transient torque
Power Rating	Maximum
Gas Generator Speed	Maximum N_{gg} rpm
Power Turbine Speed	Maximum N_{pt} rpm
Power Turbine Inlet Temperature	Maximum limit
Fuel System	Maximum and minimum temperature and pressure limits
Lubricating Oil System	Maximum and minimum temperature and pressure limits
Vibration	Maximum limit for gas generator and power turbine shafts
Compressor Discharge Pressure (P_3)	Maximum limit

234-2.11.9 OVERRIDES. Certain gas turbine installations are equipped with a battle override device. Activation of the battle override device will deactivate some of the engine-mount limiting devices, such as automatic torque limit and speed limiting governors.

234-2.11.9.1 Activation of the battle override should be accomplished only at times when ship survivability is in question. Following engine operation in the battle override mode, the engine should be shut down, conditions permitting, and a thorough maintenance check performed.

NOTE

Personnel should specifically consult the engine manufacturer's operational manual for the override limitations, and recommended postoperational inspection for each engine application in question.

SECTION 3

SUPPORT SYSTEMS

234-3.1 CONTROL AND INSTRUMENTATION

234-3.1.1 CONTROLS. Types of controls for gas turbines vary from manual to fully automatic. Most controls are designed to operate automatically but are provided with manual overrides. Controls for gas turbines are usually complex, and any adjustments to them should not be made unless personnel are thoroughly knowledgeable about each control component.

234-3.1.1.1 Gas turbine engines are equipped with three controls as a minimum. They are:

a. Fuel control governing system (engine-mounted)

b. Power turbine topping speed governor

c. Power turbine overspeed trip switch.

234-3.1.1.2 The additional optional controls may be utilized in specific applications:

a. Automatic, remote start, stop, and power control

b. Automatic, local start, stop, and power control

c. Manual, remote start, stop, and power control

d. Manual, local start, stop, and power control

e. Automatic and manual control of bleed air, waterwash, and electrical systems.

234-3.1.2 INSTRUMENTATION. Gas turbines are furnished with instrumentation necessary to provide both operator and automatic controller devices with necessary information:

a. Data to allow ship controls to monitor for safe and proper operation

b. Indication of need to perform maintenance procedures

c. Data for maintenance troubleshooting.

234-3.1.2.1 Instrumentation is provided for all gas turbine installations. As an example, detailed typical instrumentation on the LM 2500 engines installed in the DDG51 Class destroyers and FFG-7 Class guided missile frigates is:

a. Pressure, compressor inlet, total (P_2)

b. Pressure, power turbine inlet, total ($P_{5.4}$)

c. Pressure, differential, fuel filter

d. Pressure, lube oil supply static (P_1) and fuel oil supply static (P_f)

e. Vibration, gas generator (V_{gg})

f. Vibration, power turbine (V_{pt})
g. Speed, gas generator rotational (N_{gg}) (1 magnetic pickup type sensor)
h. Speed, power turbine rotational (N_{pt}) (2 magnetic pickup type sensors)
i. Overspeed, power turbine
j. Overspeed, starter
k. Temperature, compressor inlet total (T_2)
l. Temperature, power turbine inlet total ($T_{5.4}$)
m. Temperature, L.O. scavenge (T_{1s}) (four individual bearing sumps and one transfer gearbox sump signal)
n. Position, power lever angle (PLA) at idle (switch)
o. Position, PLA actuator
p. Test, torque computer passed
q. Horsepower, power turbine output
r. Torque, power turbine output
s. Overtorque, power turbine alarm
t. Fuel supply temperature and low alarm
u. LOSCA lube oil tank level alarms (high and low)
v. Lube oil cooler outlet temperature and high alarm
w. Cooling air outlet temperature
x. Fuel filter differential pressure high alarm
y. Lube oil scavenge filter differential pressure and high alarm
z. Lube oil supply filter differential pressure high alarm
aa. Fire detector failure alarm
ab. Power turbine tachometer loss alarm
ac. Bleed air valve position (open/close)
ad. Module fire alarm
ae. Cooling fan differential pressure (used for cooling system failure alarm and associated automatic shutdown)
af. Vent damper position (open/close)
ag. Cooling fan on/off
ah. Starter air on/off
ai. Igniter on/off
aj. Fuel valves open/closed
ak. Fuel purge valve open/closed
al. Compressor discharge pressure (static)
am. Fuel manifold pressure

an. Starter air temperature and high alarm

ao. Module CO_2 release alarm and inhibit indicator.

ap. Icing conditions alarm

234-3.2 GAS TURBINE FUEL OIL SYSTEM

WARNING

Never enter a gas turbine engine module to perform maintenance on fuel oil system components while the engine is in operation. Consult appropriate documentation for fuel oil system maintenance actions.

234-3.2.1 GAS TURBINE FUEL PREFERENCE. Specifications for the use of fuel oil in Marine Gas Turbines are delineated in paragraphs 234–3.2.2 through 234–3.2.2.12. The information contained herein provides guidance for the capability of, and the effects on, Marine Gas Turbines of various available fuel oils. See **NSTM Chapter 541** for more guidance in regard to fuel authorization.

CAUTION

Users are cautioned to consult manufacturer's literature as to the necessity to adjust fuel controls for specific gravity variation when switching from one type of fuel to another.

234-3.2.2 GAS TURBINE ORDER OF FUEL PREFERENCE. Fuel should be procured in the following order of preference: primary fuel, acceptable substitute fuels, and emergency substitute fuels. The definitions of these fuel preferences are provided in the following paragraphs.

234-3.2.2.1 Gas Turbine Primary Fuel. The primary fuel for use in marine gas turbine engines of the United States Navy is NATO F-76, conforming to Military Specification MIL-F-16884, **Fuel, Naval Distillate** .

CAUTION

F-76 shall not be confused with commercial fuels such as those marketed as Marine Diesel Fuel because these type of fuels may contain residual (black) fuel. Fuel oils containing any residual fuel are unacceptable for use in marine gas turbines.

CAUTION

When accidental mixing with unacceptable fuels occurs, all fuel tanks, strainers, filters and piping must be thoroughly cleaned and flushed with clean fuel oil as soon as possible. As little as 10 ppm by volume of residual fuel mixed with acceptable gas turbine fuels will completely destroy the effectiveness of coalescent filter elements.

CAUTION

When practical, fuel oil received should be sampled and tested by a competent laboratory to ensure conformance with specification requirements and to determine freedom from contamination.

234-3.2.2.2 Gas Turbine Acceptable Substitute Fuels. The NATO definition of an acceptable substitute fuel product is one that may be used in place of another produce for extended periods of time without technical advice. The authorized acceptable substitute fuels for F-76, in order of preference, are:

1. JP-5 (NATO F-44), conforming to MIL-DTL-5624, **Turbine Fuel, Aviation** . The free interchangeability of mixing or using JP-5 fuel is acceptable, although the applicable manufacturer's technical manual and **NSTM Chapter 541** should be consulted to ensure that there are no restrictions on interchangeability.

CAUTION

There are two points of caution when switching to JP-5. First, JP-5 has a tendency to loosen scale from fuel tanks and piping if it is present. Initial operation may produce a higher than normal accumulation of dirt in the fuel system strainers and filters.

Second, the use of JP-5 may increase fuel consumption by approximately 2 percent on a volume basis.

2. NATO F-75 Fuel, Naval Distillate, Low Pour Point. See **NSTM Chapter 541** , paragraph 541–10.2 for additional discussion about this fuel. The U.S. has no fuel specification that conforms to NATO F-75. Fuels designated F-76 and F-75 are compatible and can be blended in all proportions.

3. Fuel oil (100–percent distillate, no residual) procured under a Defense Energy Support Center (DESC) bunker contract, complying with the following NAVSEASYSCOM's purchase description.

CAUTION

The DESC bunker contract fuel specification requirements does not have a storage stability requirement as does the MIL-F-16884 Specification and therefore is NOT considered an acceptable substitute for applications which

Caution - *precedes*

involve long-term storage (6 weeks or greater) and, hence, must be used immediately when taken onboard. See NSTM Chapter 541 , paragraph 541–10.4.3.

The fuel referenced in this paragraph meets the following specification limits:

a.	Viscosity @ 40 °C	1.7-4.5 cSt
b.	Cloud Point	-1.1 °C, max
c.	Flash Point	60 °C, min
d.	Sulfur	1.0 wt %, max
e.	Carbon Residue, on 10 % bottoms	0.35 wt %, max
f.	Appearance @ 21 °C or ambient temp., whichever is higher, or	Clear & Bright
	Water & Sediment	0.05%, max
g.	Ash	0.01 wt %, max
h.	Copper Corrosion	3, max
i.	Distillation, 90% point	357 °C, max
j.	Cetane Number, or	42, min
	Cetane Index	43, min
k.	Color	3, max
l.	Density @ 15 °C	876 kg/m^3 , max
m.	Distillate Fuel no residual	100%

234-3.2.2.3 DESC Bunker Contract Fuel Suppliers. Sources of DESC bunker contract fuel suppliers are listed in NAVPETOFFINST 4290.1 entitled “Commercial Contracts for Bunker Fuel” (see paragraph 541–10.6.4). Fuel can be procured under national stock numbers 9140–01–313–7776 (domestic) and 9140–01–417–6843 (overseas).

234-3.2.2.4 Particulate Matter in DESC Fuel. DESC bunker contract fuel can potentially have an increased level of particulate matter entrained in the fuel. This may lead to higher fuel filter usage rates.

234-3.2.2.5 Carbon Residue in DESC Fuel. DESC bunker contract fuel has a higher carbon residue specification limit than that defined in MIL-F-16884 for F-76. Long term usage will result in an increased level of carbon and soot deposition in the combustor and turbine sections of the gas turbine.

234-3.2.2.6 Gas Turbine Emergency Substitute Fuels. The NATO definition for an emergency substitute fuel is one that may be used in an emergency, in place of another product, after local exploration of the adequacy of the product, using locally available technical manuals and personnel. See **NSTM Chapter 541** for restrictions on the use of these fuels. The allowable emergency substitute fuels, in order of preference, follow.

WARNING

All fuels accepted onboard shall meet a minimum 60°C (140°F) flash point. See NSTM Chapter 541 , Paragraph 541–10.4.4.

CAUTION

No fuel shall be taken onboard that exceeds 1.0 wt% sulfur despite the limit given in any specification of the list of allowable emergency substitute fuels given below.

1. **NATO F-54 Commercial Item Description (CID) A-A-52557 Fuel Oil, Diesel for Posts, Camps, and Stations, Grade DF-2**
2. **ASTM D 975; Diesel Fuel Oil, Grade 2–D**
3. **ASTM D 396; Grade 2**
4. **ASTM D 2880; Gas Turbine Fuel Oils, No. 2–GT**
5. **ASTM D 2069; Marine Distillate, Grade DMA**
6. **ISO 8217; Marine Distillate, Grade DMA**
7. **ISO 4261; Marine Distillate, Grade DMT.2**
8. **open fuel purchase; fuel from a commercial supplier NOT under a DESC bunker contract (local purchase); 100–percent distillate, no residual.**

234-3.2.2.7 Fuel Dye. Currently, the use of red dye in marine gas turbine fuel has not been proven harmful or benign to a marine gas turbine engine. Until definitive data is available, limited operation with red dye is acceptable. Operation with red dye at levels above 18–20 ppm, max, is not desirable. Any other dyes, e.g., blue, or black, are not acceptable for shipboard use.

234-3.2.2.8 Fuel Quality Maintenance Effects. Fuel quality can vary from batch to batch for numerous reasons. Certain specific requirements that are either at or exceed the MIL-F-16884 specification limit can increase the required maintenance in certain areas of the marine gas turbine engine. Examples of these fuel properties, which impact gas turbine maintenance, are defined in paragraphs 234–3.2.2.8.1 through 234–3.2.2.8.6 below.

234-3.2.2.8.1 Trace Metal Content. Trace metal content in fuel oils accelerates the deterioration of a gas turbine's hot section. Trace metal content, for this reason is limited by the requirements in MIL-F-16884 (calcium: 1.0 ppm (max), sodium-plus-potassium: 1.0 ppm (max), lead: 0.5 ppm (max), and vanadium: 0.5 ppm (max)). Trace metal content is not identified as a purchase requirement for fuel purchased under the DESC bunker contract. However, ensuring that the fuel accepted under the bunker contract is 100–percent distillate, with no residual, does significantly reduce the risk of trace metal contamination.

234-3.2.2.8.2 Sulfur. The use of high sulfur fuel oils exceeding the MIL-F-16884 limit of 1.0–wt% can accelerate hot corrosion in the gas turbine combustor and turbine sections. The potential damage due to high sulfur fuel increases as the amount of salt ingested with the inlet air increases. The sulfur level for fuel procured under the DESC bunker contract is identical to the permissible sulfur level in MIL-F-16884, and should therefore not be of any additional risk.

234-3.2.2.8.3 Carbon Residue. The use of fuels with high carbon residue content (exceeding the MIL-F-16884 limit of 0.20 wt%) can accelerate the deposition of carbon on the fuel nozzles, combustors and turbines. This can lead to starting problems, minor performance loss, possible turbine imbalance if deposition on the turbine is severe and increased combustor and fuel nozzle maintenance. The increased amount of carbon particles in the combustion gas also results in an increased radiation emissivity that increases liner wall temperatures and hence decreases liner life. The carbon residue specification limit for fuel procured under the DESC bunker contract (0.35 wt%) exceeds the limit of MIL-F-16884. Any liner life reduction or increased carbon deposition is difficult to predict as it is in part a function of the liner and fuel nozzle to naturally generate carbon deposition when burning fuel in accordance with MIL-F-16884. There will probably be less of any impact from this on the LM2500 gas turbine than other current marine gas turbines because of the historic lack of combustion problems with the LM2500. It can be anticipated that prolonged use of fuel procured under the DESC bunker contract will have an impact on the life of the 501 and TF40B gas turbine combustors and fuel nozzles because of the increased susceptibility of the combustion sections in these engines to fuel quality.

234-3.2.2.8.4 Hydrogen Content. Hydrogen content is in part a measure of the propensity of the fuel to emit smoke when burning. Higher hydrogen content fuels emit less smoke than lower hydrogen content fuels. Fuel procured under the DESC bunker contract does not have a hydrogen content requirement, therefore there may be a slight increase in the smoke emitted by the gas turbine if the hydrogen content is lower than that specified by MIL-F-16884 (12.5 wt% (min)).

234-3.2.2.8.5 Ash Content. Ash content is a measure of fuel cleanliness and potential for hot section corrosion and erosion. It is indirectly a measure of the potential for a fuel to contain trace metals. Fuel procured under the DESC bunker contract has an ash content requirement that is double that allowed in MIL-F-16884 (0.01 wt% (max) and 0.005 wt% (max), respectively). An increase in hot section maintenance is a potential outcome (i.e. long term airfoil and combustor corrosion and erosion).

234-3.2.2.8.6 BS & W Content. Fuel procured under the DESC bunker contract has a higher BS&W limit than the limits of MIL-F-16884. The use of fuel exceeding the limits of MIL-F-16884 may cause increased purifier and filter/coalescer maintenance.

234-3.2.2.9 Diesel fuel referred to as ARCTIC GRADE and other grades under VV-F-800 are not recommended for use in naval shipboard gas turbines because specifications allow a flashpoint below the 60°C (140°F) minimum and constitute a fire or explosion hazard. The use of JP-5 fuel will usually increase fuel consumption by approximately 2 percent on a volume basis.

234-3.2.2.10 Bunker fuel oils such as Navy Special Fuel Oil and Navy Fuel Oil Grade Heavy are not suitable for use in gas turbines.

CAUTION

Diesel fuel oil and bunker fuel oils must not be mixed and used as diesel fuel oil in gas turbines.

234-3.2.2.11 When accidential fuel mixing or contamination of fuel tanks occurs, all tanks, strainers, and liners must be thoroughly cleaned and flushed with clean fuel as soon as possible. As little as 10 ppm by volume of Navy Special Fuel Oil mixed with diesel fuel will completely destroy the effectiveness of coalescent filter elements.

234-3.2.2.12 When practical, diesel fuel oil received should be sampled and tested by a competent laboratory to ensure conformance with specification requirements and to determine freedom from contamination.

234-3.2.3 SYSTEM DESCRIPTION. Figure 234–3–1 presents the fuel system of the LM 2500 engine, which is typical of an engine-mounted integral liquid fuel system. Fuel from the ship supply flows to the fuel pump boost element. From the boost element, fuel passes through a barrier screen to the pump high-pressure element. From the high-pressure element, fuel passes through a pump-mounted filter to the fuel control. A filter bypass relief valve allows fuel to bypass the filter if the filter becomes clogged.

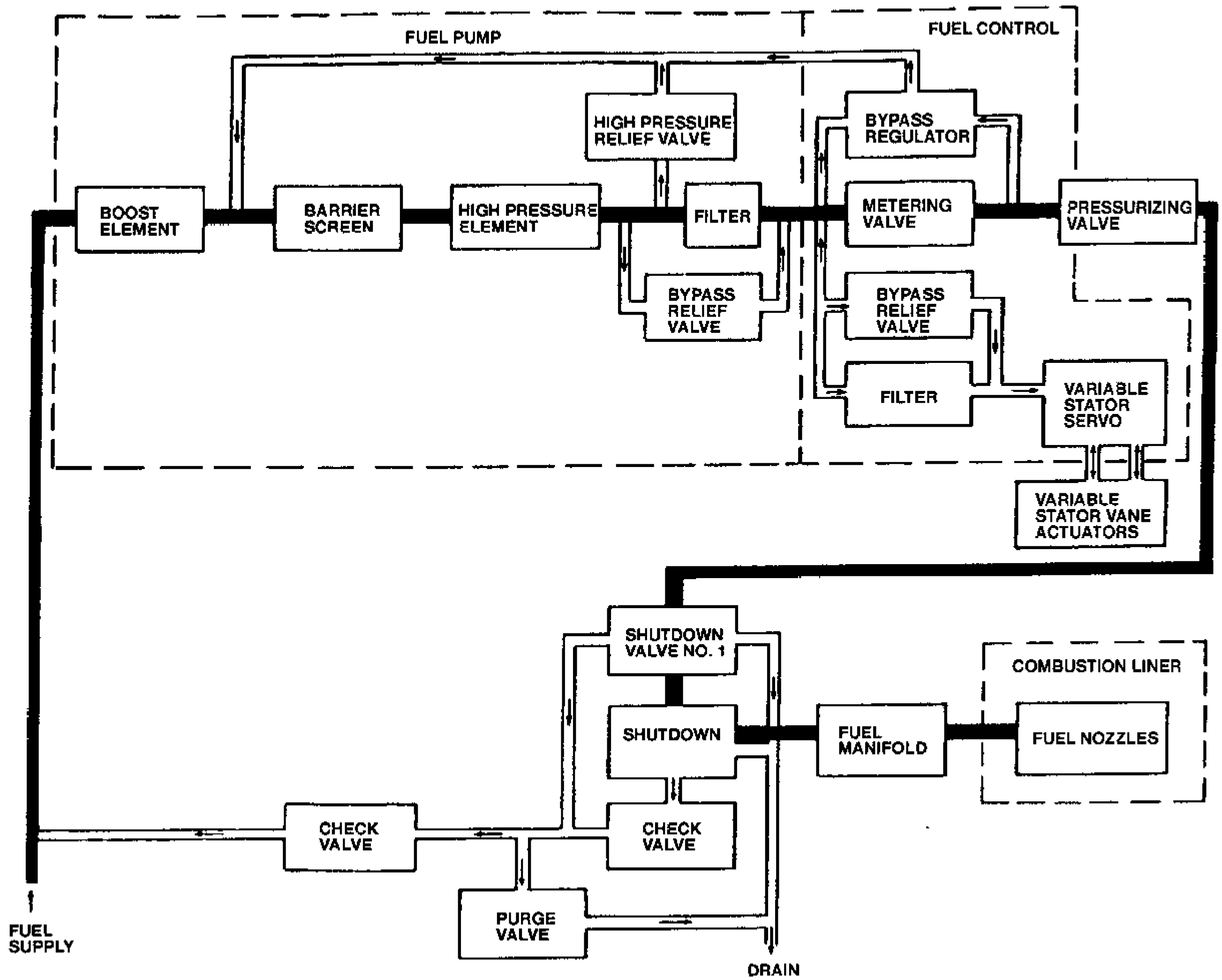

Figure 234-3-1. Typical Engine-Mounted Integral Liquid Fuel System

234-3.2.3.1 Fuel system pumps are selected to meet engine starting fuel flow requirements at minimum cranking speeds, and have excess flow capacity at higher speeds. In the engine operating range, excess flow is recirculated by a metering unit (fuel valve and limiter). The net fuel flow handled by the ship fuel supply system is high-pressure element inlet screen of the fuel pump.

234-3.2.3.2 For engines using separate start nozzles, the engine main fuel shutoff valve diverts metered fuel through a back pressure valve during the startup sequence. The main fuel shutoff valve imposes pressure resistance drop. Elevated pressure at the start nozzles ensures light-off under cold starting conditions.

234-3.2.3.3 An engine-mounted fuel bypass valve is usually provided for redundancy to the safety shutdown system but has the capability to circulate heated fuel when required. The flow divider and dump valve divert fuel to the primary manifold and nozzle passages for startup and low-power operation. This duel-orifice fuel injection system keeps pump pressures at reasonable levels while providing good atomization by means of the primary nozzle passages at low engine power (idle range).

