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EVALUATION OF MIL-L-23699 LUBRICANT PERFORMANCE IN THE TF41-A-2 ENGINE

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Trenton, New Jersey

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MIL-L-23699B Lubricant Performance in TF41-A-2 Engine

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An evaluation was made of the service performance characteristics of MIL-L-23699B oils in TF41-A-2 engines. Operational experience and problems as well as the condition of the lubricant wetted engine components at overhaul are discussed. Recommendations are made concerning the expected life of MIL-L-23699B oils in the TF41-A-2 engine.

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TRENTON, NEW JERSEY 08628

PROPULSION TECHNOLOGY AND PROJECT ENGINEERING DEPARTMENT

NAPTC-PE-59 MAY 1975

EVALUATION OF MIL-L-23699 LUBRICANT PERFORMANCE IN THE TF41-A-2 ENGINE

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INTRODUCTION

By reference 1, the Lubricants and Power Drive Systems Division of the Naval . . Propulsion Test Center (NAPTC) was assigned the responsibility of analyzing the service performance of lubricating oils. This assignment was established to assure maximum performance and cleanliness of lubricating oils in service. This goal is accomplished through chemical and physical testing of field samples, analysis of service problems when they arise, and the evaluation of deposition characteristics through inspection of service engine components.

Performance of MIL-L-23699B oils, in service, can vary from engine to engine. Deposition characteristics and useful oil life will usually vary with engine model. Therefore, the service performance of lubricating oils must be evaluated for each engine model. This project concerns such an evaluation of the TF41-A-2 turbofan engine. This evaluation was separated into two distinct areas. The first area was concerned with uncovering lubricant system problems (real or potential) and determining deposition characteristics of MIL-L-23699B oils in the TF41-A-2 engine. This work was performed by inspecting engines and discussing engine mechanical condition and performance at Naval Air Rework Facilities (NARF's), Intermediate Maintenance Activities (IMA's), and operating squadrons. The second area consisted of evaluating the chemical and physical changes in the lubricating oils during actual service use in the TF41-A-2 engine. This evaluation provides information relative to the useful life of the lubricant. A squadron oil sampling program was conducted for this purpose. It should be noted that the engines involved in these two areas were not the same specific engines.

CONCLUSIONS

1. The performance of MIL-L-23699B oils in the TF41-A-2 engine, as indicated by engine condition, is considered to be satisfactory (i.e. the TF41-A-2 exhibited no lubricant caused problem areas).

2. The performance of MIL-L-23699B oils with regard to the retention of original oil deposition, chemical and physical characteristics is satisfactory in the TF41-A-2 engine for operating periods up to 800 hours.

3. The projected useful life of MIL-L-23699B oils in this engine, based on tests conducted on used engine oil samples, is 1600 hours.

RECOMMENDATION

1. Under normal TF41-A-2 operating conditions, MIL-L-23699B oil can be permitted to go up to 1600 hours between oil changes.

DISCUSSION

Performance - Engine Condition

1. The performance characteristics of MIL-L-23699B lubricants in the TF41-A-2 engine were evaluated through discussions with NARF personnel and inspection of engines in the field. The evaluations were held at NARF's Jacksonville and Alameda and Naval Air Stations Cecil Field and Lemoore between October 1972 and January 1975. References 2 through 6 contain details of these evaluations including engine inspection reports. Discussions were held with: powerplant engineers, quality assurance personnel, examiners and evaluators, materials engineers, and chemists. The engines inspected had operating times up to 415 hours since overhaul.

2. Engines were inspected for condition of bearings, seals and gears as well as engine oil deposit levels. Figure 1, an engine lube system schematic is given for reference purposes. Bearings and gears were examined for corrosion and wear characteristics. Seals were examined for wear and proper seal action. Housings and sump areas were examined for deposits. Appendix A gives general information relative to the operation of the lube system.

3. Deposit levels throughout the engines (i.e. deposits on sumps bearings, breather and vent lines and seals) were evaluated as to type and extent of area covered. Deposits range from light sludges to varnishes to carbonaeous type deposits. Generally, only a build-up of loosely adhering carbonaceous deposits are of concern. The TF41-A-2 engine was found to exhibit very good lubricant deposition characteristics (i.e. minimal deposition).

4. Generally, bearings, gears and seals were found to exhibit no lube related problems. Non-lubricant caused problems areas were noted in Table I and described in detail in references 2 through 6. It should be noted that gear wear problems listed in Table I, might be allevaited by the use of high gear load oils (e.g. XAS-2354 oils).

5. Operational problems and procedures, involving the lubricant and lubrication system, at the squadron and the IMA levels were also investigated (references 2, 4, and 6).

