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The Allison 570/571 Gas Turbine For Patrol Boat Power

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ABSTRACT

This paper discusses the use of 570/571-KF engine in patrol boat propulsion applications. The text is composed of two basic sections — 1. The Engine, and 2. The Applications:

The engine section includes a brief review of the background and development of this free turbine engine, as well as a description of the main components and design features. The performance characteristics and fuel consumption rates are discussed relative to patrol missions.

In the applications section a comparison is made of the current 570 installations (both civil and military), along with a survey of the planned applications. Finally a review of proposed uses of these engines in other naval vessels is included to show the adaptability of this size engine in FPB and PB missions, and demonstrate the feasibility of retrofitting other turbine or diesel powered patrol boats with 570/571-KF engines.

The conclusion is drawn that for patrol boats with conventional or modified hull forms, the Allison 570/571 engines are well suited due to their excellent performance and power density ratios.

INTRODUCTION

The Allison Gas Turbine Division of General Motors Corporation has influenced the marine industry with the application of the Model 570 and 571-KF gas turbines as propulsion engines. These engines, nominally rated for continuous operation at 6350 HP and 7694 HP respectively are being used in modern military vessels where high power and low weight are essential.

This discussion describes both versions of the similar engines and then turns toward the various applications. A review of each existing and selected application will be followed by the proposed new installations, as well as the retrofits suggested.

The summary points out the increasing selection and use of the 570-KF and 571-KF engines for marine propulsion. As the engines accumulate service time their application to new marine vessels will increase as well.

DISCUSSION

THE 570-KF AND 571-KF ENGINES

History and Background

The 570-KF as shown in Figure 1 is an aircraft derivative light weight modern technology marine gas turbine. It was originally designed from several General Motors research projects aimed at uprating the aircraft turboshaft engines being produced at Allison as depicted in Figure 2. Those efforts included compressor development, and a program for optimizing an annular combustor coupled with an air cooled turbine design. The result was the 501M62 engine.

The next generation was the XT701-AD-700, selected by the U.S. Army to power the tri-engined Heavy Lift Helicopter. Re-direction in 1976 produced the initial 570-K design which incorporated several design changes to cost reduce and marinize the engines. The elements of these changes were to replace the forged titanium compressor cases with stainless steel castings, utilization of a radial flow inlet housing, and several shafting and bearing changes.

The first marine installation was in 1983 on the "Shergar," (Figure No. 3) a CODAG ocean yacht. Applications since then will be reviewed in subsequent sections.

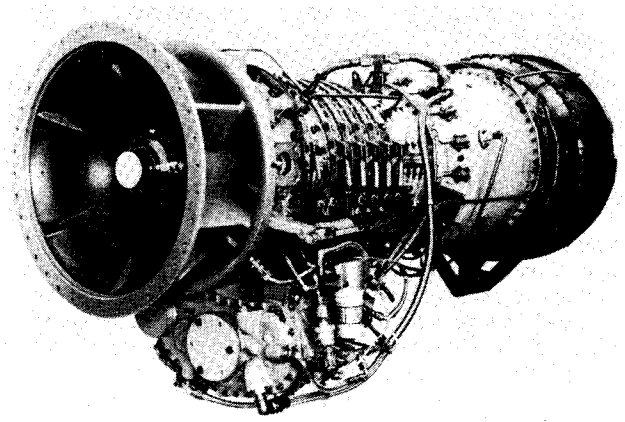

FIGURE 1.

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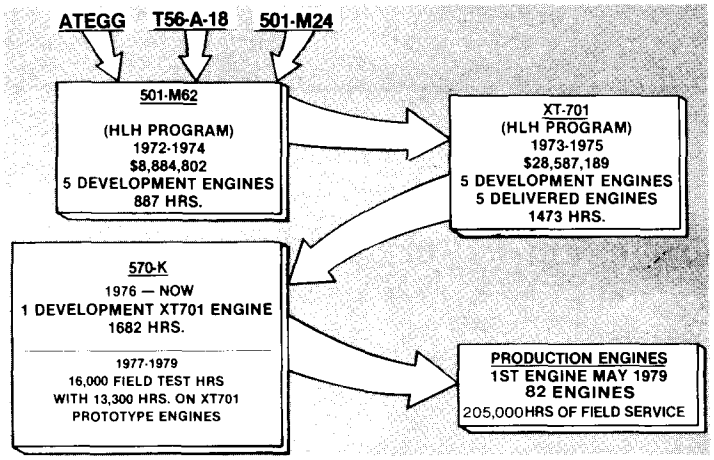


FIGURE 2.

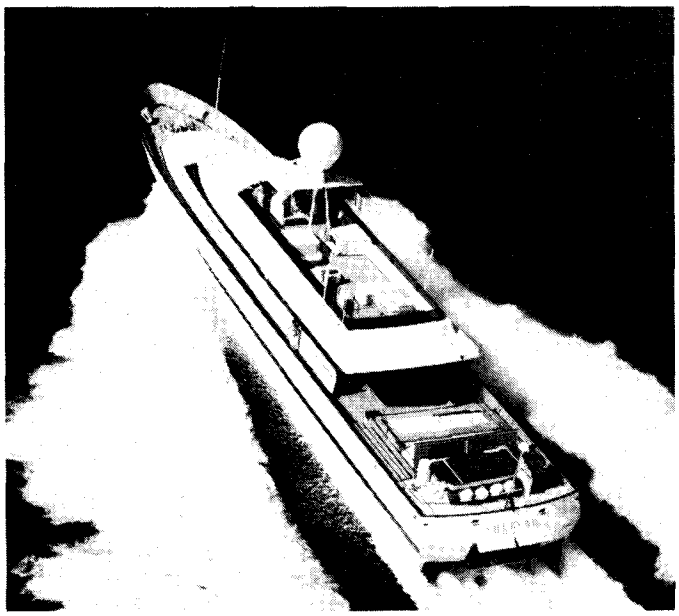


FIGURE 3.

Description

The 570-KF is a 6350 HP free turbine engine. The unit weighs 1677 pounds and is 78 inches long by 36 inches high. The cold end drive shaft operates in the clockwise direction at a nominal speed of 11,500 RPM.

Design features include a thirteen stage, axial flow, 12:1 Rc compressor, which incorporates six stages of variable geometry; a film cooled annular combustor; and an aircooled two stage gas generator turbine. The two stage power turbine is thrust balanced and drives forward through the gas generator rotor to the output flange.