234-3.2.3.4 On shutdown, pump flow is diverted through the engine main shutoff valve or (in case of malfunction) the bypass valve to the recirculate connection. With the cutoff of inlet flow to the flow divider, the spring-loaded dump valve opens so the fuel manifold and feedliness empty through the dump line to the ship drain tank.

234-3.2.3.5 During engine shutdown or coastdown, combustor air pressures drop to a point where the combustor drain valves open to discharge any unburned fuel accumulation. A fuel drain tank for contaminants is supplied to the ship fuel system to collect residual engine fuel on shutdown, and to handle drainage from shaft seals of the high-pressure fuel pump.

234-3.2.4 FUEL CONTAMINATION. Freedom from fuel contamination is obtained by use of various combinations of centrifuges, settling tanks, strainers, and filters in the engine fuel system. Instructions regarding the cleaning or replacement of elements depend on the installation and may vary with different localities.

234-3.2.4.1 Close observance of filters and strainers will assist in determining replacement or cleaning schedule. Increased pressure drop across the filter or strainer is the primary criteria for replacement.

234-3.2.4.2 The majority of operating difficulties in use of gas turbine fuel have been due to contamination within the ship service and holding tank by:

a. Rust and scale
b. Freshwater and seawater
c. Oil soluble soaps
d. Microbe growth.

234-3.2.5 RUST AND SCALE. The presence of rust and scale in diesel fuel usually can be detected by visual observation. To check for sediment, take a sample of fuel from the engine feed or head tank in a clear glass bottle or beaker and swirl it so a vortex is formed. All sediment that has settled will accumulate on the bottom of the bottle directly beneath the vortex.

NOTE

At most, the total sediment should be only a point or spot of silt. In a quart bottle, the sediment should be no more than a slight smudge if picked up on a finger tip.

234-3.2.6 WATER. Water in diesel fuel will be evident by the cloudy appearance of the fuel or by the actual separation of the water from the oil during storage.

NOTE

Occasionally, when a clean and bright fuel cools, a light cloud may form. The cloud indicates that there was a small amount of freshwater dissolved in the fuel and that the water had precipitated out in cooling. Even this small amount of water is not desirable because it is an indication of contaminated fuel.

234-3.2.6.1 Water-contaminated fuel must be recirculated through a filter-coalescent to remove the water. At present two devices, discussed in paragraphs234–3.2.6.2 and 234–3.2.6.3, are available to the fleet for detecting contaminated fuel.

234-3.2.6.2 The A.E.L. MK I Free Water in Fuel Detector, NSN 6640-00-999-2786, measures trace quantities of undissolved water in aviation fuels.

234-3.2.6.3 The A.E.L. MK III Contaminated Fuel Detector, NSN 6630-00-706-2302, detects and measures small quantities of solid contaminants dispersed in fuels.

234-3.2.6.4 If the water detector is not available, a Water Indicating Paste, NSN 9G-6850-00-243-8515, described in **NSTM Chapter 541, Ship Fuel and Fuel Systems** , can be used to detect free water. The Water Indicating Paste can be used on sounding rods to show the presence and depth of water in tanks.

NOTE

Use of Water Indication Paste is not a reliable or accurate method of detecting water contamination and should not be used if other methods are available.

234-3.2.7 OIL-SOLUBLE SOAPS. The presence of oil-soluble soaps can be detected by a laboratory ash analysis, or, in the field, by mixing water with some of the oil. If the oil emulsifies, then soap is present.

234-3.2.8 MICROBE GROWTH. Microbe growth in fuel usually can be seen with the naked eye or with the aid of a microscope. Microbe growth has the physical appearance of minute gelatinous substances. This growth has a tendency to combine with other fuel impurities and form a large gelatinous mass. This jelly-like substance then clogs filters, strainers, and intricate parts of both the ship and engine fuel systems.

234-3.2.8.1 The presence of seawater in the fuel greatly increases the possibility of microbe growth. Fuel purification using the centrifugal fuel oil purifier and proper adherence to fuel filter replacement PMS will prevent microbe growth.

234-3.2.9 FUEL OIL SAMPLING. Samples of fuel oil should be taken at definite intervals to determine whether the fuel meets all requirements. The sampling procedure is important because improper sampling procedures can cause erroneous analyses.

234-3.2.9.1 For sampling, use a round, clear, glass bottle or laboratory beaker from 1/4 liter to 1 liter in size. The bottle should be as clean as possible. Rinse the bottle with fuel being sampled before filling the bottle to ensure that a representative fuel sample will be obtained.

234-3.2.9.2 Two samples should be taken; one sample should be taken at the main fuel tank outlet and one sample should be taken just prior to entering the engine fuel system.

234-3.2.9.3 The sample bottles should be capped immediately and taken to a recognized fuel analysis laboratory. Fuel which does not meet requirements should be rejected.

234-3.2.10 FUEL OIL STRAINERS. Fuel oil strainers are made in both duplex and simplex types. Some strainers have devices for manually rotating the elements against a metallic scraper to remove material caught by the element.

CAUTION

Never use a wire brush for cleaning strainer elements unless authorized by manufacturer.

234-3.2.10.1 Care must be exercised in cleaning strainer elements. Strainer elements should be soaked in an appropriate solvent, such as diesel fuel or JP-5, then wiped with a soft lint-free cloth or brush.

234-3.2.11 DUPLEX STRAINER. A duplex strainer is essentially two elements built into one assembly which has a manual valve for redirecting the flow of fuel through either one of the elements or both. In some applications one strainer may be cleaned while the engine is running, by directing all the flow through the remaining strainer.

234-3.2.12 SIMPLEX STRAINER. The simplex strainer is similar to the duplex type strainer. The engine **must be shut down** when the simplex strainer element is removed, unless a means of bypassing the oil around the strainer has been provided. If a bypass has been provided, **normal** procedure should still be to clean or remove the strainer only when the engine is shut down, because fuel bypassing the strainer will be unfiltered.

234-3.2.13 FUEL OIL FILTERS. Fuel oil filters approved for Navy use usually consist of replaceable, throw-away elements. In certain engines filters are of the non-throw-away type which are usually cleaned with a clean diesel fuel, wiped with a clean, lint-free cloth, and blown dry with compressed air.

234-3.2.13.1 Fuel filters are of adequate size to take pumped fuel flow. Sharp increases in the pressure drop across the fuel filter are indicative of filter clogging and will result in a reduction in engine performance.

NOTE

Centrifugal purifiers are also used to ensure clear fuel. Centrifugal purifiers use centrifugal force to separate water and dirt from the liquid.

234-3.2.13.1 The main advantage of centrifugal purifiers is removing water and dirt from the fuel oil. Water removed is discharged continuously from a drain while dirt and sediment must be removed by physically cleaning the purifier bowl.

234-3.3 LUBRICATING OIL SYSTEM

WARNING

Never enter a gas turbine module to perform maintenance on lubricating oil system components while the engine is in operation. Consult appropriate PMS documentation for engine shutdown requirements for lubricating oil system maintenance actions.

234-3.3.1 GENERAL. All gas turbine engines are equipped with a self-contained engine lubrication system. Figure 234-3-2 is representative of such systems, although variations exist between different engines.

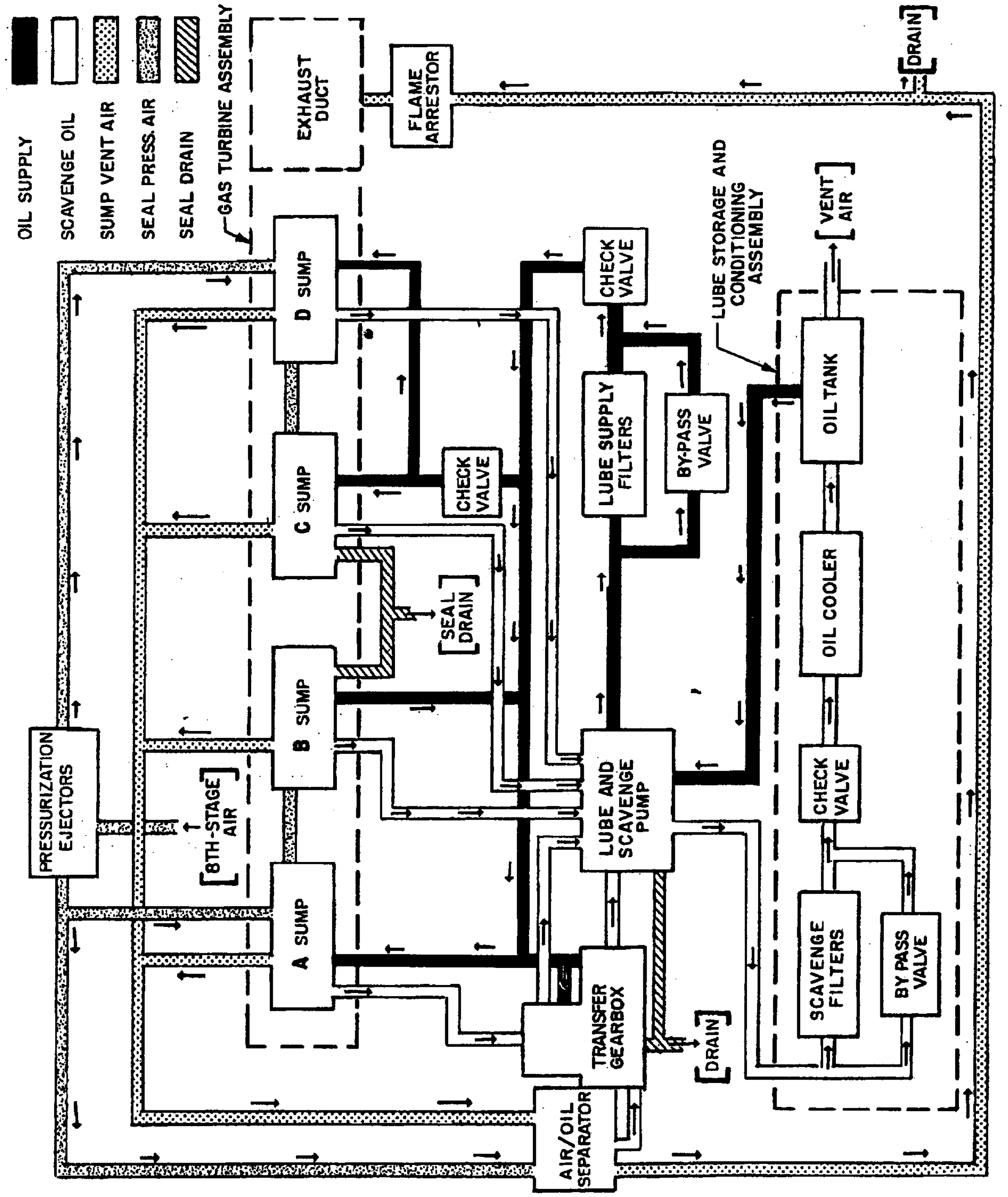

Figure 234-3-2. Simplified Schematic of Gas Turbine Internal Lubrication System

WARNING

Lube oil may cause dermatitis after prolonged contact. Wear rubber gloves, apron, and faceshield. If contact occurs, wash skin thoroughly; if clothing becomes saturated, remove immediately.

CAUTION

Never use a petroleum based oil such as 2190 TEP in a gas turbine engine.

234-3.3.2 OIL SPECIFICATIONS. The type of oil used shall conform to MIL-L-23699.

234-3.3.3 SYSTEM FEATURES. The lubricating oil system features, which include the sump, oil cooling system, venting, filters, strainers, criteria for changing oil, and inspection procedures, are discussed in paragraphs 234-3.3.4 through 234-3.3.10.3.

234-3.3.4 OIL SUMP. Most gas turbine engines have a self-contained lube oil sump. If additional oil capacity is required, a separately mounted tank may be supplied. The standard engine sump dipstick and float switch, on opposite sides of the engine, can usually be interchanged in position to ease engine servicing.

NOTE

The float switch is electrically connected to the engine control console to indicate when the oil level drops to a minimum normal operating level.

234-3.3.4.1 Some installations, such as those on high-speed, highly maneuverable ships, exhibit motions resulting in engine attitudes and movement which will cause considerable sloshing of the oil in the sump. At low oil levels this may result in momentary low-level indications, and less than optimum inlet conditions, with possible low-pressure nuisance shutdowns.

234-3.3.4.2 For most applications, an adjustable time-delay circuit within the electrical system, which inhibits shutdowns from short duration low-pressure conditions, is optionally available. For these applications, users are required to keep the oil sump at the full level. For extreme applications, baffles in the sump and on the oil level indicator will be installed to prevent such occurrences.

234-3.3.5 OIL COOLING SYSTEM. Gas turbine oil may be cooled by water, air, fuel, or oil.

234-3.3.5.1 Marine gas turbines may utilize water-cooled lubricating oil. In such applications engine oil is at a higher pressure than the water. In the event of a leak in the system, water will not leak into the oil system and cause corrosion.

234-3.3.5.2 On some gas turbines, oil is cooled by air passing over the oil sump or by an oil-to-air heat exchanger.

234-3.3.5.3 Regenerative (fuel-cooling lubrication oil) cooling can be employed on gas turbines where the cooling requirements are relatively low. In some cases, this method of cooling may be supplemented by other cooling methods.

234-3.3.5.4 The majority of marine gas turbine installations use an oil-to-oil cooling system where engine oil is cooled by the main reduction gear oil. In these installations engine oil pressure should be maintained at a higher pressure than the cooling oil so that, in the event of a leak in the system, cooling oil will not leak into the engine oil system. The major advantage of this type of oil cooling system is the decreased possibility of the engine lube oil becoming contaminated by seawater.

234-3.3.6 VENTING. To prevent excessive oil loss from venting oil vapor overboard, bearing sumps are usually vented to an air-to-oil separator. The sump air is vented to the exhaust after passing through the separator, and the oil is returned to the main sump.

234-3.3.7 LUBRICATING OIL FILTERS. Last chance filters are integrally located prior to each critical feed point. A main lube filter assembly, usually composed of a coarse filter followed by a fine filter, is supplied with each engine. For a continuous duty engine use, a valve should be provided for external bypassing of the remotely located fine filter to permit filter element changes without shutting down the engine.

234-3.3.7.1 The coarse filter is usually mounted in the lube oil system, remote from the engine, and may have no bypass. To prevent continued use of unfiltered oil, routed through the bypass to the engine when the filters are clogged, most filters and strainers have differential pressure gages to assist the operator in determining when elements require changing, and alarms to warn operators of bypassing flow.

234-3.3.8 LUBRICATING OIL STRAINERS. Lubricating oil strainers are of the same type as fuel oil strainers, although they are usually of larger mesh.

234-3.3.8.1 Lubricating oil strainers usually contain a built-in pressure relief valve of a size sufficient to bypass all the oil around the strainer in the event of clogging so an uninterrupted oil flow to the engine will be maintained. The bypass line should be connected to an audible alarm to inform engine operators that strainers are clogged.

CAUTION

Never use a wire brush for cleaning strainer elements.

234-3.3.8.2 In duplex strainers, the element being bypassed can be removed and cleaned without disturbing the flow.

234-3.3.8.3 Care must be exercised in cleaning strainer elements. The elements should be soaked in an approved solvent, such as clean diesel fuel or JP-5, then wiped with a soft, lint-free cloth or brush.

234-3.3.9 CHANGING OIL. Refer to the technical manuals for recommended oil change intervals. The oil should be changed if it is dirty, has water in it, or contains foreign particles. If the oil is contaminated, the entire lubricating oil system should be examined to determine the cause.

NOTE

By examining the lubricating oil and correcting the cause of contamination, a serious engine failure may be prevented.

234-3.3.10 INSPECTION. Sampling and inspecting lube oil for water and solids is scheduled and required by planned maintenance system (PMS). Inspect lube oil sample for water and sediment in accordance with the qualitative visual assessment procedure in **NSTM Chapter 262** , paragraph 262–5.1.3.3.

234-3.3.10.1 The presence of water in the lubricating oil usually can be detected by the cloudy appearance when a sample of the oil is shaken in a small bottle and visually inspected near a light source. In the same manner, foreign particles in the oil can be detected by the appearance of suspended particles or other adulterations. For a detailed analysis, the sample should be sent to a designated laboratory.

WARNING

Methanol is irritating to the skin, respiratory tract, and eyes. It is moderately toxic by skin absorption and highly toxic to the central nervous system and optic nerve by ingestion. The fire hazards are severe and vapors must not be permitted to accumulate in the area where methanol is used. Storage should be maintained in the plant and flammable liquids storeroom away from oxidizing materials.

234-3.3.10.2 Contamination of engine oil is not limited to water and dirt. Because of the configuration of some systems, mineral oil (2190 TEP) contamination of engine oil is also possible. The test for mineral oil contamination is:

1. Hold oil sample near light and visually inspect; oil should be transparent, uniform in appearance, and free of cloudiness, suspended matter, and sediment.
2. Mix one part of oil sample with three parts of absolute methanol.
3. Shake vigorously; oil contaminated with mineral oil will appear cloudy.

234-3.3.10.3 If the oil is found to be contaminated, the cause must be determined and corrected. The oil system must be thoroughly flushed prior to adding new oil.

234-3.4 STARTER SYSTEM

234-3.4.1 GENERAL. The gas turbine starter system includes three types of starters. They are:

a. Pneumatic starter
b. Hydraulic starter
c. Electric starter

234-3.4.1.1 The features of the three types of starters are discussed in paragraphs 234-3.4.2 through 234-3.4.4.

234-3.4.2 PNEUMATIC STARTER. Most free turbine gas turbine engines are supplied with pneumatic starters, vane-motor-powered, and operated by shipboard compressed air or compressor bleed air extracted from another operating engine. The engagement mechanism is a face-jaw which is pre-engaged by a pneumatic piston. The starter pilot solenoid valve is located within the engine controls enclosure.

234-3.4.2.1 A typical pneumatic starting system schematic, including required filters, lubricator line size, and valving, is shown in Figure 234-3-3. For flow and pressure requirements consult applicable engine manufacturer manuals.

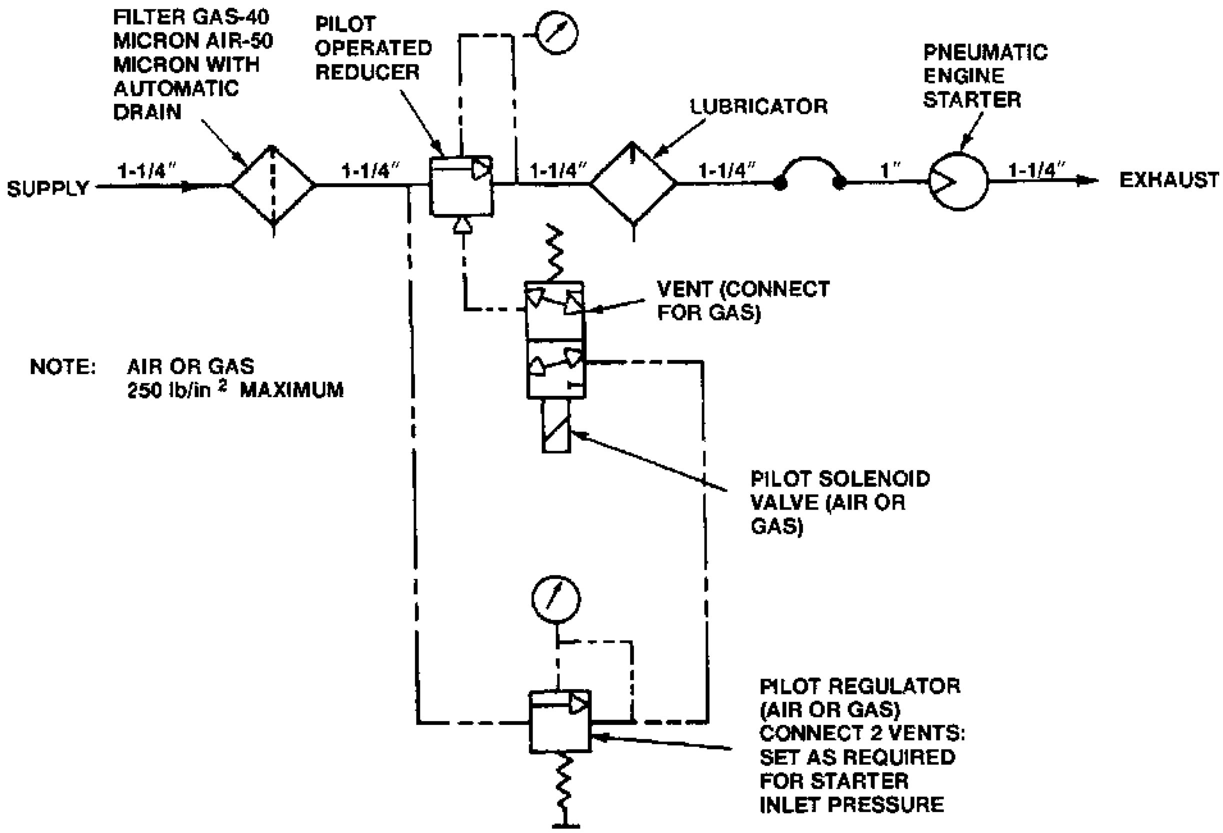

Figure 234-3-3. Schematic of Typical Pneumatic Starting System

234-3.4.3 HYDRAULIC STARTER. Some turbine engines are supplied with a fixed displacement piston-type hydraulic starter, operable with MIL-H-5606 hydraulic fluid. The engagement mechanism is usually a sprag-type over-running clutch within the engine's accessory gearbox.