6. In summary, the overall performance of MIL-L-23699B oils in the TF41-A-2 engine, as indicated by engine condition, is considered to be satisfactory.

Performance - Oil Useful Life

7. The previous paragraphs discussed the deposition and lubrication characteristics of MIL-L-23699B oils in the TF41-A-2 engine which were derived through inspections and discussions. However, the remaining

life margin of the lubricant cannot be predicted by this type of evaluation. Analyses of the ability of the lubricant to retain certain physical and chemical properties are necessary to accurately predict its remaining life margin. Therefore, in order to evaluate the retention of these properties, samples of lubricating oil from service engines were taken and subjected to laboratory testing. The following paragraphs are concerned with this part of the evaluation of MIL-L-23699B lubricating oil performance in the TF41-A-2 engine.

8. A lube oil sampling program on the TF41-A-2 engine (in the A-7E aircraft) was initiated with Attack Squadron One Hundred Seventy-Four (VA-174) in December 1972. This program using no oil drains, started with five A-7E aircraft (five engines) which were sampled every fifty hours. In all, 50 samples were received from VA-174 with time since last oil change ranging from 47 to 989 hours and total operating time ranging from 81 to 989 hours. The reason for this situation is that it was decided, at the initiation of the program, that engines with both high and low operating times would be sampled in order to determine lubricant property changes in the total operating range of service engines. These samples were analyzed for changes in physical and chemical properties. As the program progressed, sampling was discontinued on some units for various reasons (e.g. loss of oil, engine removed for repair, etc.). Other aircraft were placed on the program, when possible, to replace lost units. The program was terminated in February 1975.

9. Viscosities and Total Acid Numbers (TAN's) were used as the measure of the degree of change in the physical and chemical properties, respectively, of the oil. Viscosities and TAN's were used because they are the primary indicators of the degree of lubricant degradation.

10. Figure 2 is a graphical representation of viscosity and TAN values obtained versus oil time in four of the program engines. The remaining engines experienced either oil losses or leaks which invalidated their usefulness to the program. As can be seen in Figure 2, there were no indications of oil degradation in any of the samples. Oil viscosity and TAN values did not vary significantly from new oil values indicating that no apparent physical or chemical changes in the lubricant occurred. The baseline tests were conducted on various batches of Qualification Number 0-9B MIL-L-23699B oil, for comparison to program samples. This was the oil primarily used by VA-174. Baseline values for viscosity (at 100°F) ranged from 25.0 to 27.0 centistokes (cs) with an average value of 26.7 cs. The maximum value, for viscosity at 100°F, reached on a program sample was 27.4 cs. TAN values of the program samples remained within new oil limits (i.e. less than 0.5).

11. Although the physical and chemical properties of the used oil from the program engines indicated that the oil had not degraded significantly, it was considered desirable to determine the margin of stability of the used oil. This factor would indicate the remaining useful life of the oil. Therefore, the oxidative stability and deposition characteristics of the used oil samples from the program engines were evaluated by means of 400°F Corrosion-Oxidation test and the High Temperature Deposition (HTD) test, respectively. These are laboratory and bench type tests that evaluate the lubricant's resistance to oxidation and corrosion affect on various metals at elevated temperatures and the deposit forming tendencies of the lubricant at elevated temperatures.

12. A 400°F Corrosion-Oxidation test was conducted on a 989 hour program sample. The results of this test were compared to new oil results in Table II. The results obtained were: (a) not significantly different from new oil dates and (b) within MIL-L-23699 specification limits for new oils. Therefore, it was concluded that the oxidative stability of the used oil remained essentially unchanged with aircraft oil operating times up to 989 hours.

13. A graphical representation of program samples viscosities and post Corrosion-Oxidation test viscosities is given in Figure 3. This figure shows graphically that: (a) viscosities of program samples up to 989 hours did not vary significantly from each other or from new oil values and (b) Corrosion-Oxidation test viscosities of a program sample (at 989 hours) did not vary significantly from new oil Corrosion-Oxidation test results. Therefore the oxidation stability and the corrosive tendencies of the program samples would be considered essentially those of new oil, and the used oil was capable of at least another 989 hours of engine operation which would permit approximately 1900 hours of engine operation without oil change.

14. An HTD test was conducted on an 815 hour program sample. The results of this test is compared to new oil results in Table III. The results obtained on this test indicated that the deposition characteristics of the 815 hour sample did not vary significantly from the values obtained for the new oil. Therefore, this sample would be considered to possess the deposition characteristics of new oil, and was capable of at least another 800 hours of engine operation. These data indicate that extending oil drain intervals to 1600 hours would not increase engine deposits.