The engine has a remote analog electronic control to monitor engine inlet conditions, gas temperatures, rotor speeds, oil pressures and vibration. The control outputs are voltage signals to adjust compressor variable vane position and fuel flow. This auto-diagnostic control also includes alarm and indicator channels for incorporation into panel monitors and controls. Fuel is introduced into the combustion liner via sixteen airblast fuel nozzles. The fuel system is designed to operate on DF2 marine fuel, conforming to Specification MIL-F-16884G, as well as MIL-T-5624G, ASTM-D-1655, and ASTM-D-2880.

The 570-K engine has completed a 1000 cycle salt ingestion test, under the auspices of the U.S. Navy, conforming to standard MIL-E-17341C which demonstrates the salt environment capability of the design. Also, a new combustion liner was developed for the Canadian Navy which reduced visible smoke to a level below 84 reflectance, a requirement of spec MIL-E-17341C, paragraph 4.4.5.

Early 570-K engines experienced mainshaft bearing lives which were less than desired. That design utilized a thrust balancing hydraulic system in conjunction with a ball bearing on the power turbine shaft. After an extensive investigation the design was changed to incorporate a tilting pad thrust bearing with directed lubrication. The thrust bearing is placed aft of the power turbine rotor and readily carries the 6000 pound axial thrust loads. This change improved the bearing lives by a 5:1 ratio. Figure No. 4 shows the design change and includes a photograph of the thrust pad arrangement.

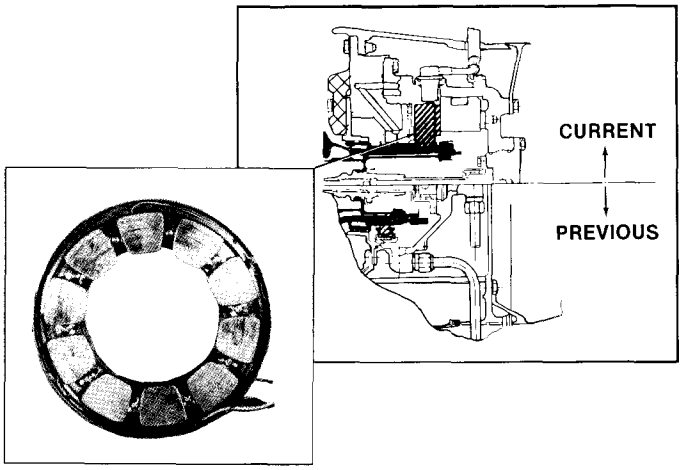


FIGURE 4.

The 571-KF, as shown in Figure 5, was introduced in January 1986 and is very similar to the 570-KF. The primary difference is that the power turbine is designed with three stages to increase the engine efficiency and power. Also the compression ratio is higher at 12.7:1, since the nominal 100% gas generator speed is increased 4%. These differences allow a 21% increase in power at the measured gas temperature of 1477 °F, accompanied by a 14% improvement in specific fuel consumption, while maintaining necessary compressor surge margin.

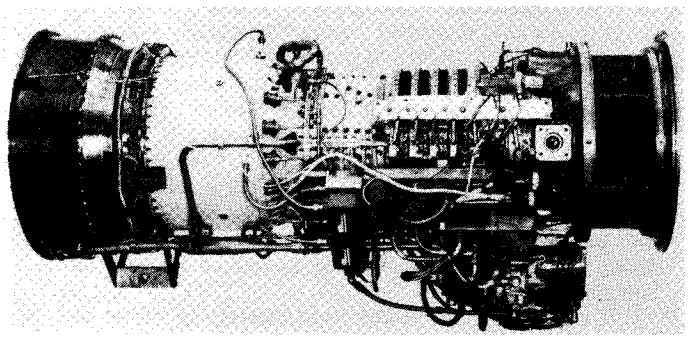


FIGURE 5.

Performance

The 570-KF and 571-KF engines are nominally rated at 6350 HP and 7694 HP respectively. These ratings are based on standard ISO conditions of 59°F air, sea level atmospheric pressure, with zero inlet duct loss and zero exhaust back pressure. Table 1 compares the engines' operational characteristics at rated conditions:

TABLE 1

Parameter	570-KF	571-KF
Tamb — °F	59	59
Pamb. — PSIA	14.7	14.7
SHP Nominal, Max. Continuous	6350	7694
Gas Gen Rotor Speed — RPM	14,286	14,879
Power Turbine Rotor Speed — RPM	11,500	11,500
Measured Gas Temp. — °F	1477	1477
Fuel Consumption Pounds/SHP-HR	.466	.408
Gal./HR	424	448

Since patrol missions typically include a loiter at low speed cruise power levels accompanied by occasional sprints at high power, the optimum engine should be fuel efficient over a wide power range. Figure No. 6 depicts the 570 and 571-K engines operating over a range of power levels at 80°F from 3000 to 8000 SHP and demonstrates the fuel efficient capability of the free turbine design.

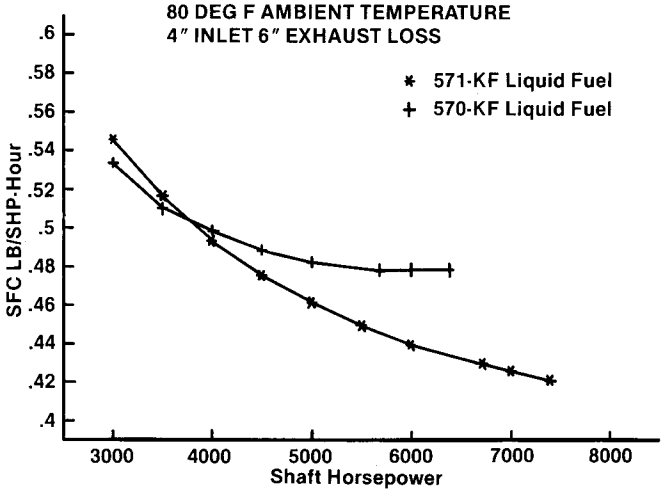


FIGURE 6.

APPLICATIONS

Existing Installations

As previously mentioned the first 570-KF installation was a 42 meter private ocean yacht built by Lurssen. This application utilizes a pair of 570-KF engines combined through an A.P.E. Allen gearbox to drive a 10,000 KW KaMeWa waterjet pump. The gas turbine drive is used with a pair of diesel driven 'wing jets' for the CODAG boost mode. Figure No. 7 shows the craft and Figure No. 8 the compact engine installation.