234-3.4.4 ELECTRIC STARTER. Some Gas Turbines use an AC volt or DC volt electric start system for starting the engine. These applications are limited due to the size of the motor for starting the gas turbine. Figure 234-3-4 is the schematic for a typical electric starter system.

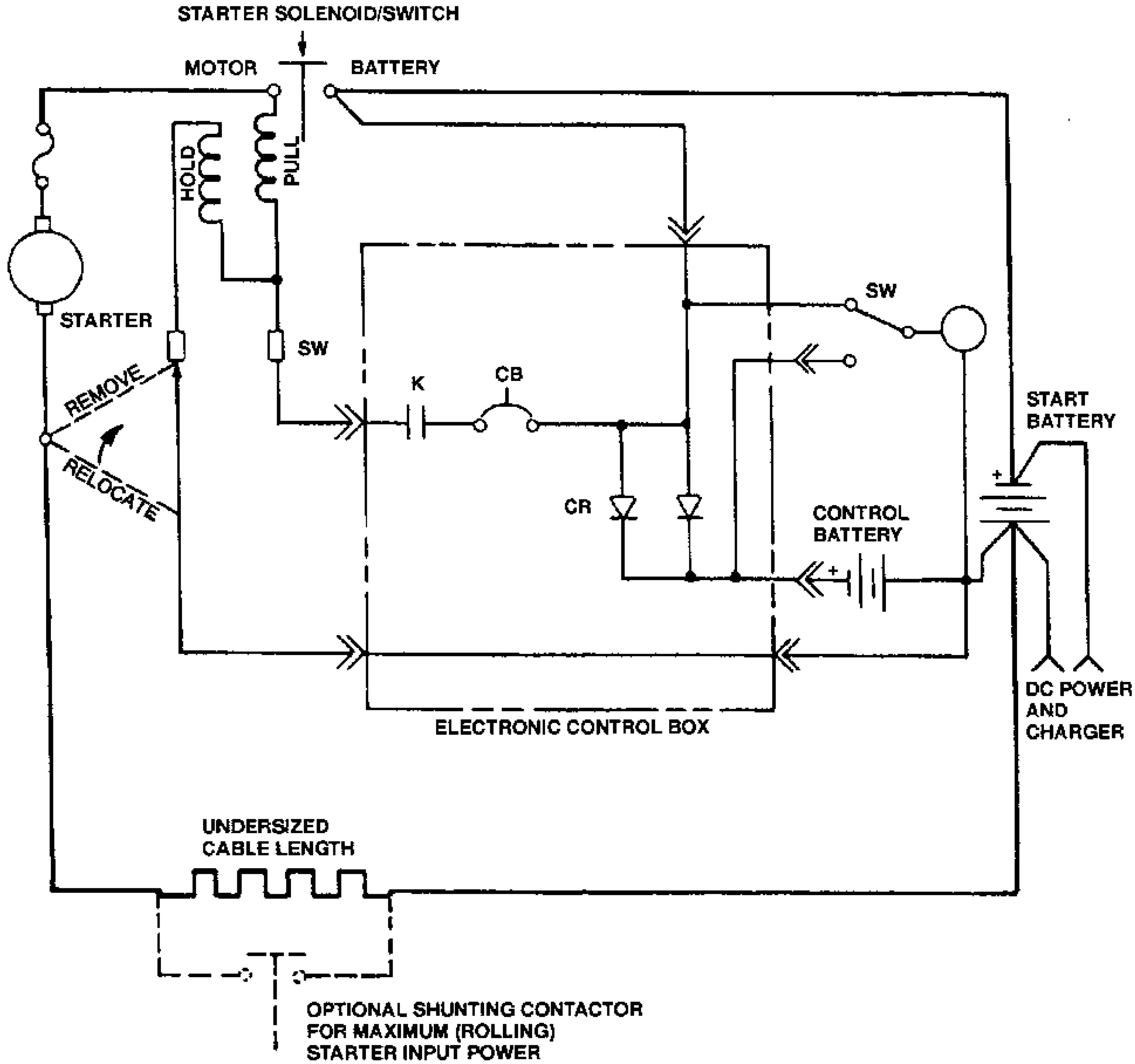

Figure 234-3-4. Soft-Start (Current-Limiting) Arrangement for Battery Power Systems

234-3.5 INLET AIR SYSTEM

234-3.5.1 GENERAL. The design and maintenance of the air inlet system is one of the most critical areas of gas turbine engine installation. A wide range of parameters must be taken into consideration, including:

a. Pressure losses

b. Flow distortions

c. Mechanical integrity

d. Aeroelastic response

e. Noise attenuation

f. Foreign object protection

g. Sand and dust filtration

h. Salt separation

i. Multiengine interaction

j. Overall system interaction.

234-3.5.1.1 Under high vibration or shock conditions, particular attention should be paid to duct fasteners (rivets, bolts, screw heads) and other ducting mounted components, so they do not fail and separate from their supporting structure. Loose objects within the ducting can be extremely hazardous if ingested by the engine.

234-3.5.2 SYSTEM CHARACTERISTICS. Characteristics of the inlet air system - intake location, inlet airflow distortion, multiengine installations, and salt separation are discussed in paragraphs 234-3.5.3 through 234-3.5.6.7.

234-3.5.3 INTAKE LOCATION. The entrance to the intake duct is located so that exhaust gases are not recirculated into the intake. Intake openings are located in areas of minimum dust concentrations, away from the exhaust stacks and air-cleaner dirt outlets, and are oriented to minimize ingestion of sea spray. Louvers, water separators, and salt separators are usually provided to minimize entry of large water droplets and limit the salt concentration at the engine inlet plane to less than 0.1 ppm by weight.

234-3.5.3.1 In general, the opening of a typical intake consists of a large mesh -5.75 cm (1/4-inch) inlet screen and some simple louver system.

234-3.5.3.2 Certain types of inlet configurations which have louvers, splitter plates, chevrons, and filters may be prone to accumulations of ice. When such likelihood exists, provision is made for the detection; that is, indication of increase in pressure drop across the intake system, or heating devices to prevent such conditions.

234-3.5.3.3 Access usually is provided to the intake systems for inspection and cleaning. Access doors to the intake system are installed to open outward so the negative pressure in the intake system will prevent them from being opened, either accidentally or by personnel, while the engine is running. Interlocks or alarms may be provided to prevent starting the engine or to warn the operator that an access door is open.

234-3.5.3.4 Expansion joints are used at the intake connection of the gas turbine engine. The purpose of expansion joints is to reduce the forces and moments which are exerted on the engine by the intake plenum and exhaust ducting due to the relative motions. These joints must be kept in good condition to ensure integrity of the inlet system and to protect the engine from external shocks and vibrations.

234-3.5.4 INLET AIRFLOW DISTORTIONS. The aerodynamic environment at the engine inlet plane may differ greatly from the test cell surroundings where the engine was evaluated during development. The inlet for each installation is designed to provide for satisfactory flow conditions to the engine over the full planned operational envelope. Pressure loss and inlet pressure distortion are minimized to prevent performance loss or operational problems.

234-3.5.5 MULTIENGINE INSTALLATIONS. When bellmouth intakes are used, a separating wall is usually installed between engines to prevent aerodynamic interaction. Unless there are overriding considerations in a particular application for the use of combined intake ducts for multiengine installations, ducts should be kept separate for each engine.

234-3.5.5.1 To combine intakes on adjacent engines, dampers should be provided to shut off an idle engine's intake. Combined intakes are avoided, where possible, because the dampers present a serious hazard. Inadvertent closure of one damper while its engine is operating can damage the duct, cause the engine to surge and possibly damage the engine.

234-3.5.6 SALT SEPARATION. Ingestion of water droplets containing salt can be hazardous to engine operation both from the effects of corrosion and from aerodynamic disturbance.

234-3.5.6.1 Sulfidation (also called hot corrosion) of turbine components is caused by condensation on and subsequent attack of turbine alloys by sodium sulfate (Na2 SO4). It is apparent that if the amount of sodium or sulphur reaching the combustion chamber can be reduced, the potential Na2 SO4 formation and corrosion is likewise reduced. The extent of corrosion that would occur directly depends on the amount of ingested salt. There is evidence to show that fuels with large sulphur contents, in the absence of salt, do not cause sulfidation attack. The use of filtration equipment to reduce the salt content of the ingested air near seawater sources is feasible and has been shown to be beneficial.

234-3.5.6.2 To minimize the effects of corrosion, no magnesium is used in the engines, aluminum is anodized, and stainless steel, titanium, or specially developed alloys are used throughout gas turbines. To further impede the corrosion characteristics of the environment, many gas turbine manufacturers use corrosion-resistant coatings on the first few compressor blade and vane rows.

234-3.5.6.3 If an excessive amount of salt is permitted to enter and remain in the engine, a buildup of solid particles on compressor blading will gradually reduce the efficiency of the compressor, cause a loss in power, and finally lead to compressor surge. A maximum limit of 0.1 ppm by weight of salt to air is required by most manufacturers. Special instructions for washing techniques and frequency are given in most manufacturers' operation and maintenance manuals.

234-3.5.6.4 To inhibit the ingestion of seawater particles, inertial or knit mesh demister units are typically used in air intakes. The demisters are placed in the inlet ducting and sized so airflow velocity is low enough to avoid blowing the water droplets through.

234-3.5.6.5 Figure 234-3-5 and Figure 234-3-6 illustrate typical demister pad composition and installation. The mesh type separator operates on the principle of adhesion and d coalescence. The inlet air passes through the mesh; the seawater particles adhere to the mesh, form larger drops, and drain out.

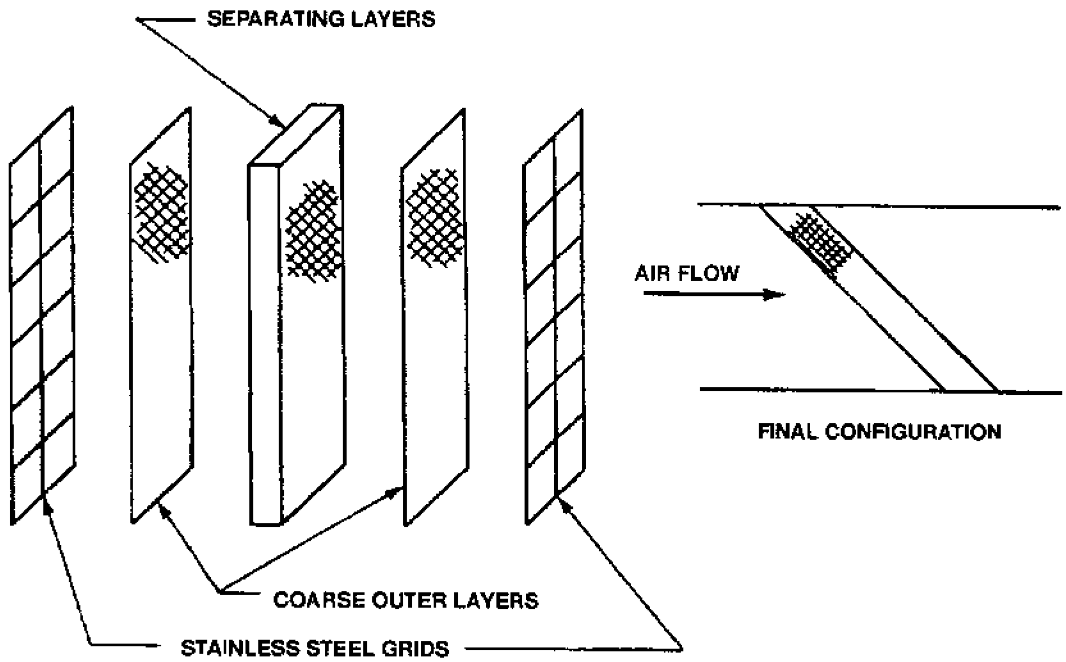

Figure 234-3-5. Typical Mesh Construction

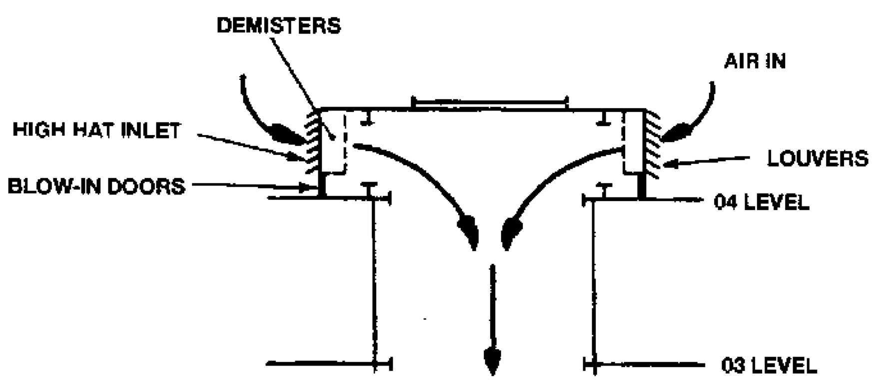

Figure 234-3-6. Demister Installation in Inlet Duct

234-3.5.6.6 The knit mesh elements are available in a range of thickness from about 1.25 cm (1/2-inch) to 30 cm (12 inches) and are sized to suit the application. The elements are set into metal frames for structural rigidity, each frame forming a separate removable panel. The mesh elements are available in a number of different materials, including stainless steel, Monel, Inconel, aluminum, copper, and polypropylene.

234-3.5.6.7 The most practical method of cleaning salt deposits from the mesh type elements is by immersion in water (see paragraphs 234-5.7 through 234-5.7.6 for typical inlet filter maintenance actions).

234-3.5.7 AIRBORNE PARTICLE SEPARATION. Ingestion of airborne particles can lead to severe damage in gas turbine machinery. Damage may include erosion and corrosion of vanes and blades, excessive wear on bearings, seals and most importantly, the blockage of cooling air passages with resulting over temperature and damage to hot section components. With this deterioration of hot section components, the gas turbine engine may not perform up to rated load specifications. Examples of airborne particles are sand, volcanic ash and industrial environments (Shipyard sand blasting operations). The high level of acidity in volcanic ash can lead to lube oil breakdown damaging bearings and shafts.

234-3.5.7.1 To inhibit the ingestion of airborne particles, foam pads are a requirement in gas turbine air intakes while operating in a sand (Persian Gulf, Red Sea, Suez Canal), volcanic ash or industrial environment with high levels or airborne particulate matter. The foam pads can be placed on the inside of the intake louvers or on the outside of the demister pads/filters. Refer to General Gas Turbine Bulletin No. 8, latest revision for foam pad installation and operation of gas turbines in environments containing high levels of airborne particles.

234-3.5.7.2 Only fire retardant foam pads are authorized. An acceptable pad is Part Number SIF20PPIQFRC, NSN: 9339-00-965-0481 manufactured by Scott Paper Company. This type is 1-inch thick and has 20 pores per square inch rating. The foam pads are supplied in 4 ft x 25 ft rolls. While in a high particulate environment, foam pads shall be inspected every 72 hours of operation and replace or clean pads as necessary to prevent Blow In Doors from opening. Foam pads are to be replaced after approximately 8 weeks of continuous use depending on condition and onboard supplies.

234-3.5.8 INLET AIR SYSTEM COMPONENTS. Components of the inlet air system, comprised of inlet ducting and filters, blow-in doors, inlet screens, and maintenance are described in paragraphs 234-3.5.9 through 234-3.5.12.1

234-3.5.9 INLET DUCTING. Ducting from atmosphere to the engine inlet is common practice on gas turbine applications. The disadvantages are large space occupied by ducting in the engine room, loss of maintenance space occupied by ducting, loss of maintenance space around the engine, and the absolute necessity for filters (and demisters) because large plenums are not available to allow long dwell times and subsequent fallout of solid particles.

234-3.5.9.1 Ducting can be acoustically treated throughout its length in any of several fashions with generally better results than the engine-mounted silencers. Acoustic treating reduces or eliminates the need for engine room silencing equipment for high-frequency, inlet-generated noise.

234-3.5.9.2 Silencing can be effected with standard acoustical duct liners of commercial grade from lead vinyl, woven metal, or commercial matting. In all cases, care must be taken to prevent liner collapse and subsequent inlet blockage.

234-3.5.9.3 Regardless of how well the inlet duct is designed, maintenance will be required to provide reliable engine operation. Any dirt, debris, nuts, bolts, or tools which are left in the duct could be ingested by the engine and cause a failure. Therefore, no acceptable amount of dirt, salt, debris, etc is allowed in the air inlet duct.

234-3.5.9.4 Most duct maintenance is for the purpose of keeping the inlet duct clean. Duct maintenance is identified in the PMS and primarily consists of periodic inspection and cleaning. In addition, special inspection and cleaning requirements are imposed after an engine change-out or any work in the inlet.

234-3.5.10 INLET FILTERS. Demister separators are designed to handle aerosol spray of very light concentration. When heavy concentrations are encountered, a substantial carryover of relatively large droplets in the intake air results. In this case the use of an inertial filter to separate the relatively large droplets, followed by another demister stage, is quite often seen.

234-3.5.10.1 In installations where large quantities of spray of relatively large particle sizes are typically encountered, an inertial filter first stage to remove the large particles, followed by demisting stages, is common.

234-3.5.10.2 Operating in an icing environment may result in a rapid blockage of the demisting filter and require a bypass airflow circuit if such blockage should occur. This alternative can be classed only as an emergency operating configuration since it eliminates the inlet protection features. If operation in an icing environment is anticipated, a thermal antiiced separating system is usually installed.

234-3.5.11 BLOW-IN DOORS. When inlet ducting is protected by blow-in doors, the door actuators will be scheduled to trigger open at or below the duct loss limits specified in the applicable manufacturer's specifications.

234-3.5.11.1 The doors should be large enough to accommodate the specification flow rate without exceeding the maximum permitted duct pressure loss. Also, they should be located so the opening is clear and the intake airflow will be free of oil, smoke, dirt, and debris. The doors, when in the closed position, should seal tightly and completely around allowing no gaps or paths for unfiltered air to pass into the air inlet duct. There is no acceptable limits allowed.

234-3.5.11.2 The flow field distribution at the engine inlet with the doors open must satisfy the engine inlet distortion criteria. Doors should be kept clear of obstruction and maintained in a totally operative condition.

234-3.5.12 INLET SCREENS. To prevent foreign matter from entering the engine, some applications are equipped with an inlet screen directly in front of the bellmouth inlet. The inlet screen ensures that dirt collected on the plenum floor or deck, material falling away from any part of the inlet plenum, and screws, bolts and other fastenings installed in the inlet plenum, do not pass through the engine.

234-3.5.12.1 The inlet screen should be a wire mesh screen, No. 3 mesh, 0.118-cm (0.047-inch) diameter wire or equivalent. A standard small turbine screen, illustrated in Figure 234-3-7, depicts a configuration which contains integral compressor waterwash, solvent, and preservative injection nozzles, as well as the protective screen.

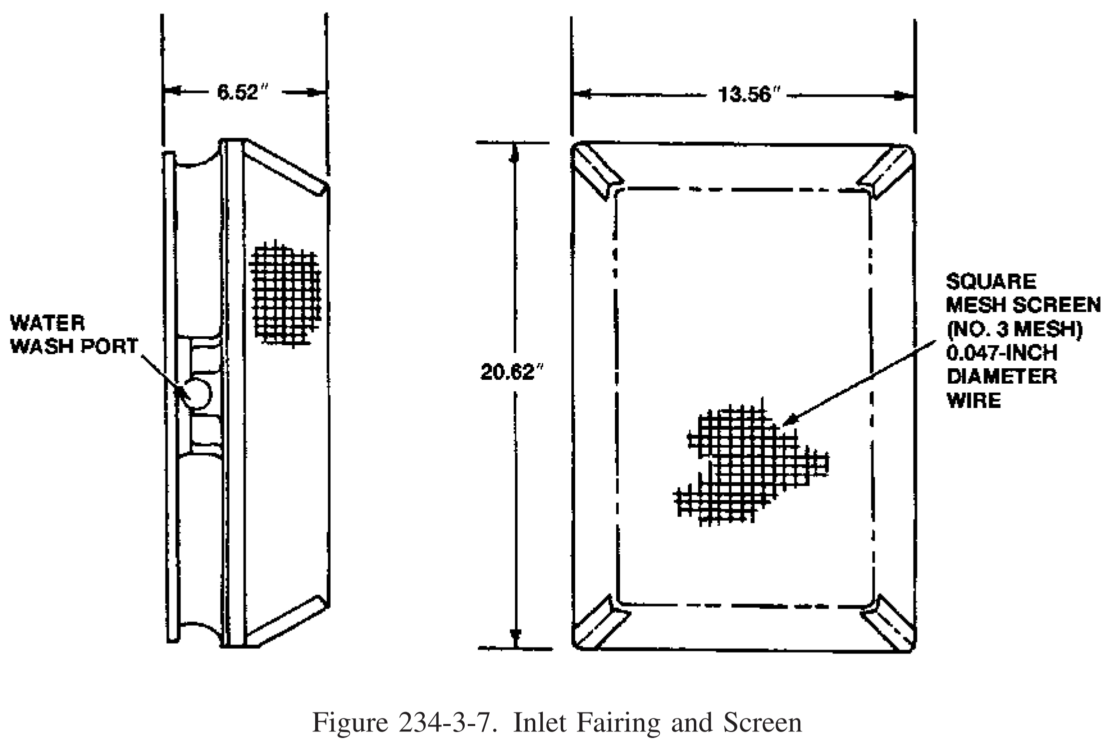

Figure 234-3-7. Inlet Fairing and Screen

234-3.5.13 EXHAUST SYSTEM. Exhaust ducting is required to remove hot exhaust gases from the engine. Exhaust gases range from 427°C to 649°C (800°F to 1200°F) per LM 2500.

