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Printed in U.S.A.

ALLISON 501-K17 SSGTGS TECHNICAL DIRECTIVE EXPERIENCE



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ABSTRACT

The Allison 501-K17 Ship Service Gas Turbine Generator Set (SSGTGS) is used to provide ship board electrical power on several U.S. Navy Class ships, including the DD-963 Spruance Destroyer, the DDG-993 Kidd Guided Missile Destroyer and CG-47 Ticonderoga Guided Missile Cruiser Classes. The first of these units were placed in service during the mid 1970's. The Naval Sea Systems Command (NAVSEA) in conjunction with the Naval Surface Warfare Center, Carderock Division, Ship Systems Engineering Station (NSWCCD-SSES) have undertaken a major upgrade effort to improve the reliability, operation, serviceability and maintainability of the unit. This paper examines the process of this program and details the specific improvements made to the unit as a result of this effort. In addition, this paper outlines the experience gained as a result of installing these upgrades in the Fleet.

INTRODUCTION

The Ship Service Gas Turbine Generator Set (SSGTGS), or simply the Gas Turbine Generator Set (GTGS) is responsible for generating all ship board electrical power required for weapons, machinery and hotel services. Each ship is outfitted with three GTGSs, strategically located within watertight bulkheads below deck, to maximize the ship's survivability during battle conditions. All three units are connected together by a ring buss and load centers that distributes power throughout the ship. Figure 1 depicts a typical unit.

As installed, a GTGS can operate in one of the following manner, individually, paralleled with shore power or paralleled with another GTGS. While in port, the ship normally operates on shore power, with one unit in automatic stand-by mode, in case shore power is lost. While at sea, two SSGTGSs normally operate in parallel, sharing the load equally, to supply the ship's full electrical load. The third unit is placed in auto stand-by, ready to start automatically, in case either on-line units fails. In extreme cases, however, any one GTGS can be operated individually, to carry the entire ship's vital electrical load.

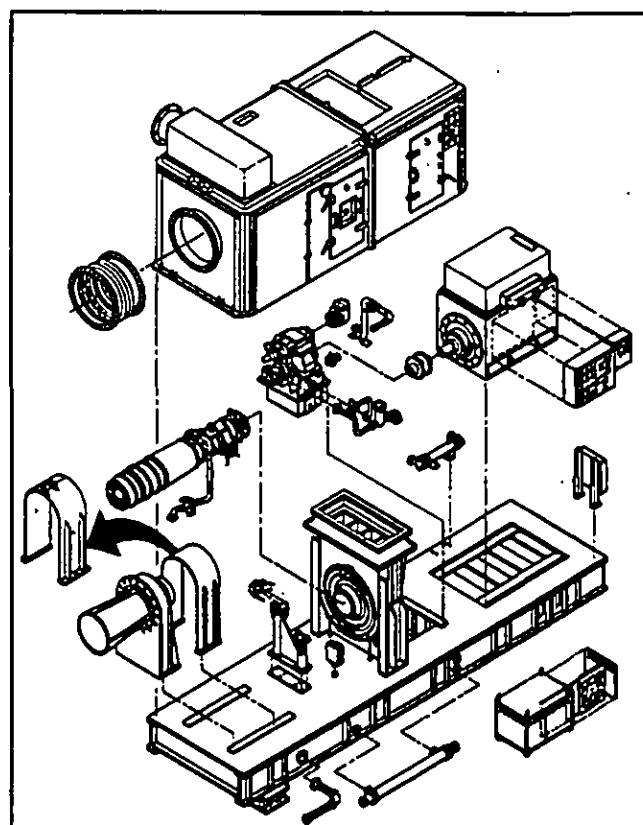


FIGURE 1. GAS TURBINE GENERATOR SET.