The initial installation paved the way for selection of the 570-K by military operators. The next installation was the Swedish Navy's "HMS Stockholm" Fast Attack Craft built by Karlskronavarvet. The "Stockholm" is 60 meters long and with a GRP hull displaces 320 tons. Figure No. 9 shows the craft on sea trials. Propulsion is a single 570-KF, along with diesel cruise engines, each driving a KeMeWa fixed pitch propeller. The design provides long range cruise capability as well as 38 knot high speed operation when required. Since this latest

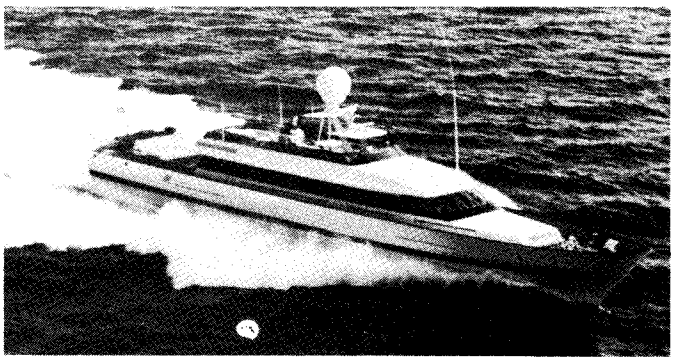


FIGURE 7.

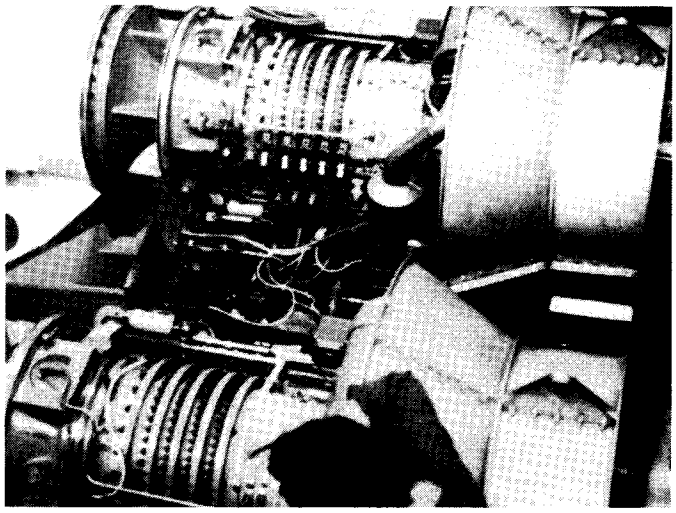


FIGURE 8.

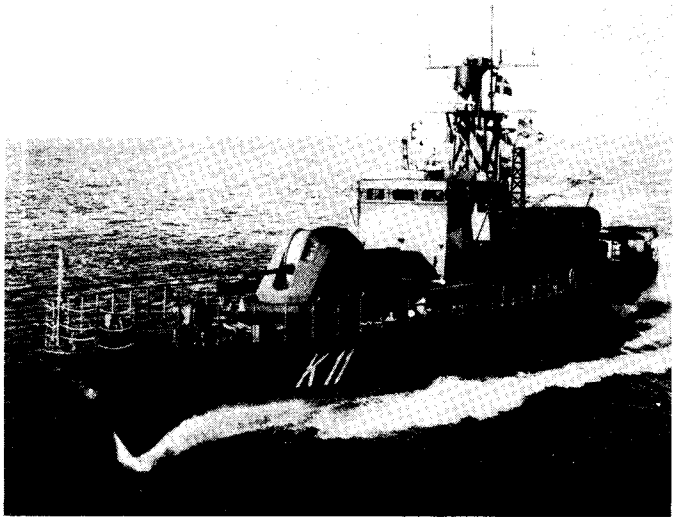


FIGURE 9.

installation is very recent, little data exists to gauge its performance.

570-KF Selections

Eleven Model 570-KF engines have been delivered to the Canadian Department of National Defense for the 'Tribal Class Update and Modernization Program' in which the Iroquois Class Destroyers, shown in Figure No. 10, will receive new cruise engines. Figure No. 11 shows the relative location of the 570-KF engines in the ships. These vessels are approximately 129 meters in length, and displace 5000 tons. Cruise speed from the pair of 570-KF's is expected to be 21 knots. Selection by the Canadian Government marks a new level of confidence in the 570-KF as a military propulsion engine, where reliability and performance are a must.

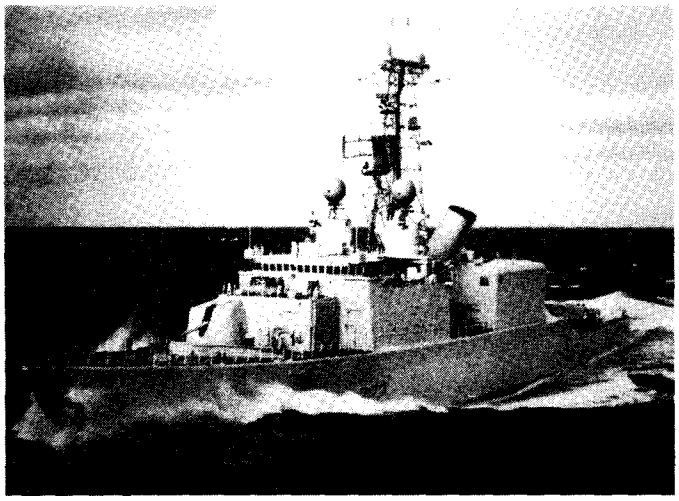


FIGURE 10.

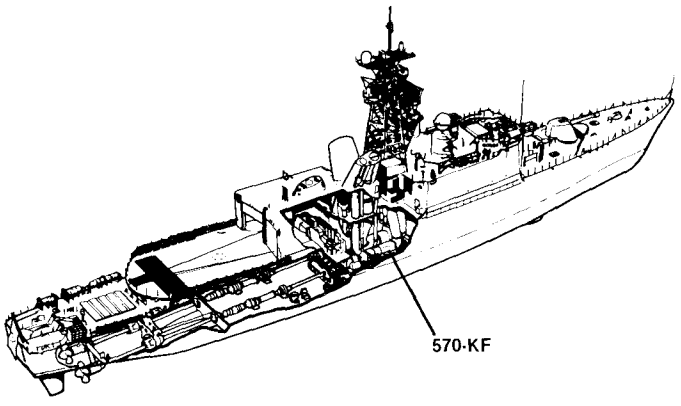


FIGURE 11.

The U.S. Navy has identified a Surface Effects Ship, among other hull forms, for the Multi-Mission Patrol Combatant Role (PXM) in their "Conform" study. This vessel as depicted in Figure No. 12, will probably use the 571-KF marine gas turbine in a two engine or four engine configuration, depending on the final size. Now in the acquisition program, this type vessel will be operational in the early 1990's.