234-3.5.13.1 There are various methods of ducting exhaust gases out of the machinery spaces. Ducts may be cooled or lagged, straight section or right angle, or pass directly to ambient air or through waste heat boilers. Figure 234-3-8 illustrates two exhaust configurations.

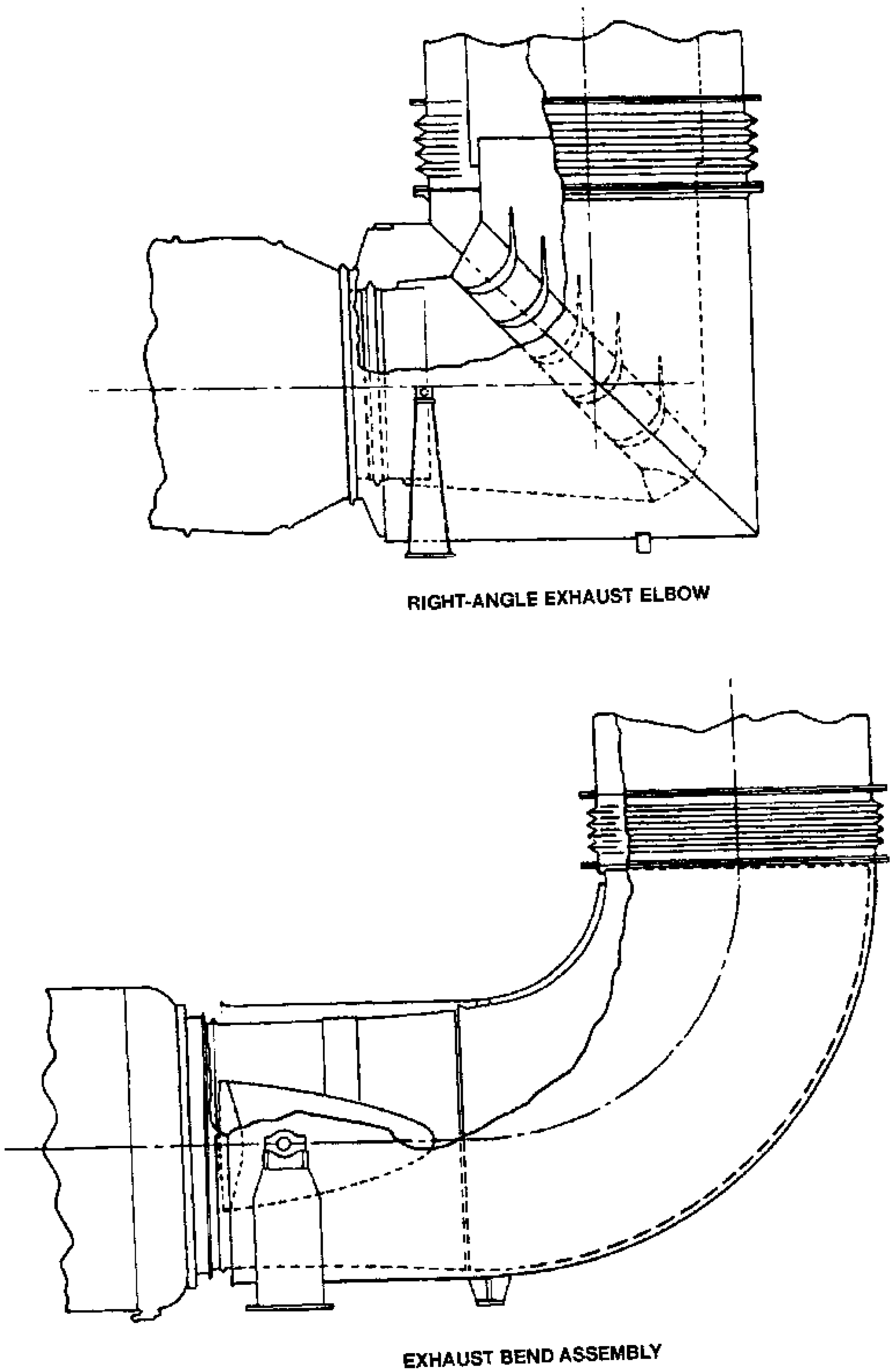

Figure 234-3-8. Typical Exhaust Assemblies

234-3.5.13.2 Exhaust ducts are equipped with expansion joints to compensate for engine and exhaust duct thermal expansion. Ducts are also fitted with drains to remove water collecting in the duct during extended periods of engine shutdown.

234-3.5.13.3 Exhaust duct cooling can be accomplished by a number of methods. One frequently used is that of eduction, which uses the high velocity of exhaust gases to draw cooling air through the annulus of a double-walled stack and then into the exhaust stream. This method of duct cooling is frequently more desirable than auxiliary blowers or refactory materials.

234-3.5.13.4 Care must be exercised to select proper cooling air entry locations to avoid spot stagnation with its resultant hot skin areas. Improperly designed eductors can cause excessive exhaust losses. Engine manufacturers should be consulted on exhaust designs.

234-3.6 COOLING AIR

234-3.6.1 All gas turbine engines and their accessories are rated for operation in ambients up to 54.5°C (130°F). While experience has shown some components can operate satisfactorily at temperatures considerably higher, 54.5°C (130°F) is considered the practical limit to attain long component life.

234-3.6.2 Temperature-sensitive components are normally mounted on the compressor (which is the coolest part of the engine) or are off-engine-mounted. Engine instruments are of commercial quality and their accuracy is affected slightly at both temperature extremes of the engine specification rating. The errors are small and generally of no consequence.

NOTE

Improved accuracy can be required for special applications in which the instruments are exposed to temperature extremes.

234-3.6.3 Depending on the installation, compartment cooling may be required to maintain engine components and other engine-compartment components within limits and to provide personnel comfort. Using partial exhaust gas energy to draw cooling air into the compartment by eduction has been accomplished with success, although loss on the engine and, alone, does not provide for compartment cooling after the engine is shut down.

234-3.6.4 If engine heat dissipation by natural convection and radiation is inadequate, auxiliary cooling may be required for a short period after engine shutdown.

234-3.6.5 In many gas turbine applications, such as the DDG 51 Class and the FFG-7 Class ships, turbines are enclosed in separate structural containers or modules. Each module is fitted with a ventilation air system, with the module serving as the ventilation airflow path.

234-3.6.6 Figure 234-3-9 illustrates the DDG 51 module with the ventilation air connection. Cooling air exits from the module around the gas turbine exhaust duct through a secondary opening.

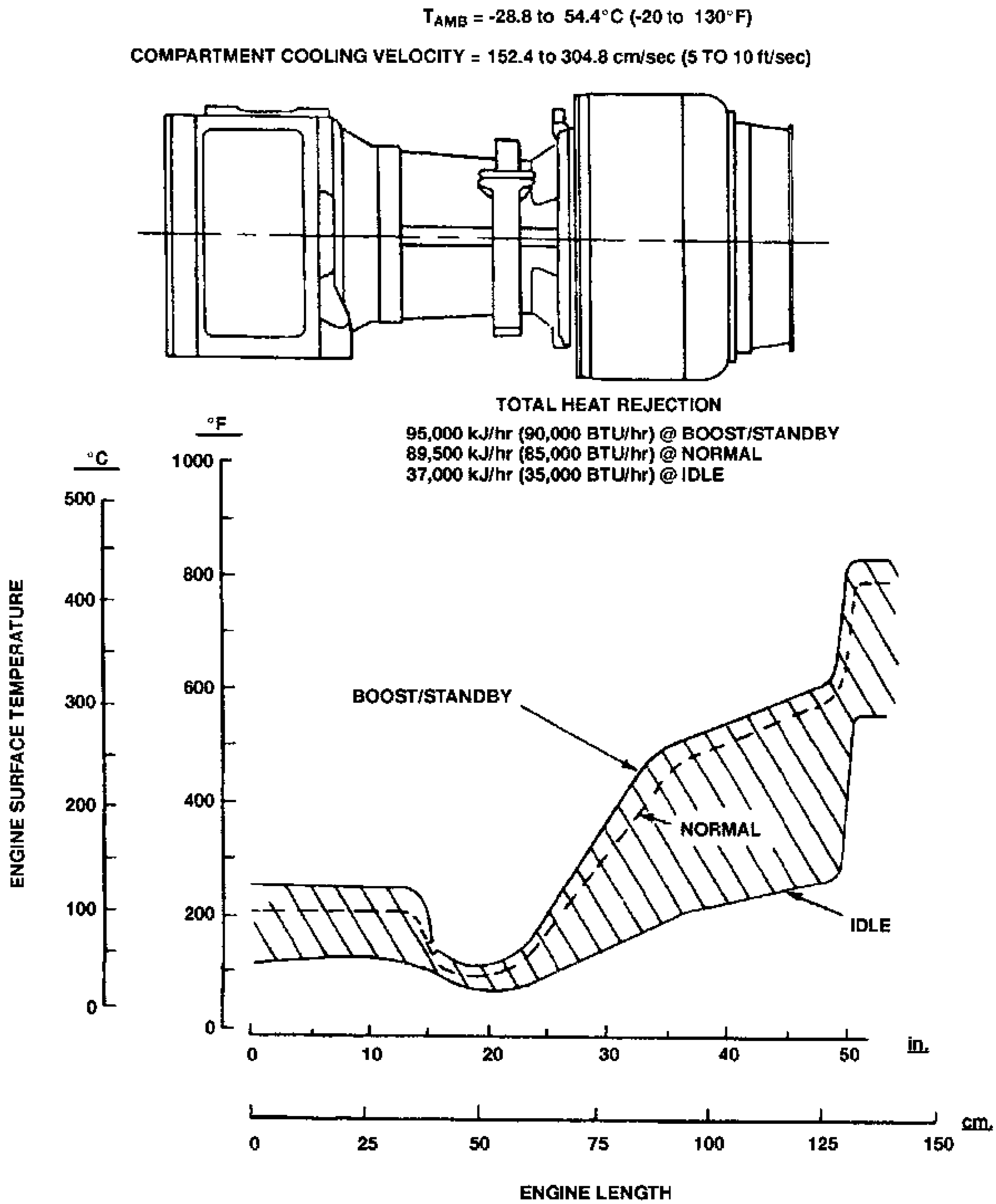

Figure 234-3-9. TF 25/35/40 and TC 35 Surface Temperature and Heat Rejection

234-3.6.7 Typical surface temperature and heat rejection rates are illustrated in Figure 234-3-10.

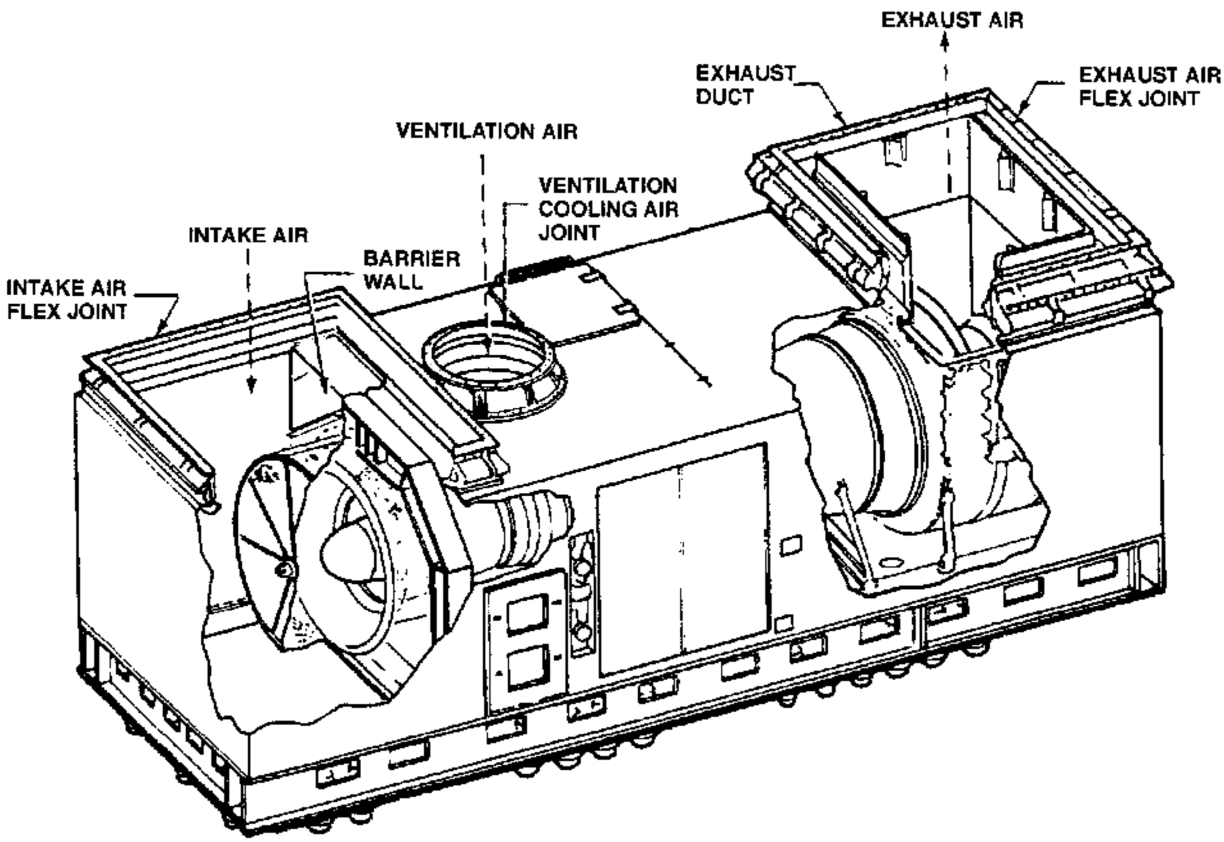

Figure 234-3-10. LM 2500 Engine Enclosure With Ventilation Air Connection

234-3.7 FIRE PROTECTION

234-3.7.1 GENERAL. Arrangement of fire detectors and extinguishers is governed by the installation. The mounting of the engine within an enclosed module will impede the spread of fire to the surrounding engine spaces. Fire detection and extinguishing devices also will be mounted within the enclosures.

234-3.7.1.1 In most applications, a fire shield is interposed between the liquid manifold and the exhaust diffuser. The fire shield isolates the manifold from the hot sheet metal of the exhaust duct in the event of leakage. The potential hazard of auto-ignition from combustible fluids leaking onto combustor housing surfaces also can be reduced by proper use of the positive ventilation system usually installed in gas turbine application.

WARNING

Ensure that all personnel are removed from the engine spaces prior to dumping a HFP, Halon, or CO_2 fire suppression system.

234-3.7.2 EXTINGUISHING AGENTS. Any fire extinguishing agent that does not leave an excessive residue can be used with a gas turbine engine. Examples of typical applications are Halon, CO_2 , Heptaflouropropane

(HFP), and water mist suppression. If CO_2 , or similar systems are used, and engine inlets are not ducted from outside the engine room, the engines must be shut down before dumping the agent in the engine room.

NOTE

If engines are not shut down prior to use of an extinguishing agent, the engine will inhale the agent and expel it from the engine room as fast as the agent can be fed to the fire.

234-3.7.2.1 A simple system includes a fire detection signal which causes engine shutdown and then automatically delays admitting the agent for approximately 20 seconds.

234-3.7.3 DETECTION. Fire detection is conveniently achieved by using resetting thermostats with open contacts and ultraviolet flame detection. The heat of the fire activates the detector, which completes an electrical circuit allowing the control to actuate the extinguishing system. The nominal setting of the detectors provides sufficient margin to prevent false actuations.

CAUTION

Improper installation or maintenance of the engine or exhaust collector can result in permanent damage to both the engine and individual components of the drive train, leading to a complete system failure.

234-3.7.4 EXHAUST DATA. If ventilation exhaust dampers are supplied, they shall be closed upon extinguisher actuation. If a system providing operator warning and manual extinguisher activation is selected, the operator shall first shut down the engine, then release the agent. In a ventilated enclosure, the fans and vents shall be closed before activating the equipment.

234-3.7.5 COMPARTMENT AND MODULE DRAINAGE. A general engine-compartment or module drain shall be provided to remove any fuel spillage which may result from accidents or defective seals or joints. Venting of the drain system is mandatory to prevent pressurizing the system from the combustor drain valve. The vent should be directed to a suitable area away from the engine installation.

234-3.7.5.1 Flame traps in the drain ducting are required to prevent an engine compartment fire from spreading to the fuel in the drain system.

234-3.8 MOUNTING SYSTEM

234-3.8.1 FOUNDATIONS. When designing foundations to accept the engine, the shipbuilder considers a number of factors to ensure proper system installation. Marine installations, in particular, require attention to the special conditions imposed by ship motion.

234-3.8.1.1 General considerations for the installation and maintenance of mounting system, which are discussed in paragraphs 234-3.8.2 through 234-3.8.4.1, include:

a. Access

b. Vibration

c. Noise.

234-3.8.2 ACCESS. Engine foundations and subbases must be installed and maintained to provide access for engine installation, maintenance, and removal. Manufacturer engine installation drawings provide details of recommended mounting techniques, lifting points, component withdrawal space, and oil sump drain requirements.

234-3.8.3 VIBRATION. Foundation systems are designed to account for the following forcing frequencies:

a. Drive shaft frequencies (lateral and longitudinal)

b. Propeller blade passing frequencies

c. Dominant frequencies of adjacent equipment, etc.

234-3.8.3.1 These forcing frequencies present a major problem in marine application since each covers an entire spectrum of modes which must be accounted for.

234-3.8.3.2 Current marine gas turbine mounting systems provide a foundation with a sufficiently high natural frequency so that, if a resonance occurs, it will have a higher harmonic than the forcing excitation frequency. The input energy will then be relatively low and the amplitudes correspondingly small. In addition, it may be necessary to provide a resilient isolation mounting arrangement when strong vibratory excitation or shock loading may exist.

234-3.8.4 NOISE. A second function of the mounting system is to isolate engine generated noises from the structure. In general, isolation of the entire engine load device and foundation is accomplished rather than isolating only the engine.

234-3.8.4.1 Materials used to isolate case-transmitted engine noise from external structure have been selected with care, taking into account such factors as cold flow, resilience characteristics to maintain shaft alignment, and ability of the materials to maintain engine flange loads within specified limits. Mounting systems shall be maintained in a high state of repair. Substitution of materials **shall not** be done without prior approval by NAVSEA.

234-3.8.5 SYSTEM MODIFICATIONS. Mounting systems are specifically designed to account for the thermal expansion, induced motion loads, and acceleration or gyroscopic loads that will be experienced by the engine in each specific application. Mounting system configurations shall not be modified without the express written approval of NAVSEA.

SECTION 4

MAINTENANCE AND CONFIGURATION MANAGEMENT

234-4.1 MAINTENANCE LEVEL IDENTIFICATION

234-4.1.1 GENERAL. Most gas turbine engines and associated equipments are maintained using an on-condition concept of maintenance. That is, equipment assemblies will normally be repaired or removed and replaced at the shipboard level on an as-required basis and will not be subjected to a fixed removal cycle.

NOTE

On-condition maintenance does not preclude the possibility of individual components or subassemblies having specified retirement life or overhaul limits.

234-4.1.2 MAINTENANCE ACTION LEVELS. Gas turbine maintenance actions are divided into the organizational, intermediate, and depot levels. Due to the complexity of the engine, the complexity and cost of required support equipment, and the high degree of technical expertise required to perform certain maintenance operations, each level has been allocated specific responsibilities and actions. Actions assigned at a specific level should not be attempted at a lower level. The organizational, intermediate, and depot levels are defined in paragraphs 234-4.1.3 through 234-4.1.5.

234-4.1.3 ORGANIZATIONAL LEVEL. Organizational level maintenance consists of corrective maintenance involving repair or replacement of failed assemblies, subassemblies, or components or accessories in accordance with applicable technical manuals; and preventive maintenance in accordance with maintenance Requirement Cards (MRCs) of the 3M Planned maintenance System (PMS). The PMS organizes into a systematic schedule of various shipboard planned maintenance actions designed to prevent or detect impending malfunctions in support of the on-condition maintenance concept.

234-4.1.3.1 No component repair or overhaul actions, other than those actions specifically authorized in appropriate technical documentation, are to be attempted at the organizational level. Organizational level maintenance action on the engine is limited to disassembly of the engine modules for removal to depot-level activities.

234-4.1.4 INTERMEDIATE LEVEL. Intermediate level maintenance consists of shore based maintenance activities equipped with special tools and equipment to repair or replace gas turbine engines and engine subassemblies. Repair of gas turbine engines is limited to replacing components and sub-assemblies that do not require the engine to be subsequently operated in a test cell. Gas turbine engine repair may be accomplished onboard or the engine or major engine section maybe removed and repaired at the intermediate level maintenance activity. Intermediate level maintenance manuals have been developed for most gas turbine engines and provide tasks and procedures for accomplishing turbine equipment repairs beyond the scope of the organizational maintenance activity.

234-4.1.5 DEPOT LEVEL. All repair or overhaul of engine components and accessories will be performed at designated Navy or contractor facilities.