Each GTGS is a module consisting of a 501-K17 gas turbine engine, manufactured by Allison Engine Company, a reduction gear assembly, manufactured by Philadelphia Gear and an AC generator, manufactured by either Electro-Dynamics or Ideal Electric. The entire assembly is housed in

an acoustical enclosure, packaged by Stewart and Stevenson Services, Inc. The assembly also contains related ancillary components as well as engine control and monitoring systems, all mounted on a common base. Each GTGS module is equipped with an independent lubrication oil system, a sea water cooling system and supply, exhaust and cooling air ducting systems.

Many years ago, the Navy initiated an equipment improvement program for the GTGS. The purpose of the program was to improve the reliability, operation and maintainability of the unit. Through Fleet investigation, a list of potential problem areas was developed and corrected through the Component Improvement Program (CIP) and the development of Engineering Change Proposals (ECPs). The implementation of these changes is through a Technical Directive (TD).

BACKGROUND

The following section will discuss the major components of the GTGS module, including the gas turbine engine, the reduction gear, the AC generator and the local control panel (LOCOP). In addition, a brief description of the three different ship classes that use these units will be presented.

Allison 501-K17 Gas Turbine Engine

The Allison 501-K17 gas turbine is a single shaft axial flow engine, as shown in Figure 2. The major engine components include the compressor, combustion section, turbine assembly, power-take off (PTO) assembly and accessory drive unit.

The fourteen stage axial flow compressor consists of an air inlet housing, compressor rotor and housing and the diffuser. These serve to collect and compress the intake air and direct it to the combustion section.

The combustion section consists of six individual cylindrical shaped combustion liners equally spaced in a circle. The liners mix fuel with compressed air, control the combustion of the mixture and direct the flow of the hot gases into the turbine section. Fuel is sprayed under pressure into each combustion liner by a fuel nozzle mounted in each liner. The fuel air mixture is ignited by two spark ignitors mounted in two of the six liners. The flame propagates to the other liners via crossover tubes which connect each liner to both of its neighboring liners. The turbine assembly consists of a four stage turbine rotor and vane assembly, turbine inlet casing, turbine vane casing and rear turbine bearing support. As the hot gases expand, the rotor absorbs the necessary energy to drive both the compressor rotor and the engine mounted accessories. The remaining energy is used to drive the reduction gear.

The power-takeoff assembly consists of a power-takeoff shaft, shaft adapter, speed sensor pickup and mid bearing assembly. This assembly transmits the engine torque to the reduction gear. The accessory drive unit is driven by the compressor rotor, through a bevel gear and radical shaft arrangement. It serves as a mounting point for the main pressure and scavenge oil pump, oil filter, fuel pump, governor actuator, speed sensitive valve and external scavenge oil pump. The overall engine design specifications are outlined in Table 1.

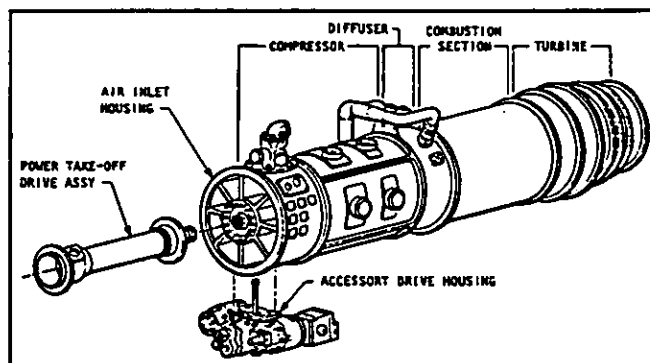


FIGURE 2. ALLISON 501-K17 GAS TURBINE ENGINE.