In 1984 the H3 Research and Development Group Ltd. organization changed their high performance patrol boat design to use 571-KF power. Named the Super H3, this planning hull

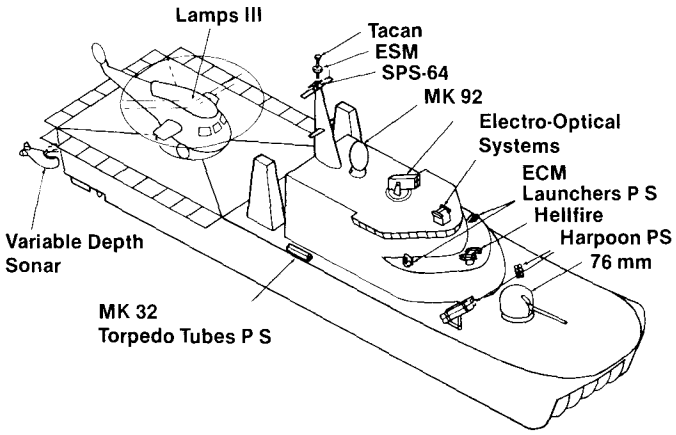


FIGURE 12. (PROCEEDINGS OCT 1985)

fast patrol boat shown in Figure 13 will use three drive modules, each containing a 571-KF engine, and a double reduction Cincinnati Gear Co. epicyclic gearbox driving a KaMeWa water jet. Figure No. 14 shows the mechanical arrangement. This powerful boat is designed for 50 + knot speeds with a full load of fuel and munitions. The Super H3 is a private venture anticipated for international marketing by the H3 group. The selection of a shipyard to build the craft is currently in process.

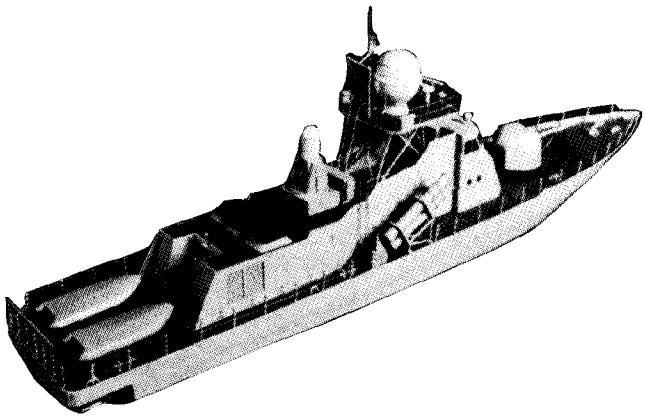
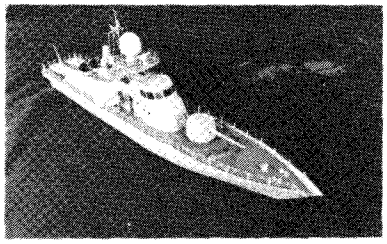


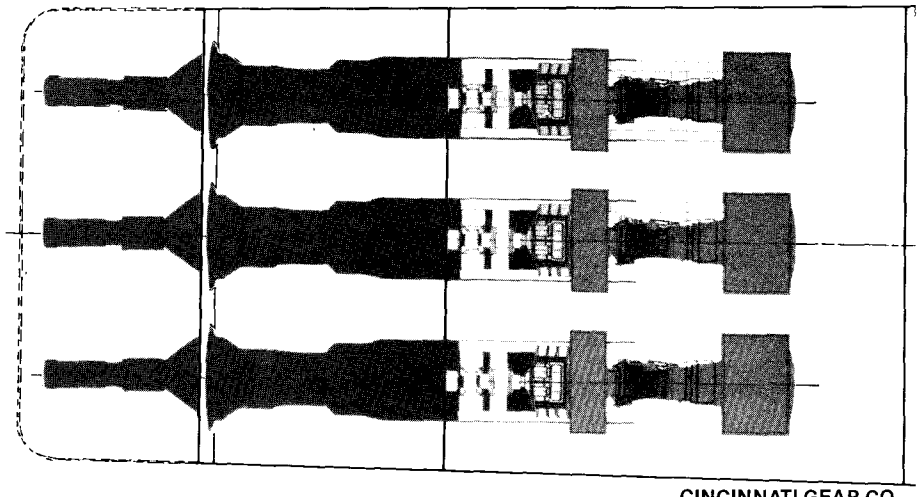
FIGURE 13.

The high power density 570/571 engines are also planned for military service in the British Hovercraft BH7 MK20 amphibious vessel, as shown in Figure No. 15. The mechanical arrangement is to drive a split reduction gearbox downward for lift fan power and upward for propeller drive, per Figure No. 16. This application is a multi-role/single platform design in which several missions could be handled depending on equipment selection. The first vessel is anticipated by late 1986.

Proposed Installations

A recent 570-KF proposal is to the Danish Government for their "Standard Flex 300." This is a multi-role hull design of GRP, which would utilize a 570-KF and two diesels in a CODOG arrangement. The design becomes the basis for use in various roles such as surveillance, MCM, Minelayer, Missile Boat, etc., depending on which containerized system is fitted to the common hull.





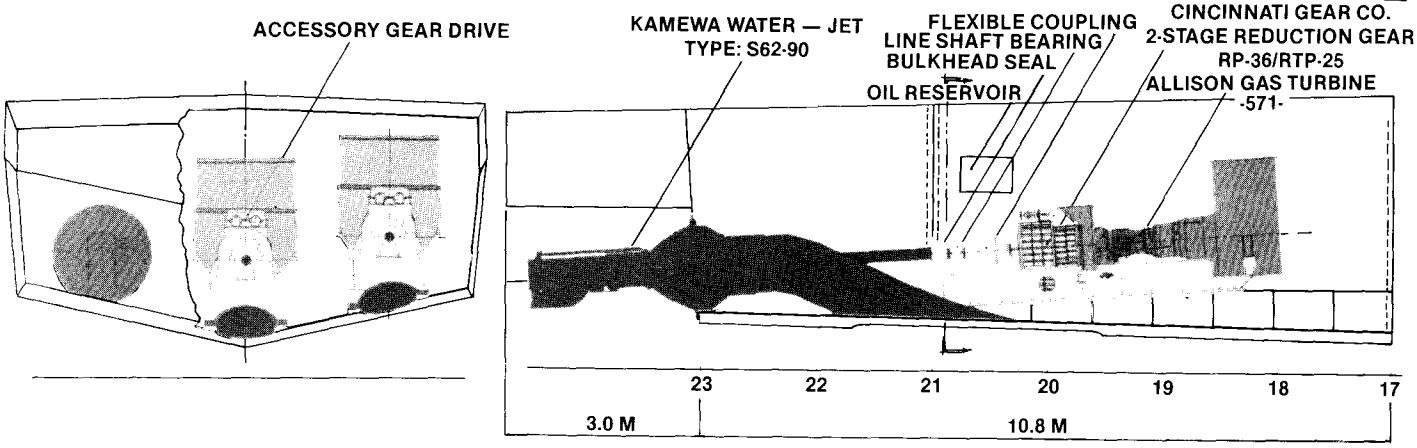


FIGURE 14.