234-4.2 PLANNED MAINTENANCE SYSTEM

234-4.2.1 The 3M PMS organizes various required shipboard maintenance actions into systematic procedures and schedules. All inspection, sampling, and servicing tasks needed for the gas turbine module are identified on the Maintenance Index Page (MIP) listing. Frequency of the maintenance (scheduled time between accomplishing the individual tasks) is also identified.

234-4.2.2 The initial MIP/MRC contents result from engineering studies which balance the need for the task against benefits derived and the workload imposed. As operational experience is gained, tasks can be added or deleted, or changes made in the tasks as a result of feedback from the organizational maintenance personnel.

234-4.2.3 Each task is fully defined on the individual MRC in terms of procedure, tools, time required, and precautions, etc. Historically, the MRC package completely defines all scheduled (preventive) maintenance activities at the organizational level.

234-4.3 CONFIGURATION STATUS ACCOUNTING SYSTEM

234-4.3.1 Although the U.S. Navy has been using isolated applications of gas turbines for both power generation and boost propulsion for the last 20 years, the engines now entering service in large scale applications such as DDG 51, CG 47, and FFG-7 Classes are of a completely different nature. Associated with these engines are logistic problems on a scale not previously encountered by the U.S. Navy.

234-4.3.2 The design and construction of the engines now entering service are such that repair of the gas generator, power turbine assemblies and most component items requires a wide range of specialized jigs and tools, and repair can be satisfactorily carried out only in a dedicated workshop.

234-4.3.3 For work in this depth, the complete gas generator and power turbine assemblies must be removed. Only routine maintenance and the exchange of certain component items, such as the starter or fuel control, can be accomplished with the engine in place.

234-4.3.4 To maintain configuration control, it is mandatory that all ship changeouts of component equipment be reported on **Maintenance - Ships Action Form (2-Kilo)** , OPNAV 4790/2K, of the 3M system. It is imperative that the ship reports accurate configuration data, including part and serial numbers of both removed and installed components. These data will be used to maintain a current configuration package for each engine within the computer data base of the Configuration Status Accounting System.

234-4.3.5 NSWCCD 933 is the Program Director for the Logistic Support Planning for Gas Turbines with the authority and responsibility for the organization, coordination, and execution of the total logistic planning efforts for gas turbine engines. Joint Configuration Management for LM2500, 501–K17, 501-K34, TF40B, T-1302S-28AA, T62T-40-7, GTCP 100-82 and RIMSS 250-KS4 gas turbine engines has been established in NAVSEAINST 4130.11. NSWCCD 933 will promulgate a detailed Instruction by the end of 2002 which will define new configuration status accounting requirements and procedures. As a result of LCM transfer, all existing instructions and procedures will remain completely in effect with all authority and responsibility assigned to NSWCCD 933.

NOTE

All activities involved in the removal and repair of the LM 2500 are cautioned to be completely familiar with this and other NAVSEA policies associated with the LM 2500 Configuration Status Accounting System.

234-4.3.6 It is anticipated that, as different gas turbine engines are introduced into the fleet, each engine will be added to the NAVSEA 05T **Configuration Status Accounting System** .

SECTION 5

GENERAL MAINTENANCE ACTIONS

234-5.1 PROCEDURES

234-5.1.1 GENERAL. Organizational level gas turbine maintenance can be divided into two generalized categories - preventive and corrective. Preventive maintenance is the normal, daily, maintenance and inspections performed on an engine to keep it in an operative condition. Corrective maintenance is maintenance done after an engine malfunction to restore the engine to an operative condition.

234-5.1.1.1 Organizational level maintenance on the larger marine gas turbine engines is limited to routine inspection, removal and replacement of major engine components, and removal and replacement of certain designated engine auxiliary components.

234-5.1.1.2 Engine major component disassembly and repair is not to be attempted at the organizational level unless specifically authorized. Appropriate manufacturers' technical manuals and 3M Planned maintenance System (PMS) MIPs and MRCs should be referenced for authorized organizational level maintenance actions and procedures.

234-5.1.1.3 Preventive maintenance is a normal function of the operating activity. In gas turbine maintenance actions, as well as all other gas turbine related activities, cleanliness is one of the most important basic essentials.

234-5.1.1.4 Particular care shall be exercised to maintain the cleanliness of the fuel, air, coolants, lubricants, rotating elements, fuel nozzles, and combustion chambers.

234-5.1.1.5 Prior to each day's operation, inlet areas shall be thoroughly checked for loose matter that could possibly be ingested into the engine. Periodic inspections shall be made on all fittings to check tightness.

234-5.1.1.6 Precautions to be observed in all maintenance actions are:

a. Proper procedures shall be followed to detect misadjustment, possible failures, and excessive clearances of wearing parts.
b. Do not use lead pencils for marking gas turbine hot parts, because the carbon from the pencil lead will cause stainless steel to become brittle and possibly result in a failure. Refer to appropriate technical manuals for correct marking techniques or devices.
c. Do not use steel wool to clean parts unless the wool is stainless steel.
d. Make sure all personnel are thoroughly familiar with the proper procedures before starting a repair.
e. Observe installation tolerances, wear limits, and adjustments.
f. Tag all removed parts for identification purposes.
g. Keep all parts clean. All openings shall be covered to protect against contamination.
h. Make sure all necessary special tools and repair parts required are available before beginning the repair.
i. Keep detailed records of repairs, replacements, and measurements of worn parts.

j. Refer to appropriate NAVSEA technical manuals, manufacturers' manuals, and MRCs for specific inspection or maintenance intervals and procedures.

234-5.1.2 OVERHAUL PERIODS. Maintenance and overhaul periods and procedures are set up by NAVSEA and are reported to the fleet through the technical manuals or the MRCs. Engine protection procedures, as outlined in the manufacturer's technical manual, shall be adhered to during all general maintenance.

234-5.1.2.1 As discussed in paragraphs 234-4.1.3 through 234-4.1.5, engine maintenance is classified as either organizational or depot and may be accomplished for:

a. Normal operational schedule

b. Engine malfunction.

234-5.1.2.2 Engine overhaul will not be accomplished on engines maintained under an on-condition maintenance concept. Engines and equipment maintained under an on-condition maintenance concept will be disassembled to the extent necessary to expose areas requiring corrective maintenance and repaired or reworked as necessary by the depot activity.

234-5.1.2.3 Accurate logbooks and equipment service records, discussed in Section 8, should be kept on each engine to ensure essential operational and maintenance history is available for repair and rework purposes. In addition, records aid in developing measures for improving engine reliability.

234-5.1.3 BORESCOPE INSPECTION. The borescope is a fiber-optic device used for in-place internal engine component inspection. Inspection shall be performed in accordance with PMS requirements.

234-5.1.3.1 Borescope inspection data can provide an early measure of component aging in the engine and allow for scheduling preventive maintenance before a defect develops to the point where unscheduled would occur. One significant aspect of borescope inspection is its capacity for pictorial trend monitoring, in which the progression of aging effects is observed, and predictions are made of the time when a condition will have reached its allowable limit.

234-5.1.3.2 In pictorial trend monitoring, a 35mm camera is used to obtain black-and-white or color photographs through the borescope. Figure 234-5-1 illustrates use of the borescope with a camera.

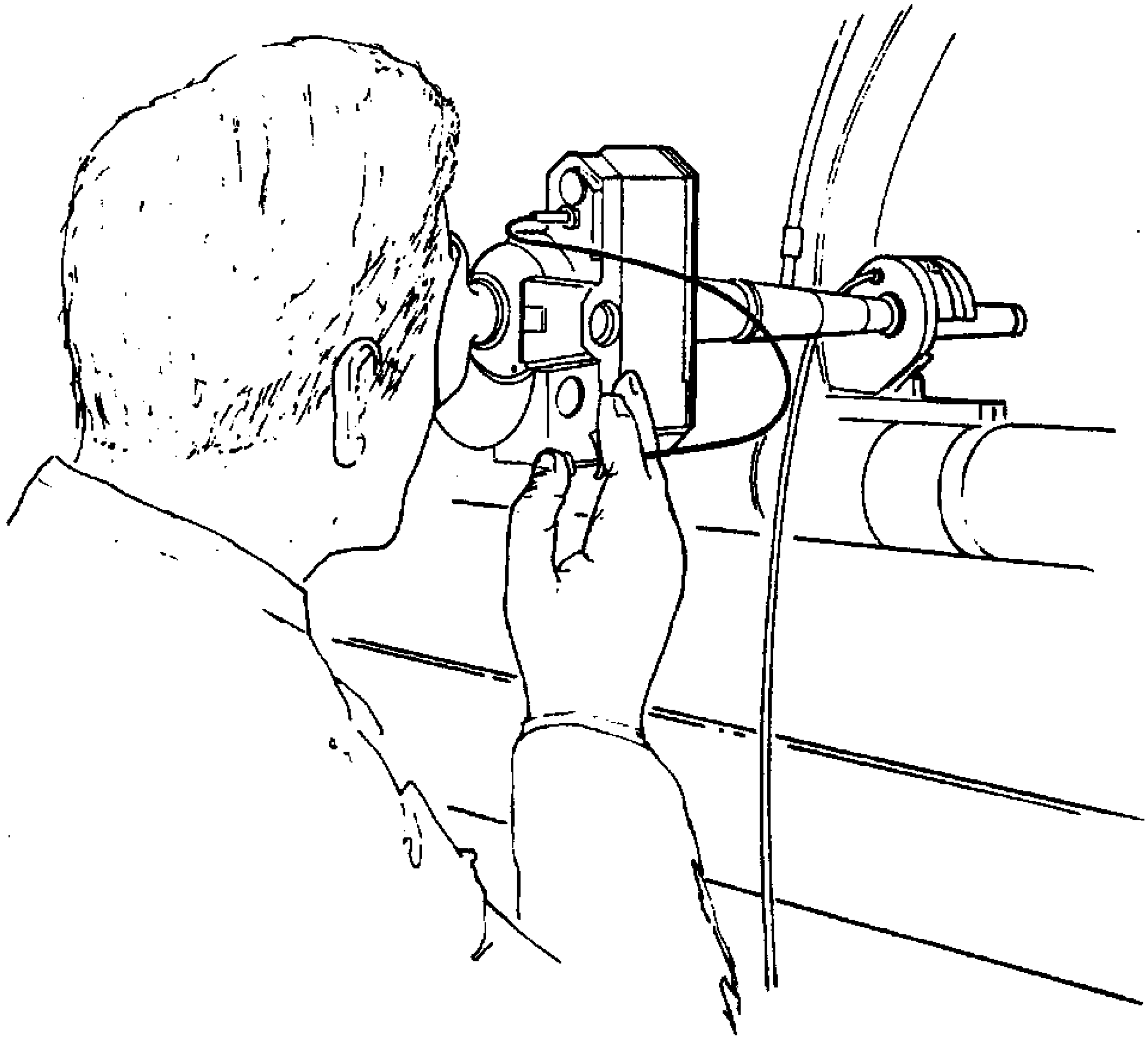

Figure 234-5-1. Borescope With Camera Being Used on LM 2500

234-5.1.3.3 A line drawing of a typical borescope photograph showing high-pressure turbine nozzle diaphragm leading edges is shown in Figure 234-5-2.

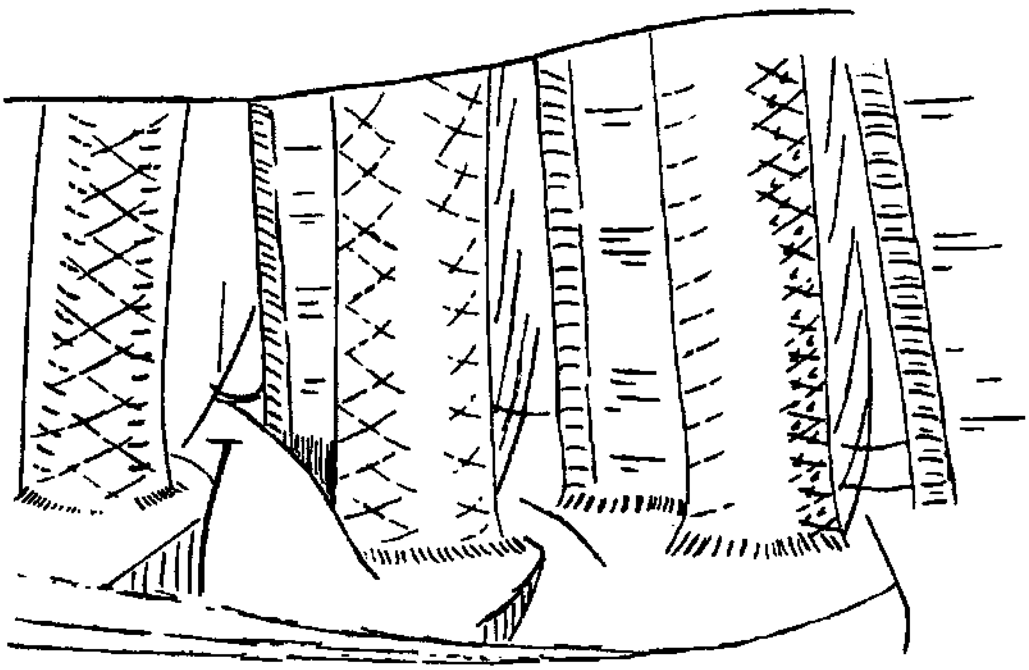

Figure 234-5-2. Drawing of Borescope Photograph of First Stage High Pressure Nozzle Diaphragm on LM 2500 Engine.

234-5.2 GEAR ASSEMBLIES

234-5.2.1 GENERAL. Internal gearing contained in the major engine assemblies shall not be removed unless specifically authorized in appropriate manufacturers' technical manuals or PMS documents.

234-5.2.1.1 For further information, see **NSTM Chapter 241 (9240), Propulsion-Main Reduction Gears, Couplings, Clutches, and associated Components** , and NAVEDTRA documents **Gas Turbine Systems Technician (Mechanical) 2** , NAVEDTRA 82157 and **Gas Turbine Systems Superviser** , NAVEDTRA 82158.

234-5.2.1.2 When problems with any gears do arise, the first cause that should be suspected is lack of lubrication. Precautions shall be taken daily to ensure that lube oil sumps are always filled to their required level.

234-5.2.1.3 Procedures for routine inspection of accessory drive gear modules are:

1. Inspect housing and visible gears for cracks and damage; replace gearbox module if unacceptable.
2. Inspect accessory gearbox for oil leakage around pad covers, plugs, and drive seals. Replace packings or seals if leaks are noted.
3. Inspect main and accessory drive pad splines for abnormal or excessive wear. Replace module if abnormal or excessive wear exists.

234-5.3 BEARINGS

234-5.3.1 GENERAL. The antifriction ball or roller bearings that are used in gas turbines are of the high precision type. Cleanliness, careful handling, and adequate lubrication are of utmost importance for all types of bearings.

234-5.3.1.1 For complete bearing information, see **NSTM Chapter 244, Propulsion Bearings and Seals** , and NAVEDTRA documents **Gas Turbine Systems Technician (Mechanical) 2** , NAVEDTRA 82157 and **Gas Turbine Systems Superviser** , NAVEDTRA 82158 applicable manufacturers' technical manuals.

NOTE

Bearing removal or disassembly shall not be undertaken unless authorized by appropriate technical documentation.

234-5.4 GAS GENERATOR

234-5.4.1 GENERAL. Organizational level maintenance on the gas generator assembly is usually limited to cleaning, inspection, and the removal or replacement of auxiliary components. Disassembly and repair of rotating components shall not be attempted at the organizational level. Such repairs require delicate, dynamic balancing machinery available only at the depot level.

234-5.4.2 COMPRESSOR. Inspection and cleaning will comprise the primary organizational-level maintenance tasks performed on the compressor.

234-5.4.3 INSPECTION. Compressor blades and vanes shall be examined periodically as specified in the manufacturers' technical manual to see that they are clean and free from nicks, scratches, cracks, or other damage. Inspection for, and removal of, nicks and dents in the compressor blading shall be in accordance with instructions provided in the technical manuals.

234-5.4.4 MAINTENANCE. Compressor rotating section maintenance shall not be undertaken at the organizational level unless specifically authorized by appropriate technical documentation. In that case, maintenance shall be performed in accordance with instructions provided in manufacturers' technical manuals.

234-5.4.5 COMBUSTOR. Combustors shall be inspected periodically for the presence of cracks, dents, carbon formations, distorted liners, and burning.

234-5.4.5.1 Appropriate 3M or manufacturers' technical manuals give the time for recommended inspection of the combustor. These documents establish criteria which will enable a determination of the condition of the liner being inspected, and also show how to correct minor liner malfunctions.

234-5.4.5.2 Nozzles shall be removed at regular intervals, inspected, and replaced, if necessary, in accordance with instructions in the manufacturers' technical manuals. Nozzles, when clean and ready for use, shall have a good spray pattern of approximately a 90° angle, and be free of streaks.

234-5.4.6 INSPECTION. Combustion section inspections are conducted at regular intervals, depending on the particular unit. Section inspections are usually comprised of a borescope inspection, or a visual inspection. The general inspection procedure is:

1. Properly support the engine to allow partial disassembly of the combustion area without causing engine sag.
2. Remove the combustion case to permit inspection of the combustion vane assembly, liners, and chambers for cracks, burning, warping, coke deposits, and other forms of deterioration.
3. Inspect fuel nozzles for carbon buildup and replace, if necessary.
4. Check the condition of the exhaust temperature thermocouples for breakage, severe burning, and crust formation; replace as required.
5. Inspect nozzle guide vanes and turbine blades for evidence of burning, warping, and corrosive attack.
6. Inspect visible portions of compressor for nicks, cracks, and contamination.
7. Inspect lube and fuel oil strainers, filters, and piping; replace elements as required.

WARNING

Because voltage to igniters is dangerously high, ignition must be off before any igniter is removed for inspection purposes. To ensure complete dissipation of electrical energy, a sufficient period of time (5 minutes minimum) shall elapse between shutoff of ignition and removal of its components.

8. At periodic intervals, check condition of igniter plug. Clean all carbon deposits in accordance with PMS documentation; if plug cannot be restored to its original condition, plug should be replaced.

234-5.4.7 MAINTENANCE. Care shall be exercised in cleaning the combustor section to prevent damage to section components, especially to fuel nozzles.

NOTE

Low-power operations may cause the nozzles to accumulate carbon deposits more easily than will heavier loads.

234-5.4.7.1 Usually soft carbon deposits can be removed by increasing the power output for short periods. A defective nozzle or combustor may be indicated by the following abnormal engine operations.

a. Booming or rumbling noises at high-power settings
b. Failure of any burner to ignite
c. Burner flame-out
d. Engine reaching idle speed but failing to accelerate
e. Delayed or aborted light-off

234-5.4.8 HIGH-PRESSURE TURBINE. The high-pressure turbine wheel should be clean. Where cleaning is required, instructions will be included in the appropriate engine technical manual.

234-5.4.8.1 High-pressure turbine blade damage may be caused by pieces of carbon or other foreign particles passing through the turbine, or by turbine overheating. Periodic borescope or visual inspection, as specified in the manufacturer's technical manual, shall be made to see if turbine nozzles and blading are clean and free from nicks, scratches, cracks, or other damage.

234-5.4.8.2 The frequency and procedure for periodic inspection is given in the appropriate technical manuals and PMS documentation:

a. Inspect turbine blades for nicks and dents. Refer to appropriate technical manuals for acceptable limits.

b. Inspect for cracks and deformation in blades and rotor assemblies.

234-5.4.9 GAS GENERATOR SHAFTING. Inspection and maintenance procedures for gas generator shafting are discussed in paragraphs 234-5.4.10 and 234-5.4.11.

234-5.4.10 INSPECTION. Inspection procedures for gas generator shafting are:

a. Inspect for cracks.

b. Inspect for damaged or excessively worn splines.

234-5.4.11 MAINTENANCE. Deficiencies in gas generator shafting usually necessitate major module replacement. Consult appropriate technical manuals for required actions.

234-5.5 POWER TURBINE

234-5.5.1 GENERAL. Power turbine inspection and maintenance actions are identical to those outlined for the high-pressure turbine in paragraphs 234-5.4.8 through 234-5.4.8.2.

234-5.6 COMPRESSOR CLEANING

234-5.6.1 GENERAL. In the salt-laden marine environment, cleanliness of the compressor is vital for maintaining good performance. Compressor contamination will usually result in the engine being unable to attain rated power without exceeding temperature limits.

234-5.6.1.1 It is essential that the compressor be cleaned to keep it operating at its design performance. The cleaning agent used will generally depend on the substance deposited on the blades. Table 234-5-1 provides Military Specifications and Qualified Products List for cleaning agents to be used for contaminating substances.

234-5.6.2 WATERWASH METHOD. Methods of gas turbine waterwashing are by detergent wash and on line wash. Applicable technical manuals or MRC's should be consulted before any engine is waterwashed. General detergent waterwash procedures are:

1. Ensure that engine has cooled at least 1 hour.
2. If air line to compressor air bleed valve can be disconnected, disconnect the air line, cap the union, and air-bleed port.
3. Prepare a mixture of clean freshwater and detergent.
4. Motor engine while directing a moderate stream of mix into compressor air inlet.
5. Allow engine to soak for 10 minutes.
6. Rinse engine twice by repeating procedure with freshwater only.
7. Reconnect air line and uncap air bleed port.
8. Operate engine at idle for 5 minutes to dry compressor.

234-5.6.3 ON-LINE WATERWASH METHOD. On-Line waterwashing consists of injecting a mixture of water based detergent and deionized/distilled water into the engine while the gas turbine is operating. Some model gas turbines only use deionized/distilled water while performing the on-line waterwash method.