Table 1 - Allison Gas Turbine Engine Design Specifications

Description	Design Specification
Model	501-K17
Weight	1,495 lbs [678.12 kg]
Dimensions	89.22"L x 24.63"W x 29.20"H [2.27mL x 0.63mW x 0.74mH]
RPM @ 60 Hz	13,821 rpm
Shaft Horsepower @ 100%	2,886 hp (min) [2,153 kW]

Reduction Gear

The reduction gear is a single reduction, 3,000 hp, single helical gear-type speed reducer, with a reduction ratio of 7.678 to 1. The design of the gear is over/under, vertically offset and parallel shaft configuration. The reduction gear is coupled to the AC generator by a diaphragm type flexible coupling. The gear box transmits power from the gas turbine, which rotates at 13,821 rpm to the AC generator, which rotates at 1,800 rpm.

AC Generator

The AC generator is a totally enclosed, salient pole, two bearing air cooled type unit. The generator is driven at 1,800 rpm by the reduction gear. On the DD-963 Class, the SSGTG is designated as the Model 104. The AC generator for this Class supplies 2,000 kilowatts of regulated, 450 volt, three-phase, 60 Hz power, with a power factor of 0.8. Its rated full load current is 3,207 amperes. On the DDG-993 Class, the SSGTG is designated as the Model 119 and on the CG-47 Class, as the Model 139. Both of these AC generators supply 2,500 kilowatts of regulated, 450 volt, three-phase, 60 Hz power, with a power factor of 0.8. Their rated full load current is 4,009 amperes.

Generator Local Control and Operating Panel (LOCOP)

The LOCOP, as shown in Figure 3 is mounted to the side of the generator enclosure. The gas turbine generator local control and operating panel provides the start and stop sequencing to the GTGS. In addition, it provides monitoring and alarms for critical turbine and generator operating parameters, signal conditioning for the panel meters and data transmission to the Engineering Control and Surveillance System. The internal control logic cards, panel meters and indicator lights are powered by 28 VDC supplied from either the switchboard or batteries. The SSGTG can be operated remotely from the Central Control Station (CCS), or locally within the engineering space, at the LOCOP.

Although all three LOCOPs operate in a similar manner, there are several differences that exist between the Model 104, 119 and 139 sets. The major difference revolves around the type of control logic that is used. The Model 104 and 119 LOCOPs utilize an older relay logic system to control the engine. The Model 139 LOCOP however utilizes a computer based microprocessor logic system to control the engine. In addition, the Model 104 and 119 LOCOPs are housed in a carbon steel enclosure, where as the Model 139 is housed in a stainless steel enclosure.

The Spruance, Kidd and Ticonderoga Class Ships

The Spruance (DD-963), Kidd (DDG-993) and Ticonderoga (CG-47) Class ships were designed with the same hull, propulsion and auxiliary systems. All three classes use a similar GTGS design, that includes the Allison 501-K17 gas turbine engine. The Model 104 and Model 119 GTGSs are virtually identical, with the exception that the Model 119 has been equipped with an upgraded AC generator. This upgrade was accomplished via a shipboard modification, known as Ship Alteration (Shipalt) 109. This Shipalt replaced the existing 2,000 kW generator, with the 2,500 kW unit used in the CG-47 Class. The upgraded generator was required to enhance the capability of the weapon systems for the DDG-993 Class. Although all three model GTGSs are functionally the same, they are not configured the same. These differences lead to numerous logistics, maintenance and operational challenges. One of the focuses of this improvement program is to correct these differences.

501-K17 GTGS TECHNICAL IMPROVEMENT PROGRAM

The purpose of the 501-K17 GTGS Technical Improvement Program is as follows:

- To correct any design inadequacies and develop design modifications to improve and refine engine performance, reliability and maintainability.
- To correct logistics and supply problems by raising all GTGSs to a common baseline configuration.
- To test and install state-of-the-art hardware and to replace all high failure items.
- To investigate and resolve Fleet problems through product testing and analysis and by developing design and procedural refinements.

The following section will describe the improvement process used by NSWCCD-SSES and will discuss a number of improvements that were developed as a result of this program.