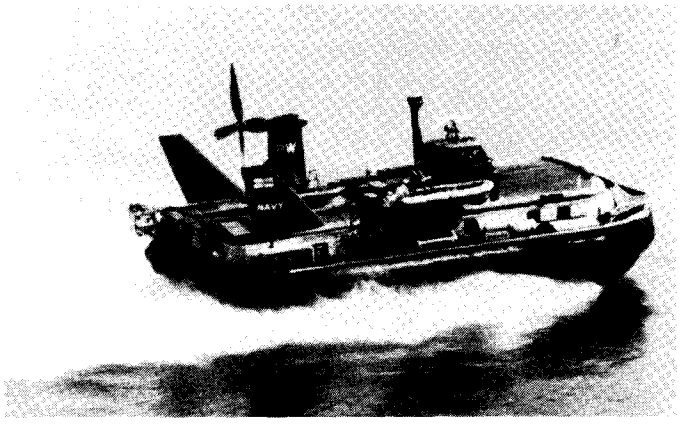


FIGURE 15.

The 570-KF engine has been proposed to power a modified S.E.S. type craft called the "Air Ride 200." This unique aluminum hull design combines the control and maneuverability of a "vee" hull form accompanied by the low resistance benefits of air cushion technology. In this case a 200 foot craft would use two 570-KF engines and double reduction epicyclic gears to drive controllable pitch propellers or waterjets, as shown in Figure No. 17. The other unique feature of this design is that the engine airflow provides the air cushion! Exhaust air is ducted into the cushion space and at 1 psig will provide enough lift to support the hull while cruising at 47 knot speeds.

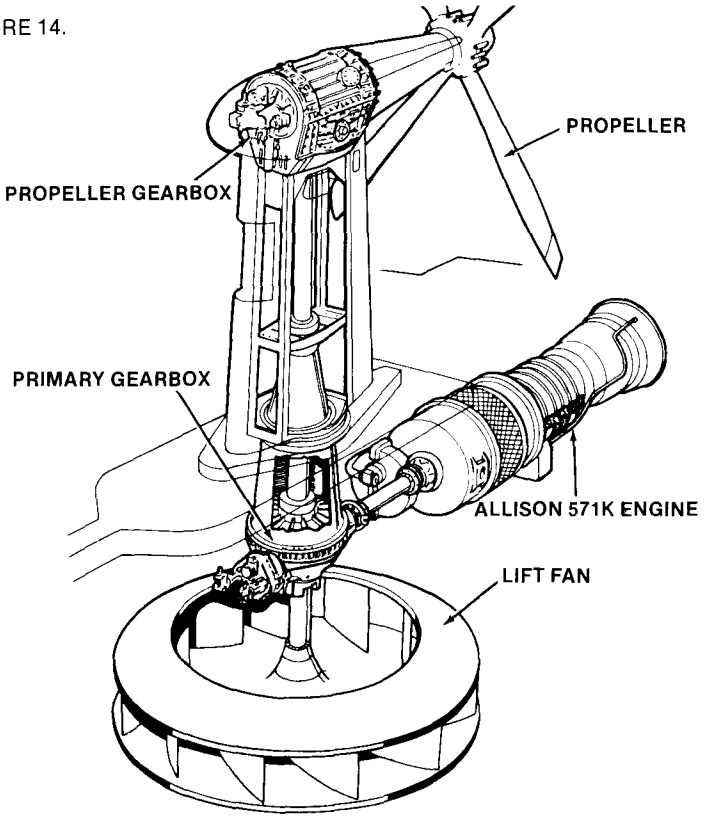


FIGURE 16.