Table 234-5-1. COMPRESSOR CLEANING AGENTS

Contaminating Substance	Cleaning Agent
Salt, Grease, or Oil	Distilled/Deionized Water and Detergent (Mil-C-85704 and QPL-85704-8)

234-5.7 INLET PASSAGES

WARNING

Never enter the gas turbine module or inlet ducting to perform inspections or maintenance while the engine is in operation.

234-5.7.1 GENERAL.

234-5.7.1.1 Inlet passages shall be subject to periodic fresh water washdown to remove accumulated contamination. Potable or fresh water shall be used.

234-5.7.1.2 Engine inlets shall be covered during washdown to preclude ingestion of contaminants into the engine.

234-5.7.2 SCREENS. Suitable screens usually are provided to protect the compressor. It is the responsibility of the engine operator to ensure that protective screens provided with the engine are not left out of the air system, or damaged so foreign materials or pieces of the screen can be drawn into the compressor during engine operation. As a minimum, screens shall be inspected weekly.

234-5.7.3 DRAINS. Water traps or drains must be kept in good operating condition and cleaned periodically. The engine inlet passages should be free of all fuel and lubricants. Water traps and drains shall be fitted with check valves to preclude re-entrainment of water from the drain system into the inlet air stream.

234-5.7.4 BLOW-IN DOORS. Blow-in doors shall be checked for freedom of movement and corrosion. Door gaskets shall be inspected for cuts and tears across sealing surface. Torn or worn gaskets shall be replaced. Door linkages and linkage assemblies shall be cleaned with a wire brush and lightly oiled. The doors, when in the closed position, should seal tightly and completely around allowing no gaps or paths for unfiltered air to pass into the air inlet duct. There is no acceptable limits allowed.

234-5.7.5 DEMISTER PADS AND FOAM PADS. Demister pads, foam pads and filter assemblies shall be removed and cleaned to remove accumulated high levels of airborne particles such as dust, salt deposits, sand and volcanic ash. Inspect foam pads for tears, cuts, and surface erosion. Replace as necessary.

CAUTION

1. Never use a wire brush for cleaning demister pads or foam pads. The use of heavy detergents will remove foam pad fire retardancy.

2. Do not use water pressure above 65 psi while cleaning foam pads or damage to the pads will occur.

234-5.7.5.1 Unless otherwise noted in appropriate manufacturers' manuals, demister pads and foam pads shall be cleaned by directing a compressed air jet across the pad, first from the back and then from the front.

CAUTION

Foam pads shall be allowed to dry before handling. Handling the foam pads while wet will cause the pads to rip due to excess water weight. Operating with wet foam pads will cause particulate matter to adhere to the foam pads and cause clogging.

234-5.7.5.2 Heavy contaminant buildup can be removed by soaking pads for 30 minutes in 10 percent by volume solution of institutional Ajax and distilled water at 54.5°C (130°F) maximum for demister pads. Use a solution of mild soap and distilled or fresh water for foam pads. Following soaking, pads shall be rinsed clean with distilled water and allowed to dry thoroughly at room temperature.

234-5.7.5.3 Structural members or frames shall be washed with Ajax and water solution and thoroughly rinsed with clean distilled water prior to installation of pads.

234-5.7.6 ANTI-ICING HEATERS. Anti-icing louver heaters shall be tested for operability and cleanliness. Louver assembly shall be cleaned with a wire brush and lightly oiled.

CAUTION

Ensure that tools, rags, and other materials are removed from the inlet air passage prior to engine startup.

234-5.8 EXHAUST PASSAGES

WARNING

Never attempt maintenance or inspection of the engine exhaust ducting until the engine is shut down and the exhaust ducting has had sufficient time to cool.

234-5.8.1 GENERAL. Exhaust ducts are made as large as practical to minimize exhaust pressure losses. A small increase in the duct back pressure will result in sizeable decreases in engine output power.

234-5.8.2 DRAINS. Drains and water traps must be maintained in working order to remove rainwater and condensation that could collect in the exhaust duct when the engine is not in operation. During an aborted start, some fuel may collect in the ducting and must be removed to prevent ignition on subsequent start attempts.

234-5.8.3 INSULATION. Ducting thermal and acoustic insulation shall be examined periodically for indications of deterioration. Damaged or soaked (oil or water) insulation and lagging shall be replaced in accordance with instructions given in **NSTM Chapter 635, Thermal, Fire, and Acoustic Insulation** .

234-5.8.4 EXPANSION JOINTS. Expansion joints shall be inspected periodically for damage and deterioration. Joints shall be checked for flexibility and replaced as required.

234-5.9 INSTRUMENTATION AND CONTROLS

234-5.9.1 INSTRUMENTATION. There are a few basic instruments that are usually on all gas turbines. These instruments measure:

a. Exhaust gas temperature or turbine inlet temperature

d. Lube oil temperature

c. Lube oil pressure

d. Gas generator speeds

e. Power turbine speed (where applicable).

234-5.9.1.1 Most of the instruments used are either waterproof or splashproof. Care shall be exercised in handling these instruments, to ensure their watertight integrity.

234-5.9.1.2 All engine-related instruments are calibrated by the manufacturer prior to installation. Recalibration shall be done on a periodic basis to ensure accuracy of reading. Periodic calibration of all instrumentation shall be accomplished annually as a minimum, or sooner if indicated by manufacturer requirements. If replacement is necessary, the appropriate manufacturer's technical manual should be consulted for determining the correct identification.

234-5.9.2 CONTROLS. Controls for gas turbines may be manual or fully automatic. Most controls are designed to operate automatically but are provided with manual overrides. Controls for gas turbines are usually complex devices and no adjustments on them shall be made unless personnel are thoroughly knowledgeable in each control component. The manufacturer's technical manual should be consulted before any adjustments are made.

234-5.9.2.1 Temperature-sensing instrumentation furnished with most gas turbines consists of thermocouples or resistive temperature elements (RTE) placed in the inlet and exhaust of the engine and the lube oil system. Other temperature-sensing devices may be placed by the manufacturer at various locations, depending on the size and function of the engine.

234-5.9.2.2 During continued operation, the hot junction of the thermocouples may become coated, causing the thermocouple to read low and lose its quick response to sudden changes in temperature. To preclude thermocouple malfunction, stems shall be checked periodically and the calibration checked by immersion in water of known temperature, such as boiling distilled water 100°C (212°F).

234-5.9.2.3 Thermocouples, along with their wiring and contacts, shall be checked periodically for proper operation and physical deterioration. Proper isolation of thermocouples circuitry is required to prevent electrical interference with other ship electrical or electronic equipment. The thermocouples shall be calibrated at the same temperature at which they normally operate, if possible. Thermocouples and associated wiring and contacts shall be replaced at the first signs of deterioration or physical wear.

234-5.10 MOUNTS

234-5.10.1 GENERAL. Engine shipboard mounting may vary depending upon engine size and application. In most installations, the mounting used is of the resilient type. Resilient mounts are defined as those made of materials having elastic properties. Resilient mounts are designed to isolate shock or vibration of continuous or intermittent origin and to serve as a supporter for the item to be isolated. For specific information on mounts, refer to appropriate manufacturers' technical manuals.

234-5.11 VENTILATION

234-5.11.1 GENERAL. Ventilation of the engine compartment is sometimes accomplished by designing eductors in the exhaust ducts. Since the exhaust gas velocity of a gas turbine is high and the quantity of gas exhausted is larger than on other internal combustion engines, the eductor method of using exhaust gas energy has proved to be highly effective. The eductors provide for adequate engine cooling with no intermediate systems required.

234-5.11.1.1 Another ventilation system used is that of ventilation blowers in the engine compartment. Ventilation blowers take their suction from outside the engine compartment and discharge into the engine compartment which in turn is vented to the outside.

234-5.11.1.2 The ventilation blower system provides a continuous flow of air over the engine. The advantage of the forced air system over the eductor is that the forced air system can remain operational once the engine is shut down, while the eductor system, since it depends on exhaust gas velocity, does not function once the engine is secured.

234-5.11.1.3 Ventilation system components shall be checked periodically for cleanliness and deterioration. System electrical components shall be replaced at the first signs of deterioration and wear. Mechanical components such as fans and louvers shall be cleaned of contaminants with a wire brush and lightly coated with oil or corrosion-retardant compound.

SECTION 6

REMOVAL AND REPLACEMENT

234-6.1 ALIGNMENT

234-6.1.1 GENERAL. Most gas turbine installations use a flexible, high-speed coupling assembly between the power turbine shaft and the driven unit input shaft, The high-speed coupling allows for minor misalignment of the shafting. Typical coupling assemblies will accept an offset of up to 0.635 cm (0.125 inch) between the engine shaft and the driven shaft, plus an angular misalignment of 0.00436 radians (1/4°).

234-6.1.1.1 Alignment of the engine and driven unit shall be accomplished in a cold set condition with a pre-stressed tensile load in the coupling axial direction to accommodate coupling shaft growth during operation. For general installations, the axial set for most applications will be in the order of 0.4064 cm (0.160 inch).

234-6.1.1.2 In aligning the engines to the driven unit, the general procedures to be employed are discussed in paragraphs 234-6.1.1.3 through 234-6.1.1.6.

234-6.1.1.3 When checking alignment, use two dial indicators 180° apart instead of one indicator, in order to check one indicator against the other. Readings on each indicator shall be taken at quarter points 0°, 90°, 180°, 270°, and 360°, and the 0° and 360° readings should check with each other. The two shafts being aligned to each other shall not be connected in any way.

234-6.1.1.4 Both facial and periphery readings shall be taken. If difficulty is encountered in measuring facials with dial indicators, a thickness gage may be used between the two mating flanges.

234-6.1.1.5 Alignment shall be accomplished only after the ship or boat is waterborne and with normal trim and load conditions. This procedure eliminates the possibility of alining the machinery when the abnormal stress of drydock support distorts the hull and machinery foundation.

234-6.1.1.6 When the proper alignment deflection readings have been achieved, take three successive readings to make sure the alignment readings will repeat.

234-6.2 ACCESSORY UNITS

234-6.2.1 GENERAL. To facilitate periodic maintenance and reduce engine downtime, gas turbine engine accessories have been designed to make maximum use of modularized plug-in or pull-out accessories. Most modularized plug-in or pull-out accessories. Most engine accessories, such as the auxiliary power takeoff, power lever actuators, fuel pump and fuel control system, lube and scavenge pumps, speed sensors, and starter, are mounted to an integral engine accessory gearbox. This gearbox is driven by the gas generator section through a radial drive train. Mounting pads are provided on the accessory gearbox for mounting required equipment and any optional equipment necessary for the engine. Applicable manufacturer's manual should be consulted for pad configuration, location, and accessory mounting or alignment requirements.

234-6.3 HANDLING

234-6.3.1 GENERAL. Gas turbine engines usually are designed to facilitate removal or replacement of accessories and major engine assemblies (gas generator, power turbine) as a total module without having to disassemble either the section to be removed or the adjacent assemblies. An example of this modularized concept is illustrated in Figure 234-6-1.

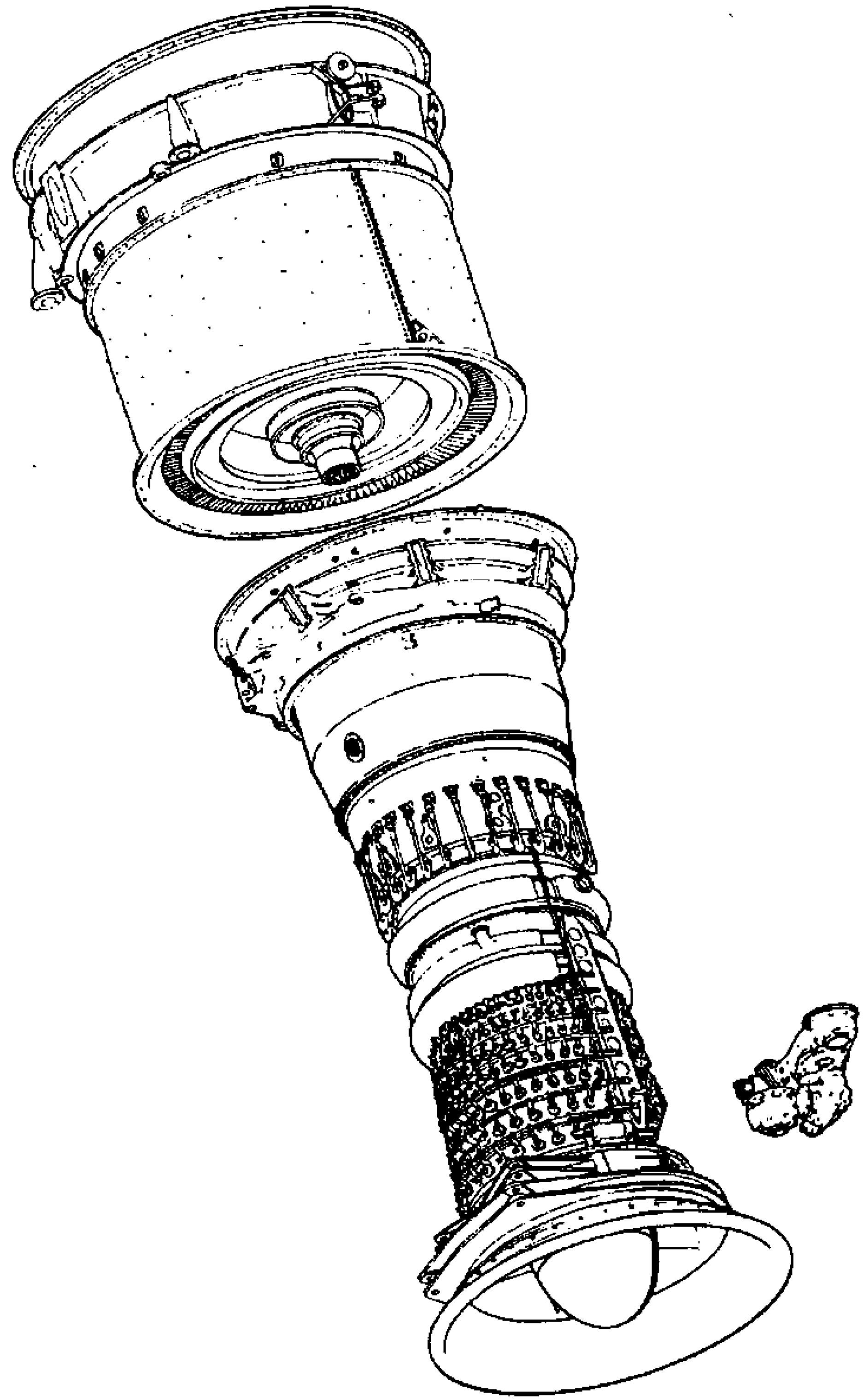

Figure 234-6-1. Typical Modularized Engine Concept (LM 2500)

234-6.3.1.1 Depending on the configuration of engine installation and the closeness of surrounding structure, a single module could be removed without disturbing adjacent modules. In other applications, where space and adjacent structure prevent in-place disassembly, the engine can be disassembled and removed by modules until the desired section is free. The engine is then reassembled in the reverse sequence.

NOTE

In such instances, any required special tools and handling equipment are usually supplied with the equipment.

234-6.3.1.2 Routing for installation or removal of the entire engine is of primary consideration in design of the engine application. Several alternative routing schemes are currently used, from removal through soft patches in deck and hull to removal through the inlet air ducting, as employed on the DDG 51 Class destroyer and the FFG-7 Class frigates.

234-6.3.1.3 Prior to removal or disassembly of a gas turbine engine, removal routes shall be identified and cleared and all required special handling equipment shall be assembled.

234-6.3.2 INSTALLATION. When installing an engine, care must be taken to ensure that the proper lifting hoists are attached to the turbine lifting lugs.

CAUTION

If the turbine is not lifted correctly, damage may occur.

234-6.3.2.1 Before installing the turbine, ensure that all ducting and piping are arranged to prevent interference with the installation.

234-6.3.3 CHECKING REPLACEMENT. After an engine is installed, all lines shall be connected and a check made to ensure that no line is leaking. Lock-wiring, when required, shall be performed. The area around the engine inlet shall be checked to ensure that no rags, tools, nuts, or bolts are left which might possibly be ingested into the engine.

234-6.3.4 MARKING DISASSEMBLED OR REMOVED PARTS. Marking of disassembled or removed parts is either permanent or temporary. Permanent and temporary marking are discussed in paragraphs 234-6.3.5 and 234-6.3.6.

CAUTION

Any temporary marking method which leaves a heavy carbon deposit (such as pencil lead) will cause a part to become brittle when it is subjected to intense heat. Such marking methods are expressly prohibited.

234-6.3.5 PERMANENT MARKING. Permanent marking is marking which is legible during the entire service life of the part. Manufacturer's part numbers are always permanently marked. Parts may be permanently marked by electrolytic etching, vibration peening, and engraving.

234-6.3.6 TEMPORARY MARKING. Temporary marking is marking which ensures identification during ordinary handling and storage of items prior to final assembly and use. Ink usually is used for temporary marking.

234-6.3.7 REMOVING ENGINE. When removing an engine from the ship , care must be taken to ensure that all the fuel, lubricating oil, and other lines are disconnected.

CAUTION

To prevent clogging or contamination, all exposed openings in fuel, oil, or air lines should be capped immediately. Do not use tape to seal fuel or oil openings. Tape adhesive is soluble in fuel or oil and can cause contamination.

234-6.3.7.1 Before removal, all lines and fittings, both on the engine and on the ship, shall be plugged or capped.

CAUTION

Under no conditions shall the engine be lifted from any point other than the lifting lugs provided. For specific lifting and handling instructions, the manufacturer's technical manual should be consulted.

234-6.3.7.2 The proper hoisting rig shall be attached to the lifting lugs provided on the module to be removed.

234-6.4 PACKAGING AND PRESERVING

234-6.4.1 PRESERVATION. A gas turbine shall be preserved prior to removal from a ship if it is known that the engine will be inoperative, shipped, or stored. Engines to be taken out of operation for a period of up to 1 month require only that the unit be protected from the elements. Units to be stored or out of service for more than a 1-month period must be preserved for storage.

234-6.4.1.1 Preservation of the engine ensures against gumming, sticking, and corrosion in the internal passages of the engine and related equipment. Preservation usually is accomplished by injecting a liquid preservative into the fuel and lube oil systems.

234-6.4.1.2 Consult manufacturer's technical manual for specific preservative instructions. In addition, MIL-E-17341 designates engine preservation requirements.

234-6.4.2 DEPRESERVATION. The engine may have to be depreserved if it has been in storage or inoperable for extended periods of time. Prior to connecting the engine to the external portion of the fuel and oil system (supply tank, coolers, filters, etc.) the external tubing and equipment shall be thoroughly flushed and purged. After installation, fill the engine oil sump with clean lubricating oil to the proper operating level.

CAUTION

To prevent accidental firing, ensure that engine ignition unit is disconnected when priming fuel control and fuel system.

234-6.4.2.1 Before initial operation, the engine fuel system must be flushed and purged. Crank the engine until all bubbles are out of the fuel stream and only fuel comes through. Observe engine oil pressure during cranking. If no pressure is indicated do not attempt to start engine until cause for lack of pressure has been determined and corrected.

234-6.4.2.2 The manufacturer's technical manual should be consulted for specific instructions on each particular engine.

234-6.4.3 PACKAGING FOR STORAGE. Gas turbine engines destined to be out of service for periods exceeding one month shall be packaged following preservation. Packaging should be in compliance with manufacturer's instructions for engine shipment. Lacking specific manufacturer's instructions, the engine shall be packaged in a hermetically sealed container with humidity control and external indicator.

234-6.4.3.1 Further packaging requirements are given in MIL-E-17341. Engine accessories shall be packaged per the requirements given in MIL-E-17555 and MIL-T-17286.

234-6.5 SHIPPING

234-6.5.1 GENERAL. All major engine parts, however badly damaged or worn, must be returned with the engine which is being overhauled or discarded. These parts are to be protected against further damage in shipping. Personnel preparing engines for shipment shall ensure that all fuel lines, receptacles, oil lines, intakes, exhausts, and any other openings in the engine or its components are capped or covered before removal.

CAUTION

Engines should never be shipped in a container that will transmit shock loads directly to the engine frame or its accessories. Hull parts should not be returned with the engine overhaul.

NOTE

Consult applicable General Gas Turbine Bulletin (GGTB) to ascertain engine configuration when receiving an RFI gas turbine and shipping a NON-RFI gas turbine.

234-6.5.2 METAL CONTAINERS. In preparing an engine for shipment in a metal container (a can), use the checklist included in this paragraph to ensure that all required precautions are taken:

a. Cover all openings, including inlet and exhaust, immediately after disconnecting and before removing engine from ship.

b. Check all electrical connections for caps.

c. Place all loose parts in a carton. Fasten carton securely to the engine with a wire or metal band.

d. Protect all wires by coiling or tying back. Secure engine firmly in container.

e. Check the engine logbook against the engine serial number for correct identity. Insert logbook in the outside receptacle.

f. Use only currently good, well-dried, silica gel bags. Place bags in designated baskets and seal shipping containers. Containers which need pressurization should be charged with clean, compressed air, which is free of liquid water. The outside of the containers shall be marked in accordance with MIL-STD-129, Engine, Gas Turbine, Preparation for Storage and Shipment of.