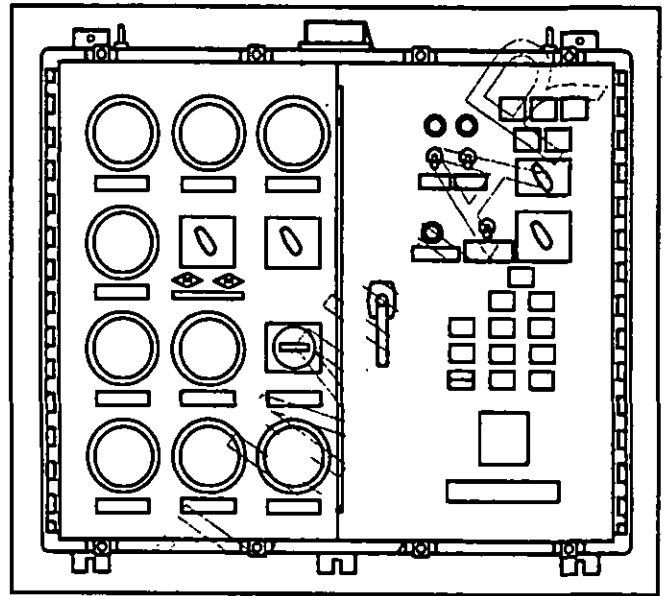


FIGURE 3. MODEL 104 LOCOP.

Improvement Process

The major goal of this improvement program is to identify and correct design deficiencies. The method used for this refinement process has been set forth by NAVSEA. Once a potential design improvement is identified through either Fleet investigation or Land Based Engineering Site (LBES) testing, an Engineering Change Proposal (ECP) is developed. The purpose of the ECP is to define the proposed hardware change or modification, to outline required removal and installation instructions and modification kit contents, and all cost estimates related to the change. Once developed, a prototype modification kit is assembled and installed in the Fleet.

Following a predetermined evaluation period, the ECP and kit contents list are modified, if required, and submitted to NAVSEA for review and approval. The ECP process is the only formal means of introducing a design modification or improvement for NAVSEA cognizant equipment. Once submitted, the ECP is reviewed for technical accuracy, cost effectiveness and feasibility. After successful review, the ECP is brought before a Joint Configuration Board (JCB) for formal approval. If approved, modification kits (if required) are procured by NAVSEA. A Technical Directive, all appropriate Advance Changes Notices (ACNs) and Provisioning Technical Documentation (PTD) are then developed by the originator of the ECP.

Technical Directives. The Technical Directive is a document that is issued by the cognizant NAVSEA Code, which directs the accomplishment of design changes or inspections. The TD is developed from the ECP. It provides detailed removal, installation and modification

instructions, with related figures, as well as a list of kit contents. Technical Directives are broken down into two types; physical design modifications, and bulletins, which are one time inspections. TDs are further broken down according to their application as either Ancillary Equipment Changes (AYCs), Gas Turbine Changes (GTCs) or Special Equipment Changes (SECs). AYC's cover design modifications made to the accessory equipment, GTCs cover changes made directly to the gas turbine engine and SECs cover changes made to tools and other special support equipment. Once the TD is written, it is forwarded to NAVSEA for their review and approval.

Verification Process. The prime objective of the TD verification process is to provide the Fleet with the most accurate detailed instructions of a new component or a modification to an existing component. NAVSEA provides the verifying activity(ies) with a copy of the preliminary TD and the modification kits. In addition, NSWCCD-SSES provides the ship with an Interim Support Package (ISP). The verifying activity then uses the preliminary TD to install the modification kits, while verifying the TD for technical accuracy, ease in installation and modification kit contents. Verification comments are later submitted to NAVSEA, who reviews the comments and updates the TD and kit contents list, if required. Based on these comments, NAVSEA also determines whether any additional verifications are required, or if the TD is ready of issue. After the verification process is complete, a final draft of the TD is provided to the verifying activity (ies) for comment, prior to issuance. Each TD is written for either Organizational Level (O-Level), Intermediate Level (I-Level) or Depot Level installation. Once the TD is issued by NAVSEA, it is the responsibility of the Fleet to install the TD.