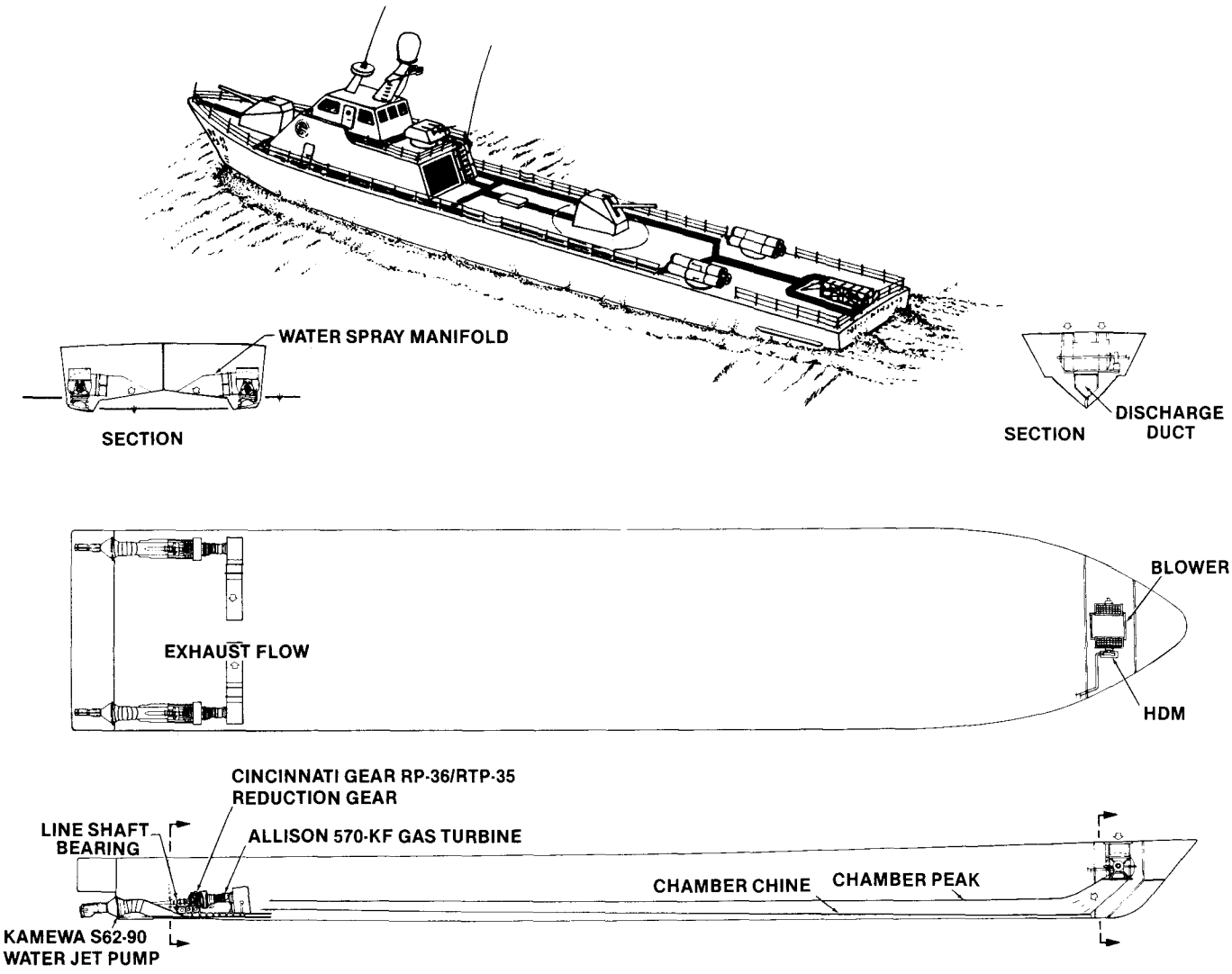


FIGURE 17.

For Corvette/Light Frigate size patrol craft a COGAG arrangement has been designed. Shown in Figure No. 18. This drive module would contain a pair of 570-KF or 571-KF engines close coupled to a Cincinnati Gear Company combining gearbox which incorporates an SSS clutch and a Franco TOSI reversing coupling for each engine. The output is a single prop shaft supporting a fixed pitch propeller. This dual engine arrangement allows efficient application of 6,000 to 16,000 HP from a single module. Variations of this scheme have been proposed for vessels up to 1500 tons. The 4 engine version is shown in Figure No. 19.

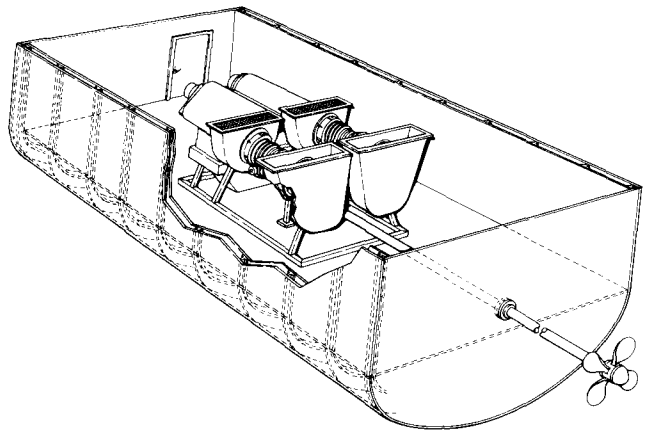


FIGURE 18.

Suggested Retrofits

In a joint effort with Cincinnati Gear Company it was proposed to re-engine the U.S. Navy's S.E.S. 200 vehicle as it was being recently readied for European deployment. A pair of

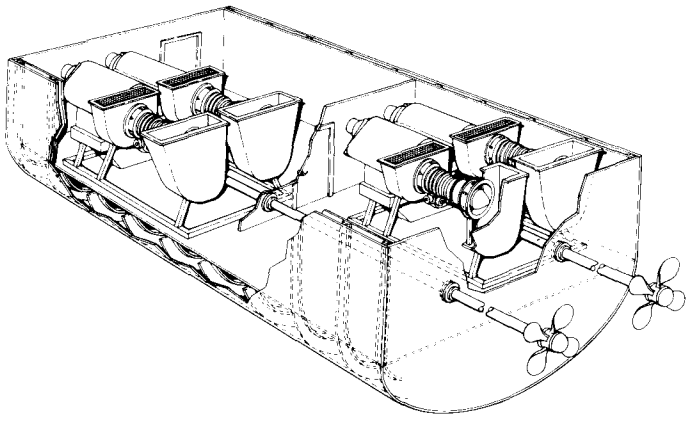
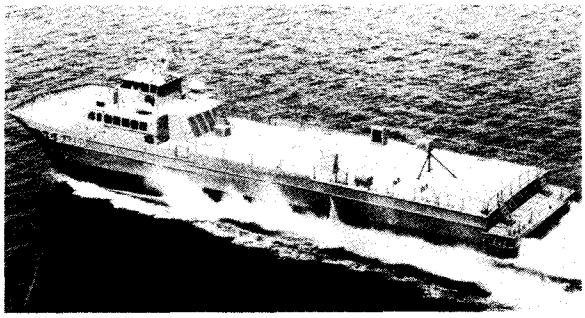
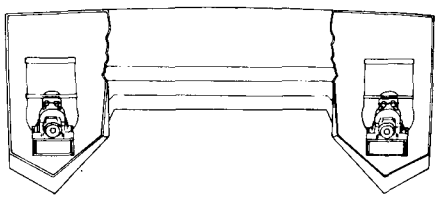


FIGURE 19.

570-KF engines would drive double epicyclic gears and LIPS controllable pitch propellers. The machinery arrangement is shown in Figure No. 20. This propulsion design will give this unique vessel the capability of 50 knot speeds in sea state 3.

Another proposal was made to replace two diesel drives with a single 570-KF engine in a passenger or military hydrofoil, the Rodriquez "RHS 200," per Figure No. 21. This application requires twin propeller shafts that are three meters apart. In order to maintain their position a gearbox was required to evenly split the 570-KF power, yet be lightweight and small enough to fit the hull. After several design considerations the optimum arrangement turned out to be a CODOG drive as shown in Figure No. 22. The diesel provides dock side and auxiliary power as a 200 HP unit, while the 570-KF provides 6000 + HP for foilborne operation. The bevel/reduction drives are designed by A.P.E. Allen Gears and output to the existing Zanradfabrik Friedrichshafen Model BW755S reversing vee drives, thereby maintaining the hull/shaft interfacing. The net effect of this