234-6.5.3 WOOD CONTAINERS. In preparing an engine for shipment in a wood container, use the checklist included in this paragraph to ensure that all required precautions are taken:

a. Cover all openings, including inlet and exhaust, immediately after disconnecting and before removing engine for shipment.

b. Check all electrical connections for caps.

c. Coil and tie all wires securely to prevent damage.

d. Place all loose parts in a carton and fasten carton securely to the engine with a wire or metal band.

e. Place protective envelope in wooden container and hold in position by engine anchor bolts.

f. Place engine in the envelope in the shipping container and bolt into position.

g. Make sure that sharp protrusions do not come into contact with envelope in any manner which will cause it to be punctured during shipment.

h. Check the engine logbook against the engine serial number for correct identity. Insert logbook in the outside receptacle.

i. Place the humidity indicator opposite the inspection window in the envelope.

j. Close and mark the container in accordance with MIL-STD-129.

SECTION 7

SPARE PARTS AND ALLOWANCE LISTS

234-7.1 GENERAL.

The Coordinated Shipboard Allowance List (COSAL) is published under the authority contained in OPNAV Instruction 4441.12A and lists the equipments, components, repair parts, consumables and operating space items required for an individual ship to perform its operational mission. The COSAL indicates the items (and quantity of each item) which an individual ship should have onboard to achieve a self-supporting capability for an extended period of time. The material allowances prescribed in the COSAL constitute the organic level of supply.

SECTION 8

MARINE GAS TURBINE AND SELECT DIESEL EQUIPMENT LOGBOOKS AND SERVICE RECORD (AUTOMATED)

234-8.1 GENERAL.

This Section establishes policy and procedures for use of automated marine gas turbine equipment service records (Weblog) and the Marine Gas Turbine Information System (MGTIS).

234-8.1.1 The provisions prescribed are applicable to all elements of the Navy engaged in operation or maintenance of marine gas turbine and select diesel equipment.

234-8.2 BACKGROUND.

234-8.2.1 The Navy extensively deploys gas turbine and diesel equipment in propulsion and ship-services systems in its fleet. Selection of gas turbine and diesel equipment for these systems reflects a desire to increase ship availability through reduction in system downtime.

234-8.2.2 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.

234-8.3.3 System downtime and lower shipboard manning levels have been realized through properly directed maintenance, logistic support, and reliability and maintainability improvement efforts.

234-8.2.4 Use of automated service records, as described in this section, to retain significant historical operating and maintenance data with gas turbine and diesel 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.

234-8.3 OBJECTIVE.

234-8.3.1 The objective of this section is to describe the policy and procedures:

1. Maintaining and updating the Marine Gas Turbine and select Diesel Automated Service Records for inputting data related to complete equipment assemblies or associated components and accessories.
2. Maintaining and updating the Marine Gas Turbine and select Diesel Automated Service Records for inputting data related to Ancillary Equipment.
3. The Automated Marine Gas Turbine and select Diesel Equipment Service Record is a sectioned data input format for a complete equipment assembly, including a section providing assembly- designation and installation-history information.
4. The Automated Marine Gas Turbine and select Diesel Equipment Logbook (Weblog), is the application containing the sectioned data input format for each installed equipment assembly. Weblog contains complete data for all installed equipment. It is arranged by activity, engine type and position, and incorporates each engine's respective logbook sections.

5. The Marine Gas Turbine Information System (MGTIS) is the main database repository for all Weblog data. There is an Internet interface between the Weblog and MGTIS.

234-8.4 POLICY.

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 herein. Also to be included are FFG, FSF, and LCS diesel engines.

234-8.5 PROCEDURES.

Equipment data is an essential element of the gas turbine and diesel 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 review of the data.

234-8.6 WEBLOG AND OPERATING REQUIREMENTS.

234-8.6.1 The Weblog is part of the Marine Gas Turbine Information System (MGTIS). It is a browser, form based, automated, equipment record keeping application.

234-8.6.2 MGTIS is the main database repository for all Weblog data herein described. Activities will use Weblog to update the MGTIS, superseding Autolog and GGTB 4. The requirements and guidelines to do so are detailed in this document (NSTM 234) and in the Weblog Users' Guide. Ships experiencing internet outages may provide MGTIS database updates via email to NSWCCD-SSES, Code 933. No standard e-mail format is required. Other activities supplying needed MGTIS updates will do so directly via Weblog.

234-8.6.3 During construction of a ship which uses gas turbine and select diesel equipment, the shipbuilding contractor updates the MGTIS database via Weblog under the direction of the supervising authority (SUPSHIP), until the ship is delivered.

234-8.6.4 The Weblog 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 Weblog and will be provided a users' guide.

234-8.6.5 Weblog updates are provided by the manufacturer, the activity originally accepting the equipment for the Navy, repair/rework facility, or NSWCCD-SSES. The Weblog is subsequently maintained by the ship having custody of the equipment.

234-8.6.6 The types of equipment assemblies which currently require an Weblog 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).

4. FFG, FSF, LCS diesel engines.

234-8.6.7 The requirement for maintaining Weblog 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 Weblog.

NOTE

Refer to General Gas Turbine Bulletin Number Zero (GGTB Nr. 0) the index for current amendments/revisions to GGTB Nr. 3 and/or all other TDs.

234-8.6.8 For new ship construction, the Weblog records shall be closed out at the time of acceptance/custody transfer of the ship to the Navy. Serial numbers recorded in the Weblog shall be verified before acceptance.

234-8.6.9 After the ship is delivered, all necessary Weblog entries for installed equipment shall be made under the direction of the ship's designated Weblog custodian. The Weblog custodians must have a page 13 entry in their service record and be listed on the ship's collateral duties list designating them as a Weblog custodian. The Main Propulsion Assistant (MPA) or appropriate engineering department/division Leading Chief Petty Officer (LCPO) are accountable for all data entered and must review entries for accuracy and certify entries by inputting the name of the certifying official in all "Verified By" fields were required. Ship Weblog custodians must logon to the Weblog site by the 5th of each month to update their records or provide an email update.

234-8.6.10 The ISIC or RMC Inspectors shall provide oversight to ensure compliance with instructions.

234-8.7 Automated Marine Gas Turbine and Select Diesel Equipment

234-8.7.1 SERVICE RECORD. The Automated Equipment Service Record,

NAVSEA 9400/1, page is used for equipment identification and installation data. NSWCCD-SSES will update these records for the ships.

234-8.7.2 CUSTODY AND TRANSFER RECORD. The Automated Custody and Transfer Record, NAVSEA 9400/2, is updated when there is an equipment transfer. The Custody and Transfer Record shall be completed in the manner described in the following paragraph.

234-8.7.2.1 The transferring activity shall input the Date, From, To, Authority, Removal Coding, Verified by, Verified Date, and Remarks information. When equipment (serviceable or unserviceable) is transferred from a ship to another activity, the Remarks column shall contain a certification stating that the engine is complete (uncannibalized) at time of transfer. NSWCCD-SSES shall update these records for from/to ship transfers.

234-8.7.2.2 The overhaul activity shall inventory the engine and container, and update the MGTIS database accordingly showing acceptance and date. NSWCCD-NAVSSES and the transferring activity shall be promptly notified if the engine is found to be incomplete.

234-8.7.3 OPERATING LOG. The Automated Operating Log, NAVSEA 9400/3 provides for the logging of all operating hours and starts on the equipment by month.

234-8.7.3.1 For new ship construction, operating hours and starts accumulated during the construction period shall be totaled and the MGTIS database updated only with the final totals. After acceptance of the ship by the Navy, operating time and number of starts will be logged on a monthly basis.

NOTE

Start is defined as successfully going through the start cycle to idle; motoring and hung starts are not counted.

234-8.7.3.2 The Weblog "Notes" field is provided for entering a synopsis of significant events or unusual trends which have occurred or developed since the previous recording period. Any event or trend which deviates from normal, can be described here, but must be described in the Miscellaneous History section described below. The field shall be left blank when operations are normal.

234-8.7.3.3 For new equipment, or repaired/reworked equipment, any non-ship operating time and starts shall be entered in the MGTIS database and identified as test cell or pre-delivery. The Weblog shall reflect this data on separate lines with the appropriate identifier (Test Cell or Pre-delivery) entered under "Remarks". Totals will be generated automatically. Operating data will be entered on time per assembly position with companion data being carried over automatically. In the case of a change-out, the end of month operating data may need to updated manually for the replacement and the removed assemblies.

234-8.7.3.4 All monthly starts for the 501-K34 unit initiated by the 250-KS4 RIMSS unit shall be recorded in the appropriate RIMSS Operating Log section. Any RIMSS starts not used to start the K-34 should be annotated as such in the notes section. Only air starts are to be input in the K-34 log section.

234-8.7.4 INSPECTION RECORD. The Automated 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.

234-8.7.4.1 A special or conditional inspection is an inspection required by NAVSEA or another major command, and is generally necessitated by an unusual equipment problem. A special inspection is normally specified by a bulletin and may or may not be recurring in nature. A conditional inspection is an unscheduled event required as the result of a specific abnormal operating condition (over temperature, overspeed, or stall).

234-8.7.4.2 The performance of routine or periodic inspection requirements of the Planned Maintenance System (PMS) are not mandatory inputs. The performance of an inspection according to a Gas Turbine Bulletin (GTB) for the equipment [may also be a General Gas Turbine Bulletin (GGTB)] shall be recorded in this section of the Weblog, unless specifically stated not to in the directive. This includes both initial and subsequent inspections. The initial inspection shall also be input in the TD (9400/6) section. The results of bulletin inspections must be input in the Miscellaneous History Section (9400/7). The MGTIS database shall be updated with all inspection data.

234-8.7.4.3 The Ancillary Equipment Automated Inspection Service Record shall list performance of special inspections as specified by Ancillary Equipment Bulletins (AYBs). Also listed are conditional inspections, such as those scheduled, (predeployment inspections and gas turbine readiness review) nonscheduled, (class advisories and casualty summary reports) and abnormal events (post shutdown fire and gearbox failure, etc). Explanatory notes concerning results of the above events shall be annotated in the Ancillary Equipment Miscellaneous History Service Record. Any AYB or AYC instructions to the contrary not withstanding

234-8.7.5 RECORD OF REWORK. The Automated Record of Rework, NAVSEA (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.

234-8.7.5.1 Ancillary Equipment Automated Record of Rework (9400/5) shall contain a record of all repairs, reconditioning, conversions, modifications, SHIPALTS or K-ALTS performed on the ancillary equipment or reduction gears. A summary of the above events shall be entered in the Automated Ancillary Equipment Miscellaneous History Service Record.

234-8.7.6 TECHNICAL DIRECTIVES. A Record of Technical Directive (TDs) affecting the equipment and accessories is entered on the automated Technical Directive page, NAVSEA 9400/6. Currently, diesel units have no TD requirement. If required by separate instruction, the custodian will select Service Bulletin (SB) or Equipment Change Proposal (ECP) as the TD "Type".

234-8.7.6.1 Gas turbine Technical Directives (TDs) are issued as Gas Turbine Bulletins (GTBs) or Gas Turbine Changes (GTCs); either may be an interim type. Ancillary Equipment TDs are issued as Ancillary Equipment Bulletins (AYBs) or Ancillary Equipment Changes (AYCs); either may be preceded by an "I", indicating an interim type.

234-8.7.6.2 TDs shall indicate the action category and include a brief description and the applicable status code.

234-8.7.6.3 Gas Turbine Bulletins/Changes are employed 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.

234-8.7.6.4 Ancillary Equipment Changes/Bulletins are employed 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. These TDs (AYCs and AYBs) are input into the Ancillary Equipment Weblog section; regardless of any AYC and AYB instructions to the contrary.

234-8.7.6.5 All active gas turbine TDs, including their active amendments, shall be recorded by number in this section (NAVSEA 9400/6) of the Weblog. Record compliance by Type Directive, AYB, AYB Revisions/Amendments, AYC, AYC Revisions/ Amendments, GTBs, GTCs, GTB Revisions/ Amendments, and GTC Revisions/ Amendments. Initial accomplishment of a bulletin shall be input here. Initial and subsequent inspection bulletin accomplishments shall be input in section 9400/4. Repair/rework facilities will update TD data as needed in the MGTIS database through Weblog.

NOTE

LM2500 Service Bulletins will state which TD it is equivalent to and whether or not it must be entered in NAVSEA 9400/6.

234-8.7.6.6 Custodians, including shipbuilders, shall use a single entry procedure for recording TD data on the automated NAVSEA 9400/6 page and use the same numbering system used in the GGTB 0. For example, GTC 99, Revision 1, Amendment C shall be input as 99R1AC; the first letter indicating an amendment. Interim directives shall also be recorded and are identified by “I” preceding the directive number. When the cancellation instructions in an interim directive indicate that it will be superseded by a formal directive, enter the basic directive number on the following line.

NOTE

In instances where a directive is composed of multiple parts to be accomplished at different times separate consecutive inputs shall be made for each part.

2. Shipbuilders are required to record TDs in the Weblog so that at the time the ship is delivered, the records are up to date. The current Zero Bulletin should be consulted and every applicable TD should be entered into the Weblog with the appropriate status. The only time the status should differ from the Zero Bulletin is when TDs are issued subsequent to the published date of the Zero Bulletin. Once the TD is received by the shipbuilder, the status should be changed from NIS to NINC, as appropriate. Shipbuilders are responsible for all current TDs are the time of the ship Custody and Transfer to the Navy.

3. Due to the large number of GTCs, the DDG-51 and AOE-6 Class ships were instructed to consolidate many of the older LM2500 TDs into a one line entry in the paper logs; as per GGTB 9. This procedure will not be applicable to the Weblog; GGTB 9 not withstanding.

4. Due to mixed configurations between K-17 and K-34 compressor and hot sections, all GTBs and GTCs are to be input under the hot sections only; unless directed otherwise by GGTB 3.

5. Status: Enter the appropriate status code - INC, NINC, NA, NIS, or C. Definitions of the codes and instructions for their use are listed below:

   a. Incorporated (INC) indicates that the modification or production equipment thereto has been completely incorporated, or the inspection has been completed.

   b. Not Incorporated (NINC) indicates that compliance with the modifications or inspection has not been accomplished includes modifications or inspections that have only been partially completed. This code should be edited and changed if the TD status changes.

   c. Not Applicable (NA) indicates that the directive does not apply to the particular equipment of the MGT model or serial number or that status is indicated elswhere.

NOTE

In instances where a directive has not been received (NIS status) and it is determined that the directive would not be applicable to the particular equipment of the MGT model or the equipment serial number, NA shall be entered for the status of the directive.

   d. Not Issued (NIS) indicates that the directive has not been issued. This code should edited and changed once the TD is issued.

   e. Canceled (C) indicates that the directive has been canceled, superseded, or rescinded.

NOTE

When a TD has been incorporated and it is subsequently canceled, superseded, or rescinded, the status code remains INC.

5. Category: Enter the appropriate category code: U for urgent or R for routine.

6. Title: Enter a brief description of the directive. (This need not be the complete subject of the directive.)

NOTE

For a TD that has an NA status, enter a brief notation in the title field to indicate non-applicability such as not this serial number.

NOTE

For a TD that has a C status, enter the canceling or superseding reference in the title field.

7. Activity: Enter the name of the activity complying with the directive and the date installed. If the status code is NINC or NIS, enter the unit's custodial activity.

8. Verified by: All entries shall be verified. A single name is authorized.

9. Revisions Issued: The complete log entry for the revision or amendment is entered as an additional record.

10. When a new version (dash number) of the same model engine is produced, the original accepting activity shall account for all TDs applicable only to the original equipment model by Weblog entry, such as 1-50, NA, and the notation Previous Models Only inserted in the Titles field. These entries ensure accountability of all TDs per model series, and cites, by number, those TDs that do not apply to the new version and for which no action is required by Navy activities. The entry is not to be construed as indicating that the modifications prescribed by the GTCs contained within the field entry were or were not incorporated into the production models of the new version.

234-8.7.7 MISCELLANEOUS HISTORY. The Automated Miscellaneous History, NAVSEA 9400/7, is used in Weblog 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.

234-8.7.7.1 The Ancillary Equipment MGTE Miscellaneous History Service Record shall contain pertinent historical and configuration data for which no other place has been provided. It is important for ships force and the technical community to maintain, access, and trend this data. Examples of these events include the high speed coupling shaft H&J alignment readings, resilient mount changeouts, FSEE (PWB) or (Hardware) replacement, exhaust collector inspection/repairs, inlet screen repair/replacements, vibration survey, full power data, realignment of engine/module, PLOE, LOCOP, PAMISE, ECU, GENERATOR and support items.

234-8.7.8 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.

234-8.7.8.1 Data on all equipment components or accessories that are required shall be recorded in this section of the Weblog. A list of components requiring entries for each equipment type of model has been promulgated by NAVSEA in GGTB Number 3. Equipment custodians shall update the MGTIS database through Weblog with new or changed component information.

234-8.7.8.2 Sound maintenance practices and safety considerations will dictate any additional items, other than those that are mandatory, that should be recorded in this section.

NOTE

For new construction ships that have MGTE and select diesels installed, the automated NAVSEA 9400/8 form for each engine at time of ship delivery shall have accurate entries for each selected component replaced subsequent to delivery of the engine by the engine manufacturer to the Government as Government Furnished Equipment (GFE) or to the shipbuilder as Contractor Furnished Equipment (CFE).

234-8.7.9 SUPPLEMENTAL RECORDS. The Automated 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 Weblog.

234-8.7.9.1 The activity initially accepting the equipment for the Navy shall ensure that the manufacturer provides properly completed original records or that the data is incorporated into the MGTIS database.

1. Turbine Rotor Disc Assembly Service data for gas turbine engines, gas generators, power turbines, and spare turbine rotor assemblies shall be received. Data is required for each turbine rotor disc or stage in the equipment. The supplying activity will update the MGTIS database with all pertinent data or supply the necessary data to NSWCCD-SSES.
2. Compressor Rotor Assembly Service data for gas turbine engines, gas generators, and spare compressor rotor assemblies shall be received. Data is required for the complete compressor rotor assembly in the equipment. The supplying activity will update the MGTIS database with all pertinent data or supply the necessary data to NSWCCD-SSES.

234-8.8 PROCESSING DATA FOR SUPPLEMENTAL RECORDS.

The rework activity performing maintenance on turbine or compressor rotor assemblies shall process the data as described in paragraphs 8.8.1 through 8.8.5.

234-8.8.1 When a turbine rotor disc assembly is to be reworked, the rework activity shall note the total number of operating hours in the MGTIS of the Turbine Rotor Disc Assembly upon induction of the equipment.

234-8.8.2 The latest MGTIS data shall then be used to appropriately reflect changes or actions occurring during rework. Upon completion of rework, the MGTIS database shall be updated to reflect modification information, new disc and/or blade times, and pertinent measurement.

234-8.8.3 When a compressor rotor assembly is to be reworked, the rework activity shall ensure that data associated with each stage and the shaft are properly recorded at the start of rework. The latest MGTIS data shall then be used to appropriately reflect changes or actions occurring during rework.

234-8.8.4 The single blade time entry for a stage shall reflect the total operating time of the oldest blade. This is particularly important when reblading occurs during rework and a mixture of new and used (or used blades with various operating times) are installed.

234-8.8.5 Upon completion of rework, The MGTIS database shall be updated to reflect modification information and new disc, blade, and shaft times.

SECTION 9

SAFETY PRECAUTIONS

234-9.1 GENERAL

234-9.1.1 To ensure safety, operating personnel must be thoroughly familiar with the technical manuals and other publications concerning equipment under their care. Safety guards shall be provided at exposed danger points and proper handling of tools and parts emphasized.

NOTE

Good judgment cannot be overemphasized when considering safety.

234-9.1.2 The generalized precautions listed in this paragraph shall be observed in operating and maintaining the gas turbine.

a. Do not attempt to operate the engine by wiring around or opening circuits to automatic shutdown or warning devices.

b. Disconnect batteries or other sources of electrical power before performing maintenance to prevent injuries from short circuits and accidental cranking of engines.

c. Avoid holding or touching sparkplugs, ignition unit, or high-tension leads while energized.

d. Use proper caution when cranking an engine by hand to preclude injuries to fingers or hands.

WARNING

Do not, under any circumstances, disconnect governors when operating or starting an engine.

e. Retain adequate speed control of power turbine by keeping fuel control and speed control governors connected together.

f. Do not use oxygen to pressure-test fuel passages.

g. Do not use compressed air to spin ball or roller bearings after cleaning.

h. Avoid prolonged contact with lubricating oil to prevent skin rash. All clothing that comes in contact with lubricating oil shall be removed and affected skin areas washed immediately. Areas in which lubricating oil is used shall be adequately ventilated to keep mist and fumes to a minimum. If lubricating oil is spilled on painted surfaces, these surfaces shall be washed to prevent softening of paint.

i. Immediately cap all exposed openings in fuel, oil, or air lines to prevent clogging or contamination. Do not use tape to seal fuel or oil openings. Tape adhesive is soluble in fuel or oil and can cause contamination.

j. Disconnect the main wiring harness from the ignition unit when priming the fuel control. This will prevent accidental firing of the engine.

k. Wear protective clothing as required to prevent contact with cleaning agents. Adequate ventilation shall be provided. Accidentally spilled acids shall be treated immediately according to prescribed remedial instructions. Open flames shall not be allowed within 15 meters (50 feet) of cleaning areas, and firefighting and safety equipment shall be readily available.

l. When cleaning an engine compressor, if a carbon removing compound comes in contact with skin, eyes, or clothing, flush areas with running water, and seek immediate medical attention.

m. When handling parts that have been exposed to fuels containing tetraethyl lead, ensure that the byproduct (poisonous lead oxide) is not inhaled or taken into the body through cuts or other external openings. If exposure occurs, drench affected area with water and obtain immediate medical attention. Protective clothing shall be worn at all times when handling contaminated parts.

n. Do not use cadmium-plated tools for any disassembly or reassembly procedures.