Interim Support Packages (ISP). To address the need for shipboard documentation to support these Technical Directive verifications, an ISP is provided during each installation. An ISP is a vehicle to provide logistic technical data to the engineering community on an interim basis, until the final logistic support is in place. The ISP contains a table of contents, description of change, point of contact list, interim document stamp, supply support and technical documentation. In addition, it includes maintenance and configuration information, drawings, operational changes and a sign off sheet. These ISPs are normally presented to the Chief Engineer (CHENG) and Main Propulsion Assistant (MPA) onboard ship. These ISPs have been very well received and provide valuable information needed for maintenance and troubleshooting of the modified GTGS.

Advance Change Notices. Advance Change Notices (ACNs) are changes to the technical manuals, which are provided to the Fleet in advance of issuing formal changes to the manual. When verifying a TD, the applicable ACNs are part of the ISP and when a TD is issued by NAVSEA, the ACNs accompany the TD. The ACNs are officially incorporated into the technical manual either through a change package or a revision to the manuals. Depending upon the complexity and applicability of the change, many technical manuals can be affected by the ECP or TD. These ACNs are developed by the originator of the ECP or TD and submitted to NAVSEA for technical approval and issuance.

Provisioning Technical Documentation. Provisioning Technical Documentation (PTD) either introduces the new items or identifies an additional requirement for existing items in the supply system as a result of the ECP. The PTD is developed by the originator of the ECP,

after official notification of ECP approval. All PTD's are submitted to NSWCCD-SSES for review, who then submits them to the Navy Inventory Control Point (NAVICP) for implementation into the stock system.

Prior to NAVSEA issuing a TD, all modification kits (if required) need to be on the shelf, to support Fleet requisition. In addition, NAVICP must ensure that supply support is available for the end item. Also, NAVSEA must issue all appropriate ACNs at the same time the TD is released. In essence, all supply support and technical documentation must be in place before a TD can be released. The TD remains in effect until all affected ships report compliance of this change, at which point, the TD is rescinded by NAVSEA.

The following is a summary of major TDs that have been written for the 501-K17 GTGS:

Thermocouple Monitor System (AYC4)

The purpose of this directive is to provide instructions for the installation of a thermocouple monitor system for the Model 104, 119 and early 139 GTGSs. The purpose of the thermocouple monitor system is to provide the means to track temperatures at the exit of each of the six combustion liners, compute the average of these temperatures and to determine the difference between the hottest and coldest combustion liners. In addition, the system also monitors for defective thermocouples. This system was installed on the CG-51 and follow, during construction and has been verified and installed on several DD-963 Class ships, without problems.

5th and 10th Stage Bleed Air Control Valve (AYC25)

The purpose of this directive is to replace the existing 5th and 10th stage bleed air control valve, with a new valve that is more reliable. The TD is written for all three model GTGSs. The new valve has already been verified and installed on several DD-963 and CG-47 Class ships, without problems. The TD is currently ready for issue.

Replacement of 14th Stage Bleed Air Valve (AYC26 and 27)

The purpose of this directive is to modify the 14th Stage Bleed Air Valve to incorporate a quick closing capability for the Model 119 (AYC26) and Model 104 (AYC27) GTGSs. The modified valve is designed to remove the stress from the 14th Stage Bleed Air Manifold and to minimize the premature failure of the manifold. This directive was written as a result of the valve's high failure rate. In addition, the modification enables the valve to become Turbine Overspeed Protection Systems (TOPPS) compatible. To date, AYC27 has been successfully verified and installed on several DD-963 Class ships and the TD is currently ready for issue.