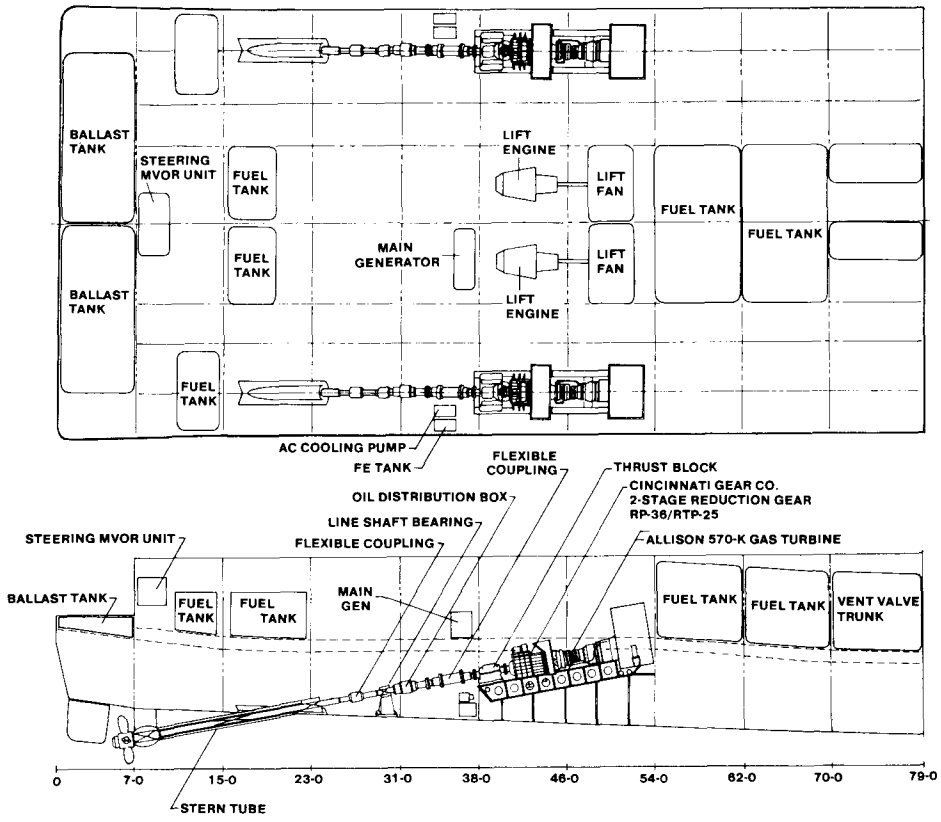


FIGURE 20.

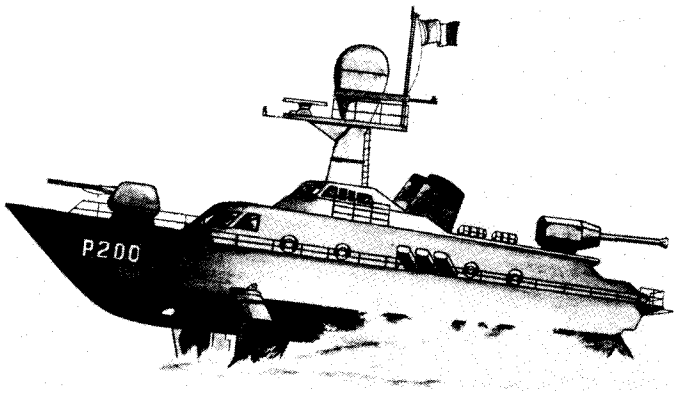


FIGURE 21.

arrangement was to uprate the hydrofoil from 4000 to 6000 + HP capability, while reducing the displacement more than 7 tons.

Also a proposal was made to re-engine the Boeing Marine System designed, Italian built, Sparviero Class Hydrofoil Boats used by the Italian Navy. The layout in Figure No. 23 shows the appropriate size of a 570-KF in the Sparviero engine room if connected to the existing waterjet. This arrangement would uprate the vessel from 4500 to 6000 + HP and optimize the foilborne performance.

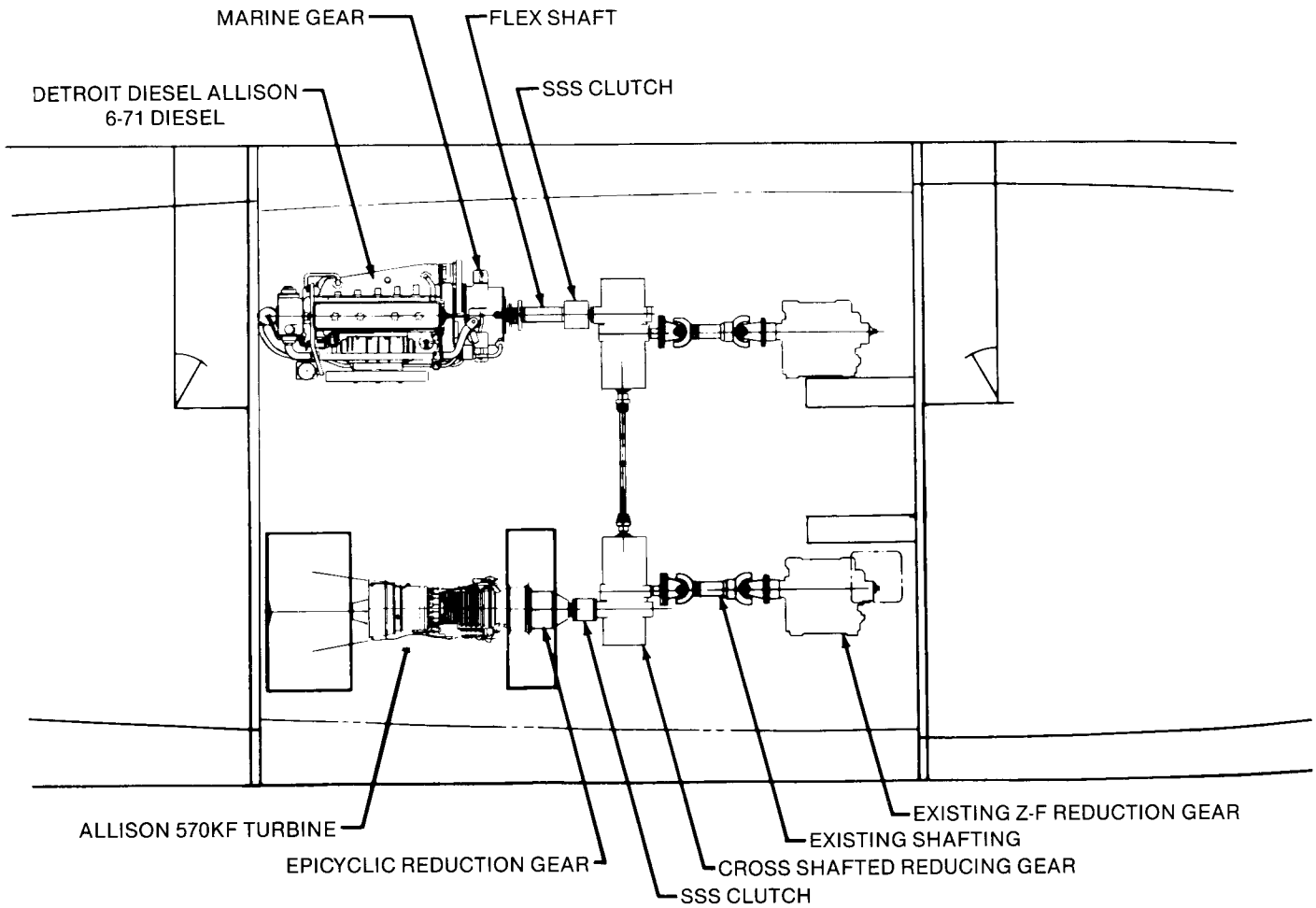


FIGURE 22.