234-9.2 NOISE

234-9.2.1 Gas turbine engine-generated noise levels are on the order of 100 to 125 decibels. These levels are sufficient to cause partial or total deafness to unprotected personnel. Three primary noise sources exist in a gas turbine installation:

a. The inlet passages

b. The exhaust ducts

c. The engine core.

234-9.2.2 Noise from the first two sources, the inlet and exhaust ducts, can be controlled by the installation of acoustic insulation to the structure. To prevent negation of the soundproofing characteristics of structural acoustic insulation, the insulation must be constantly maintained at a high degree of repair.

234-9.2.3 Similar acoustic treatment shall be applied to engines mounted in a compartmentalized shroud or enclosure. If such an enclosure or shroud is not installed, the entire compartment in which the engine is installed shall be acoustically insulated.

234-9.2.4 In any case, personnel having to work in or on any duct, compartment, or enclosure not acoustically treated and containing an operating gas turbine engine must wear ear protection devices no matter how long the exposure to the engine-generated noise is anticipated to be.

234-9.3 FIRE

234-9.3.1 The possibility of a fire being started by a fuel line rupturing and spraying fuel on the engine hot sections is a hazard in gas turbine installation. To preclude such fire hazards, the precautions listed shall be observed:

a. Shield all equipment surfaces which could attain a temperature of 204°C (400°F) or higher, and where impingement of a flammable fluid on the surfaces is a possibility, when this would not interfere with the proper functioning of the equipment.

b. Equip engine modules, shrouds, and compartments with a fire detection and extinguishing system.

c. When a fire or excessive temperature is detected, installed automatic extinguishing equipment shall shut airtight all compartment or enclosure ventilation louvers and openings, except main inlet and exhaust ducts.

d. Activation of the fire detection and fire extinguishing system will activate alarm signals in the Central Control Station (CCS).

e. Fire extinguishing systems shall be equipped with both remote and local manual release and engine shutoff controls.

f. Once an engine has been shut down in a fire condition, the engine shall not be started again until a thorough inspection, in compliance with the manufacturer's operational manual, has been conducted and the cause identified and corrected.

234-9.4 SUPPORT PIPING SYSTEMS

234-9.4.1 Fuel and lubricating lines shall be shielded from engine hot surfaces. Piping shall be located to preclude crew members from standing on components to service other equipment. Piping and hose assemblies shall be tight without leaking. Hoses shall be clamped to avoid chafing.

234-9.4.2 Hose routing shall provide smooth radius bends without kinks in hoses. Figure 234-9-1 illustrates proper installation techniques for hose assemblies and Figure 234-9-2 illustrates proper hose installation routing and clamping techniques. Additional information on hose routing, securing, maintenance, and replacement is in **NSTM Chapter 505 Piping Systems** .

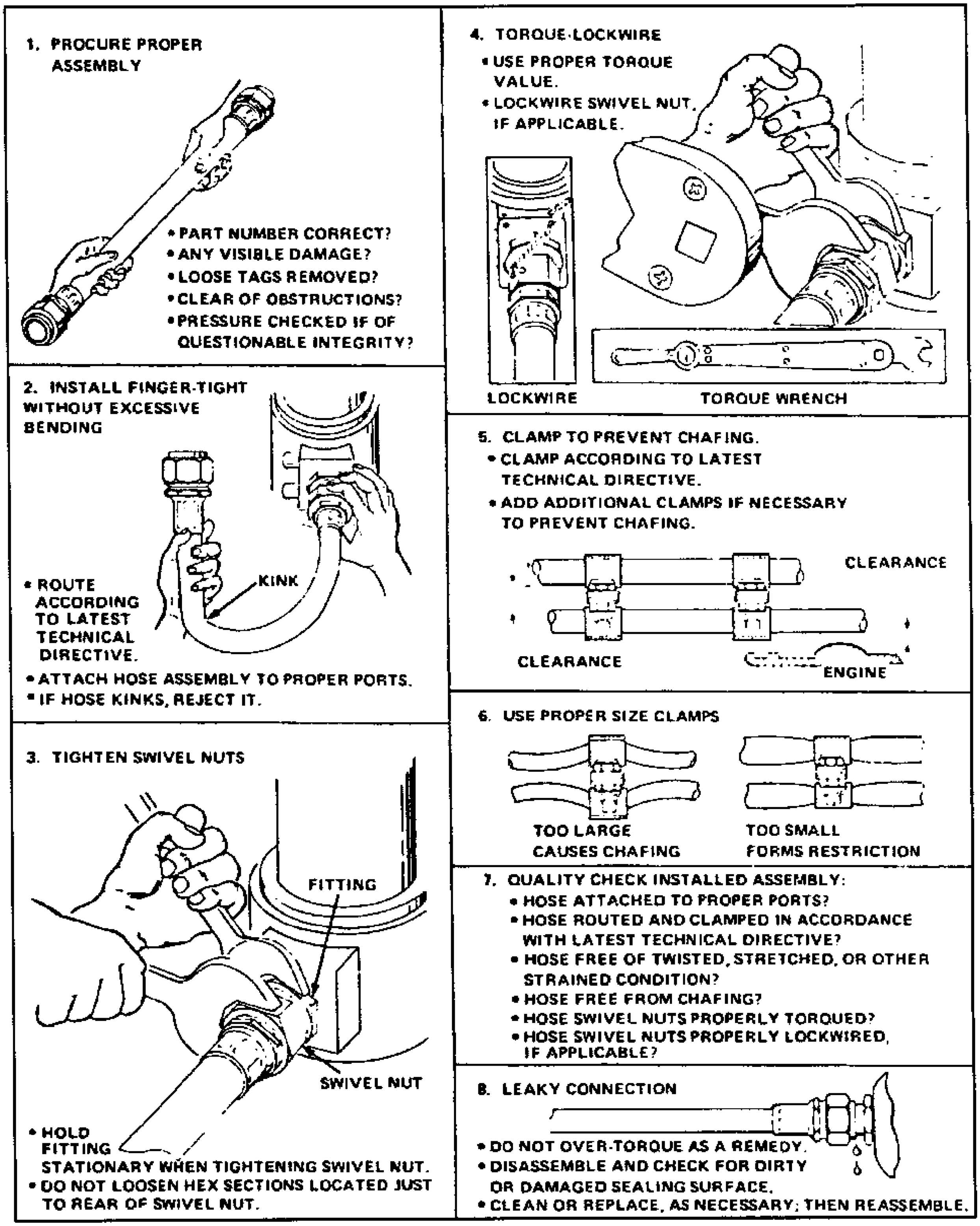

Figure 234-9-1. Proper Installation Techniques for Hose Assemblies

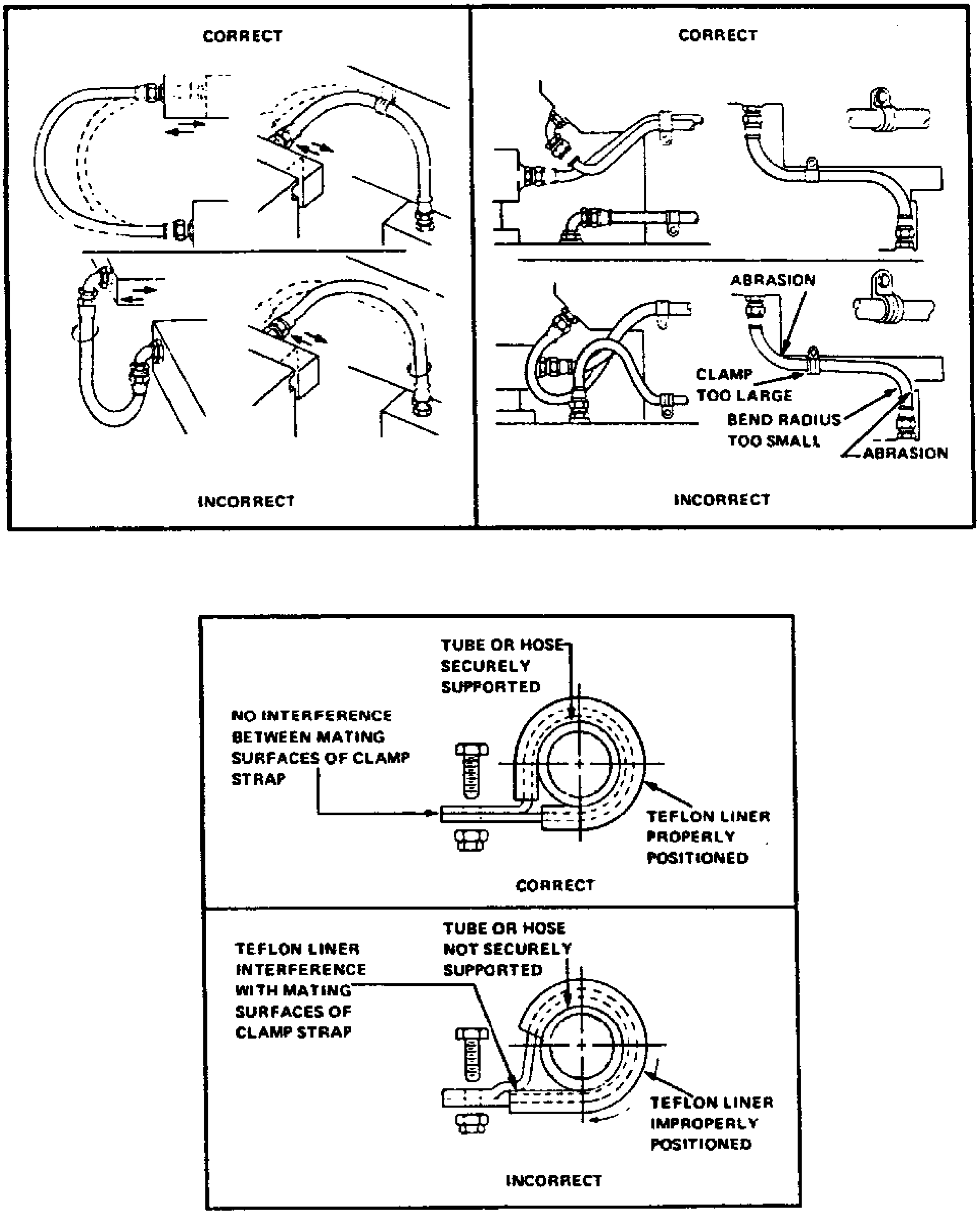

Figure 234-9-2. Hose Routing and Cushion Clamp Installation Techniques

234-9.5 ENGINE-INSTALLED SAFETY DEVICES

234-9.5.1 GENERAL. Various safety devices are installed on gas turbine engines, and safety wiring practices are in effect. Engine-installed safety devices are discussed in paragraphs 234-9.5.2 through 234-9.5.7.

234-9.5.2 TORQUE LIMITS. Several different gas turbine installations are equipped with a power turbine output torque computer. This device will vary engine speed and power to maintain power turbine below established limits, preventing output shaft failure. In installations not having an automatic activating torque computer, torque values will have to be monitored by operating personnel.

234-9.5.3 VIBRATION MONITOR. Most gas turbines are equipped with vibration sensors. Vibration sensors detect abnormal engine vibration usually indicative of a blade or disc failure. In most applications, high-vibration levels will activate an alarm system and initiate automated engine shutdown sequences.

CAUTION

In case of vibration-induced engine shutdown, the engine shall not be started again under risk of catastrophic engine failure.

234-9.5.3.1 An engine shutdown for high-vibration levels shall be borescoped to determine whether it should be removed and returned to the depot for tear-down and repair.

234-9.5.4 OVERSPEED PROTECTION. All gas turbine engines are protected by automatic overspeed governors that will limit gas generator and power turbine speeds below preestablished levels.
Should the overspeed governors fail to limit the gas generator or power turbine speeds to the nominal speed, an overspeed switch will shut down the engine fuel control.

234-9.5.4.1 Overspeed switches and governors shall not be bypassed for any reason. Activation of an overspeed reset will be required prior to further engine operation.

234-9.5.5 CONTAINMENT. Gas turbine engines are shielded from operating personnel to preclude personnel injuries in case of any failure of blades, blade attachment devices, discs, etc. that may penetrate the engine casing upon failure.

234-9.5.6 SAFETY-WIRING PRACTICES. Safety-wiring is used to prevent disengagement of parts by securing two or more threaded parts with wire so the tendency for the parts to loosen is counteracted by tightening the wire. Safety-wire is not intended to maintain torque values.

234-9.5.7 Examples of safety-wiring techniques are shown in Figure 234-9-3. Although all possible safety-wiring combinations are not shown, safety-wiring practices shall conform generally to those shown. Specific manufacturers' technical manuals shall be consulted for approved materials and techniques to be used with the engine in any given application.

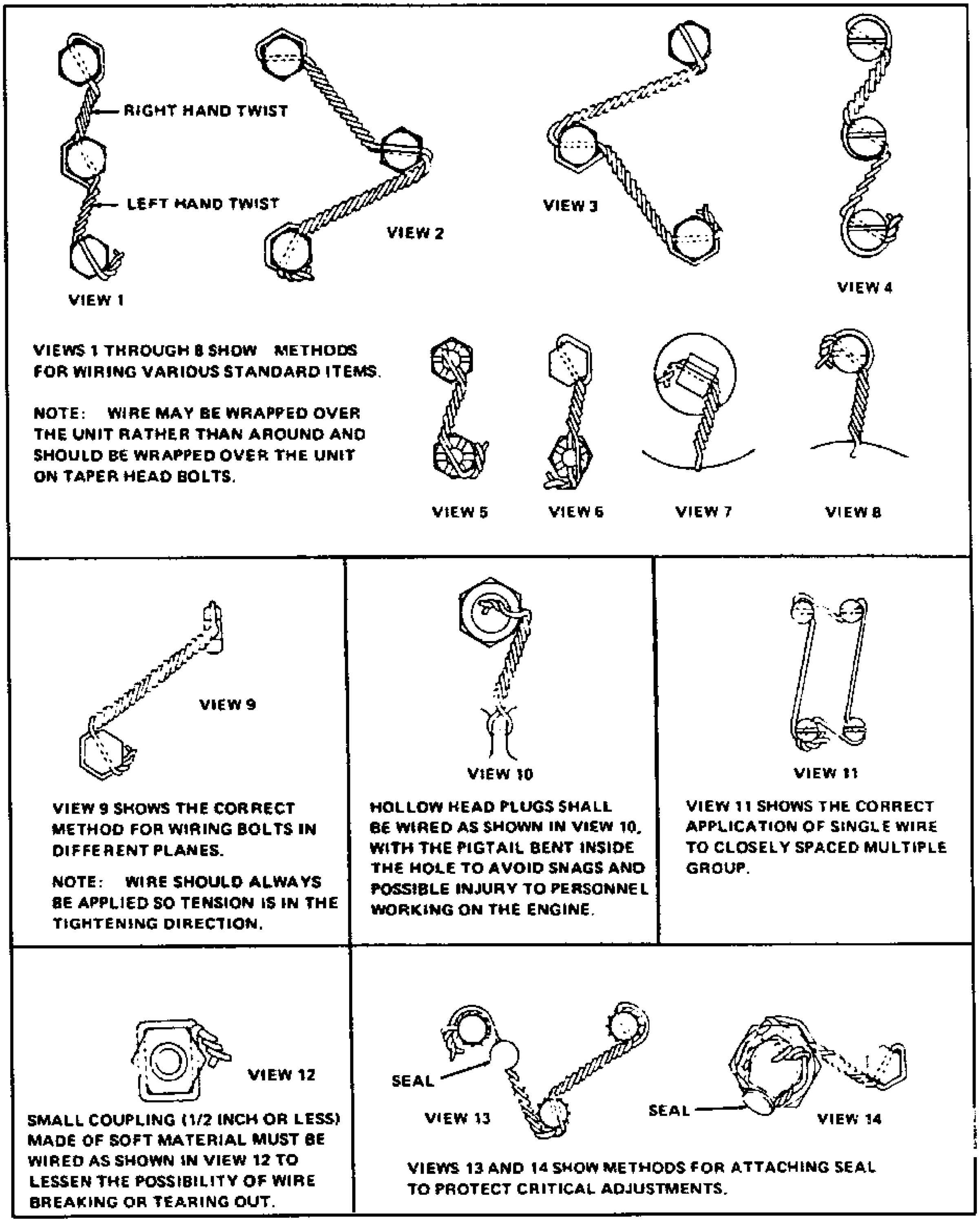

Figure 234-9-3. Safety-Wiring Practices (Sheet 1 of 2)

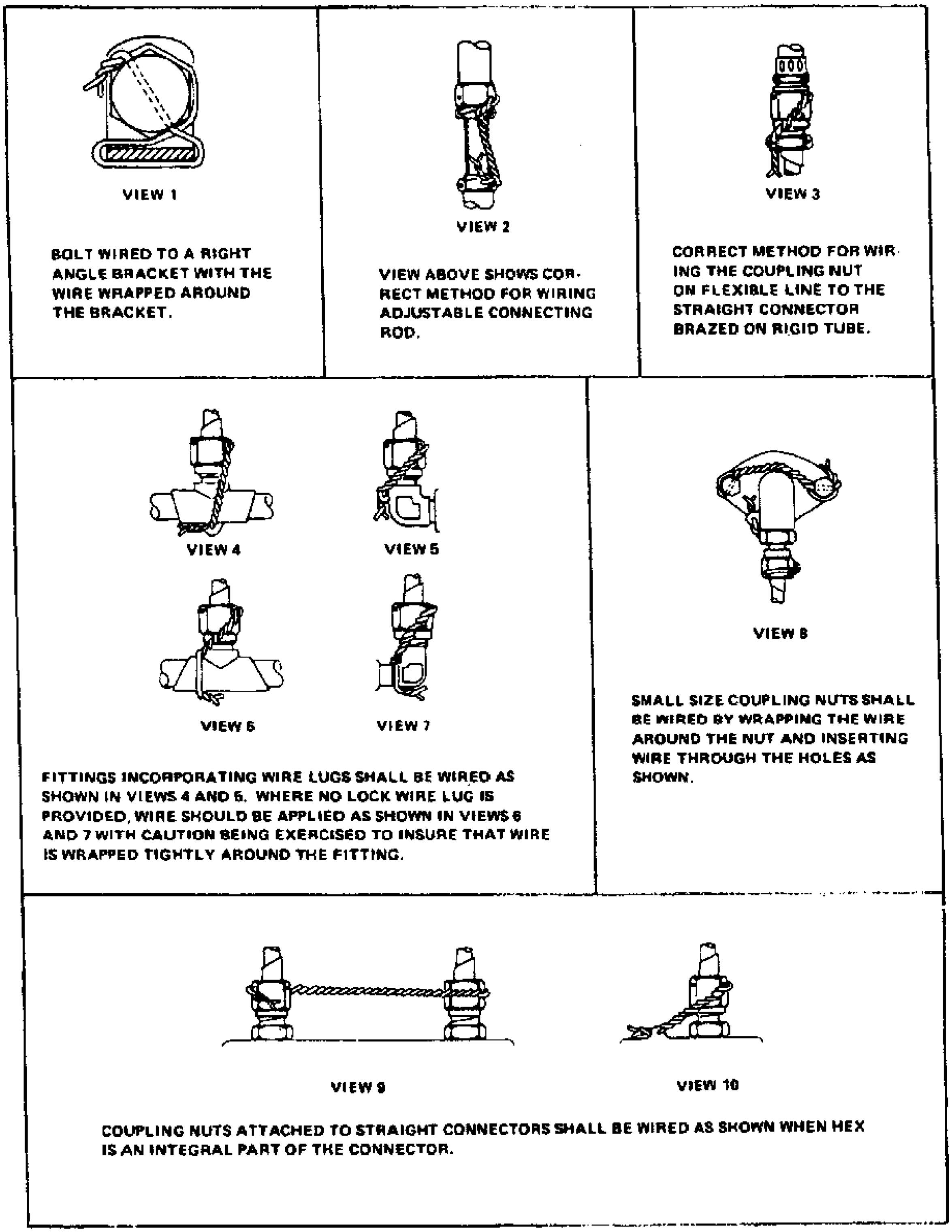

Figure 234-9-3. Safety-Wiring Practices (Sheet 2 of 2)

APPENDIX A

TECHNICAL MANUAL DEFICIENCY/EVALUATION REPORT (TMDER)

NOTE

Ships, training activities, supply points, depots, Naval Shipyards, and Supervisors of Shipbuilding are requested to arrange for the maximum practical use and evaluation of NAVSEA technical manuals. All errors, omissions, discrepancies, and suggestions for improvement to NAVSEA technical manuals shall be reported to the Commander, NAVSURFWARCENDIV, 4363 Missile Way, Port Hueneme, CA 93043-4307 on NAVSEA/ SPAWAR Technical Manual Deficiency/Evaluation Report (TMDER), NAVSEA Form 4160/1. To facilitate such reporting, print, complete, and mail NAVSEA Form 4160/1 below or submit TMDERS at web site https://nsdsa2.phdnswc.navy.mil/tmder/tmder-generate.asp?lvl=1. All feedback comments shall be thoroughly investigated and originators will be advised of action resulting therefrom.

TMDER / MAILER