Installation of Model 39E152-4A Starter (AYC28)

The purpose of this directive is to provide instructions for the installation of the improved Model 36E152-4A (Model 152) air turbine starter. This starter provides a more reliable replacement for existing Model 36E129-2S (Model 129) starter. The Model 129, which is currently not available in the federal stock system, has proven to be unreliable over a period of time. In addition, the 129 starter is also on the top ten failure items list. This TD has already been verified and installed on several CG-47 Class ships, including the USS Thomas S. Gates (CG-51) and the USS Leyte Gulf (CG-55), with great success. A sister TD, AYC23 installs the new starter on the DD-963 Class ships. These directives are installed

and CG-47 Class ships, with great success. The TDs are currently ready for issue.

This directive provides instructions for the installation of the status indicator panel. This panel, as shown in Figure 4, provides a visual indication of start inhibit, 2,200 rpm, 600°F, 8,400 rpm, 12,780 rpm, 1,500°F and 1,600°F. This panel is used by maintenance personnel while troubleshooting the LOCOP and to reduce the time required to conduct rpm and temperature tests. This panel is mounted directly to the front of the LOCOP, for the Model 104 and 119 GTGSs. This modification has been installed during LOCOP overhauls and has received an overwhelming favorable response from the Fleet. The TD is currently ready for issue.

This directive provides for the lubrication of the generator and reduction gear bearings prior to an engine start. The six journal bearings located in the generator and reduction gear are currently not lubricated during startup. Installation of this prelube system supplies lube oil to these bearings during startup, which result in extended bearing life. This directive covers the Model 104, 119 and early Model 139 GTGSs. A prototype system was installed on board the USS Thorn (DD-988). This installation encountered several problems, most of which involved the generator side pump. As a result, both the ECP and TD were revised and re-submitted to NAVSEA. The revised ECP was later installed on the USS David Ray (DD-971), USS Caron (DD-970), USS Conolly (DD-979), USS Spruance (DD-963) and USS Hancock (DD-981) with good success. NSWCCD-SSES plans to convert the earlier prototype system on board the USS Thorn to the final version. in the near future.

This directive provides instructions for the installation of the Low Pressure Start Air System. The system replaces the existing Low Pressure Air Start Valve and provides a means to start the GTGS using bleed air at a regulated pressure of 45 psig. The TD is broken down into two parts; Part 1 covers the Models 104 and 119 and Part 2 covers the Model 139 GTGSs. This directive has already been installed on several CG-47 Class ships, including the CG-51 and CG-55 and on the USS Caron (DD-970), with great success. The main problems encountered to date, were a result of different GTGS module configurations. As a result, some of the piping and support hardware had to be field fitted. This directive is installed concurrently with AYC28 - Installation of Model 39E152-4A Starter and AYC46 - Installation of Improved High Pressure Air Start System.

These directives provide for the installation of a piston liquid fuel valve (PLFV), a compressor discharge pressure (CDP) sensor and associated hardware. The present configuration consists of a liquid fuel valve which uses a diaphragm based CDP section. The diaphragm is prone to failure, which limits the amount of fuel supplied to the engine. This limits the load carrying capability of the GTGS and will cause the engine to shut down on underspeed. The new configuration provides for a liquid fuel valve which uses a piston configured CDP section that has a higher reliability. AYC41 and GTC30 are installed concurrently. The TD is broken down into two parts; Part 1 covers the Models 104 and 119 and Part 2 covers the Model 139 GTGSs. These directives have been installed on numerous DD-963