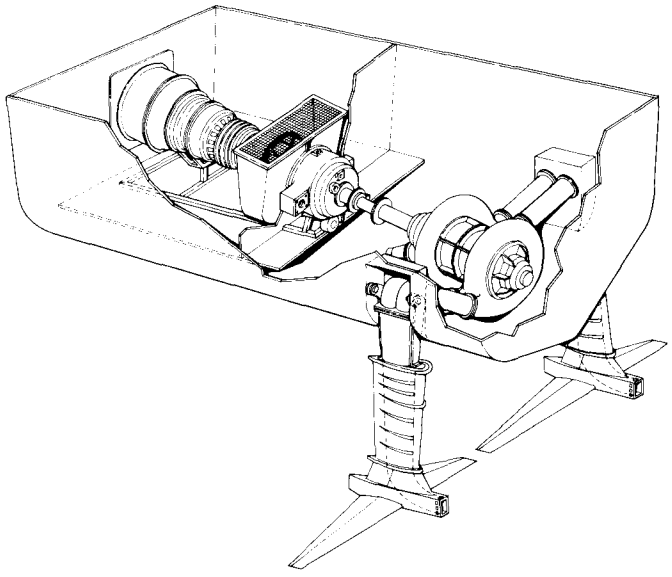


FIGURE 23.

SUMMARY

This paper has attempted to show the suitability of the Allison Model 570-KF and 571-KF engines for propulsion service in light to medium size naval vessels. The engines have been based on "tried and true" materials technology of other Allison aero-industrial engines and continue to accumulate service time per Figure No. 24. The lightweight, fuel efficient design is most appropriate where high power density is a criteria. The list of applications continues to grow from the first private yacht, to the Scandanavian vessels, the Canadian Cruise Engine Program, and the newer concepts like the "Super H3," the "PCM," "BH7 MK20," and beyond towards the vessels of the future.

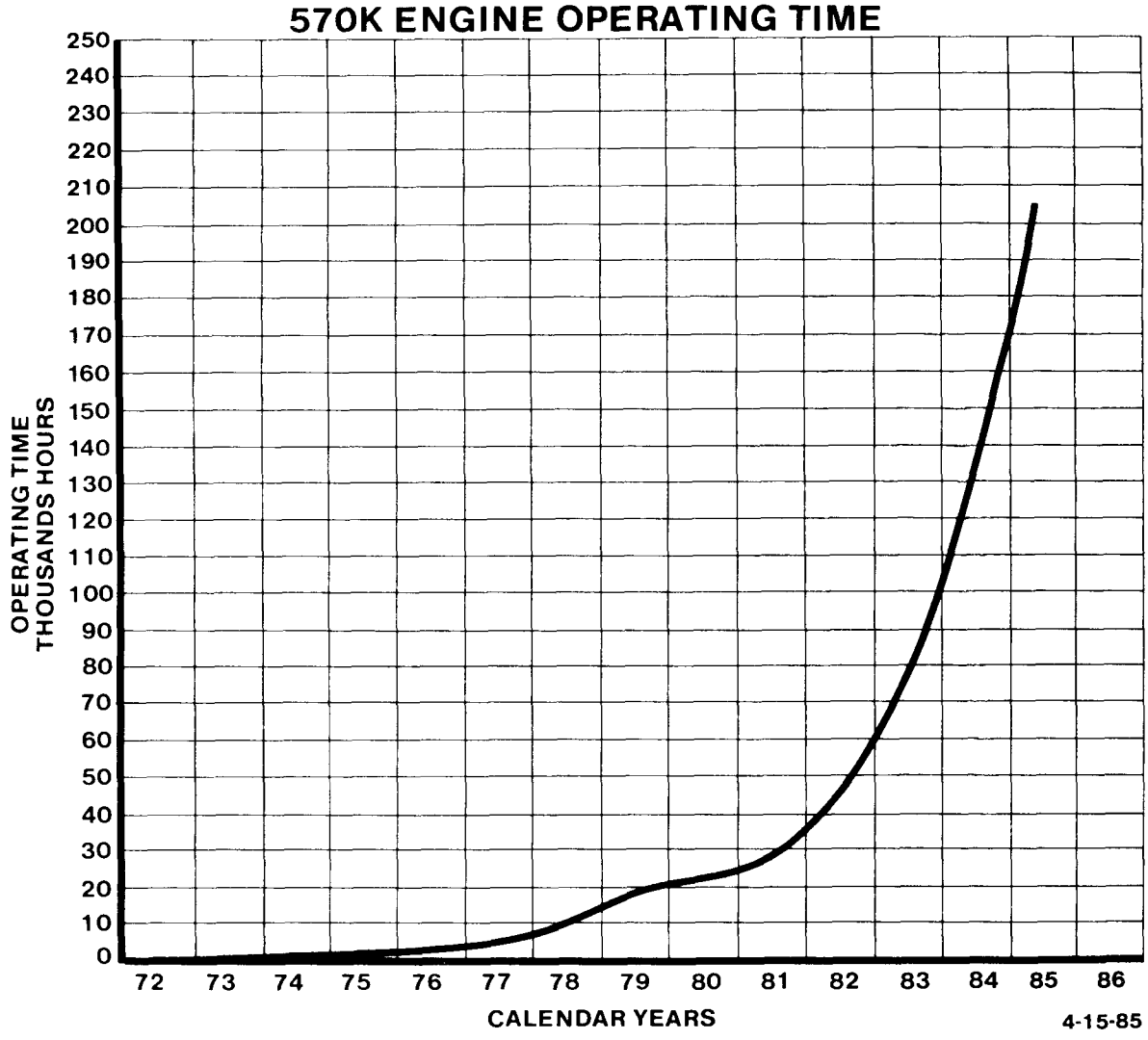


FIGURE 24.