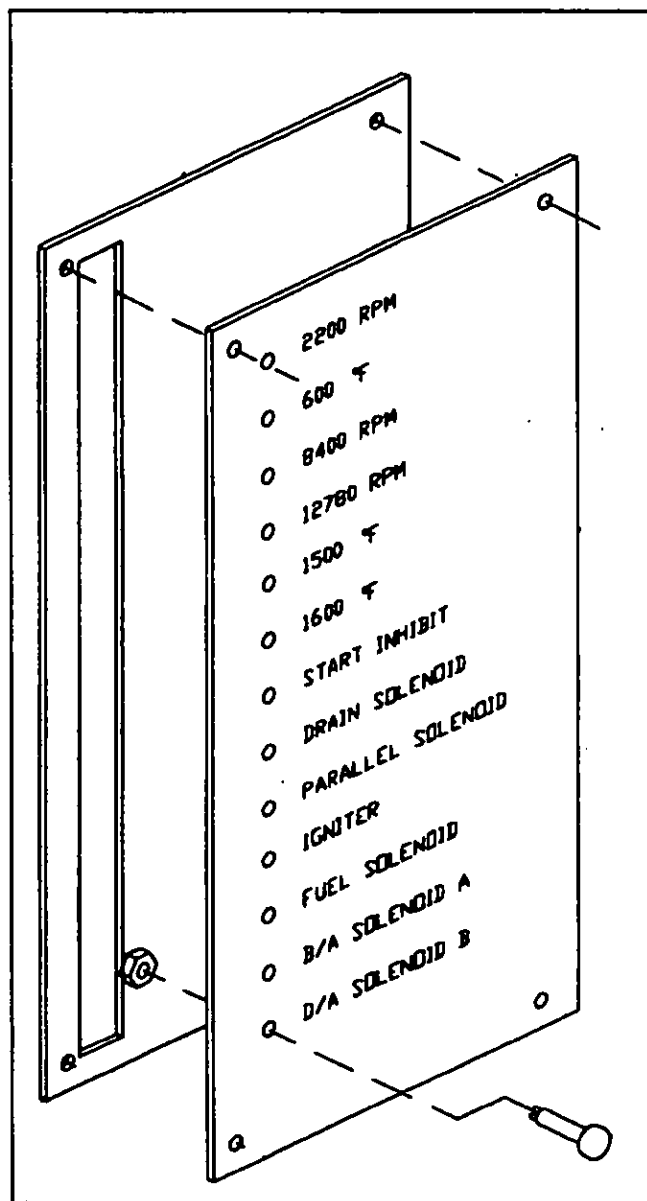


FIGURE 4. STATUS INDICATOR PANEL.

This directive details the removal of the existing engine side mount and the installation of an improved side mount assembly. The old mount was prone to failure. This new mount design eliminates binding corrosion in the bearing surfaces and the side mount bracket. In addition, the side mount arm with left and right hand thread permits easy adjustment for alignment purposes, because it requires no shims. The rod end bearing is also one size larger than the original one which should lower the stress and increase its

service life. Also, the side mount bracket has been designed to accommodate the new split outer combustion case. This directive has already been verified and installed on several DD-963 and CG-47 Class ships, with good success.

Remodification of Engine Wiring Harness (AYC44 and GTC32)

These directives provide instructions for the installation of a standardized engine harness and the engine module-to-LOCOP cables for the Model 139 GTGSs. In addition, the directives relocate the compressor inlet temperature (CIT) sensor from the inlet plenum to the engine inlet. These directives are required due to wire harness discrepancies encountered during engine field change outs. The incompatibility of the CG-47 module, due to various harness configurations results in the reapplication of the former harness during change out. Cannibalization of the damaged engine prevents checkout during overhaul and introduces uncertainty of the condition of the harness to the new asset. Both AYC44 and GTC32 are installed concurrently and have been verified and installed on several CG-47 Class ships, including the USS Thomas S. Gates (CG-51) and the USS San Jacinto (CG-56) with good success. The only problems encountered to date are a result of differences that exist in the wiring of the LOCOPs. More specifically, some LOCOPs are not wired in accordance with the technical manual and require some minor field wiring modifications.

Installation of Improved HP Air Start System (Grove) (AYC46)

This directive provides for the removal of the existing high pressure (HP) start air valve and related piping system. The directive installs the improved Grove HP start air valve and associated piping and is required to correct the numerous HP start system failures. This system is designed so single components can be removed instead of disassembling the complete assembly to remove one component, which provides for ease in maintenance. The new Grove valve improves the start capability by providing more consistent starts and is more reliable than the existing valve. In addition, the bypass valve handle and pressure gauge have been moved outside of the module for personnel safety during manual starts. This TD covers the Model 139 GTGS. Both the Model 104 and 119 are already configured with the Grove HP system. This directive has already been verified and installed on several CG-47 Class ships, with great success.

Installation of LOCOP Lockout Circuit Card (AYC55)

This directive provides instructions for the installation of a circuit card in the Model 139 LOCOP which eliminates potential lock-up of shutdown and alarm functions. The modification improves the survivability of the GTGS during power fluctuations. By depressing the lock-up push-button, located on the front face of the LOCOP, the engine control system can be quickly reset. This modification increases the reliability of the unit, by eliminating the need to shutdown the unit if it becomes locked up. This directive has been verified and installed on several CG-47 Class ship, with great success.

Master Technical Directive.

The Master Technical Directive (MTD) is a compilation of various technical directives that are installed on the Model 104 GTGS. For clarity, they are broken down into the two following directives:

Installation of New Fuel Control System (GTC-19). This directive is a consolidation of three major related GTCs. It provides instructions for the installation of a new fuel filtering system, which is

comprised of two 10 micron fuel filters; one single element and one double element with pressure switches for each. This modification replaces the existing single 25 micron fuel filter and should reduce fuel nozzle clogging and improve engine performance.

GTC-19 also provides instructions for the installation of a new closed loop turbine inlet temperature fuel scheduling system. This improvement incorporates the GT-400 Governor System and associated engine components. It provides increased engine temperature control through electronic fuel metering during engine startup and temperature limiting, while maintaining the existing 60 Hz GTGS operational capability. The old configuration provided for a mechanical engine startup based upon a proportional CDP based oil signal to the liquid fuel valve. Excessive engine failures have resulted from erratic engine temperature control during startup.

Finally, the directive provides instructions for the installation of a new engine wiring harness. This harness is designed to connect the latest configuration components to a fixed attached location at the governor mounting.

Installation of Closed Loop Control Governor, Service Switch, Fuel Filter LP Pressure and Chip Detector Indicators and LOCOP Cable Nr. 24 (AYC-22).

This directive provides instructions for the installation of the Cable Nr. 24, service switch, single and dual low pressure fuel filter indicators, chip detector indicator and the closed loop governor control modifications. The magnetic chip indicator modification provides for indication on the LOCOP front panel of excessive metal chips in the engine accessory gearbox. The present configuration has no LOCOP indication. The service switch improvement provides for the disabling of the low and high pressure start valves, ignitors and fuel shutoff valve from inside the LOCOP, to perform speed and temperature simulations. The present configuration requires that the cannon plugs for the starters, ignitors and fuel shutoff valve be disconnected prior to testing. The single and dual low pressure fuel filter indicator modification provides for indication on the LOCOP front panel when either fuel filter becomes clogged. The present configuration has no indication on the LOCOP.

To date, the Master TD has been installed on seventeen DD-963 Class ships, with great success. During installation, several hardware problems have been encountered. The majority of the hardware has been stored for many years and some of the electronic equipment has degraded. As a result, all hardware is inspected and tested prior to installation. In addition, several shipboard related problems have been encountered. These problems have been addressed on a ship to ship basis. NSWCCD-SSES and Fleet Technical Support Center - Pacific (FTSCPAC) installation teams have become quite versed in this installation and usually solve all installation and operational problems. Most ships are quite pleased with the installation and report that their GTGSs have never operated so well in the past.

SUMMARY AND CONCLUSIONS

Overall, the 501-K17 GTGS improvement program has been quite successful in solving many of the Fleet's equipment related problems. With this program, the Navy has been successful in developing technical directives and modification kits and in providing Interim Support Packages that include needed logistics information and training. With many of the previously described technical directives either already issued or ready for issue, NAVSEA and NSWCCD-SSES are ready to move onto newer Fleet concerns.

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