15. In summary, the overall performance of MIL-L-23699B oil in the TF41-A-2 engine, as determined by evaluation of program samples, is considered to be satisfactory. After 800 hours of engine operation, the oil gave performances in critical laboratory and bench tests (Oxidation-Corrosion and HTD) equal to that of new oil. Based on this, it is recommended that the oil be used for another 800 hours or for a total of 1600 hours. It is to be noted that the projected useful oil life was significantly influenced by the availability of high time oil samples.

FIGURE 1: TF41-A-2 ENGINE LUBRICATION SYSTEM

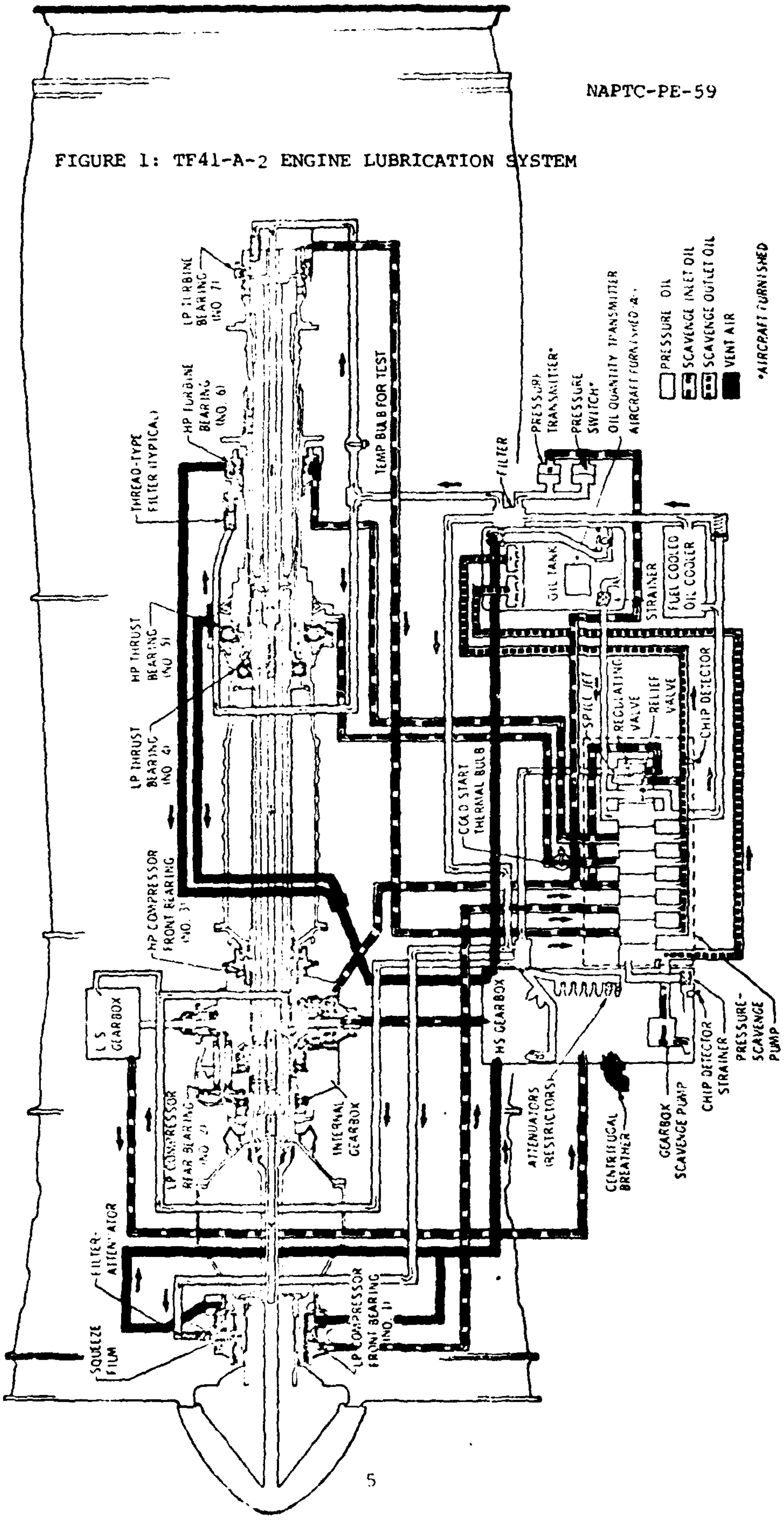

FIGURE 2: USED OIL VISCOSITIES AND TOTAL ACID NUMBERS
VERSUS
OIL HOURS FOR TF41-A-2 PROGRAM ENGINES

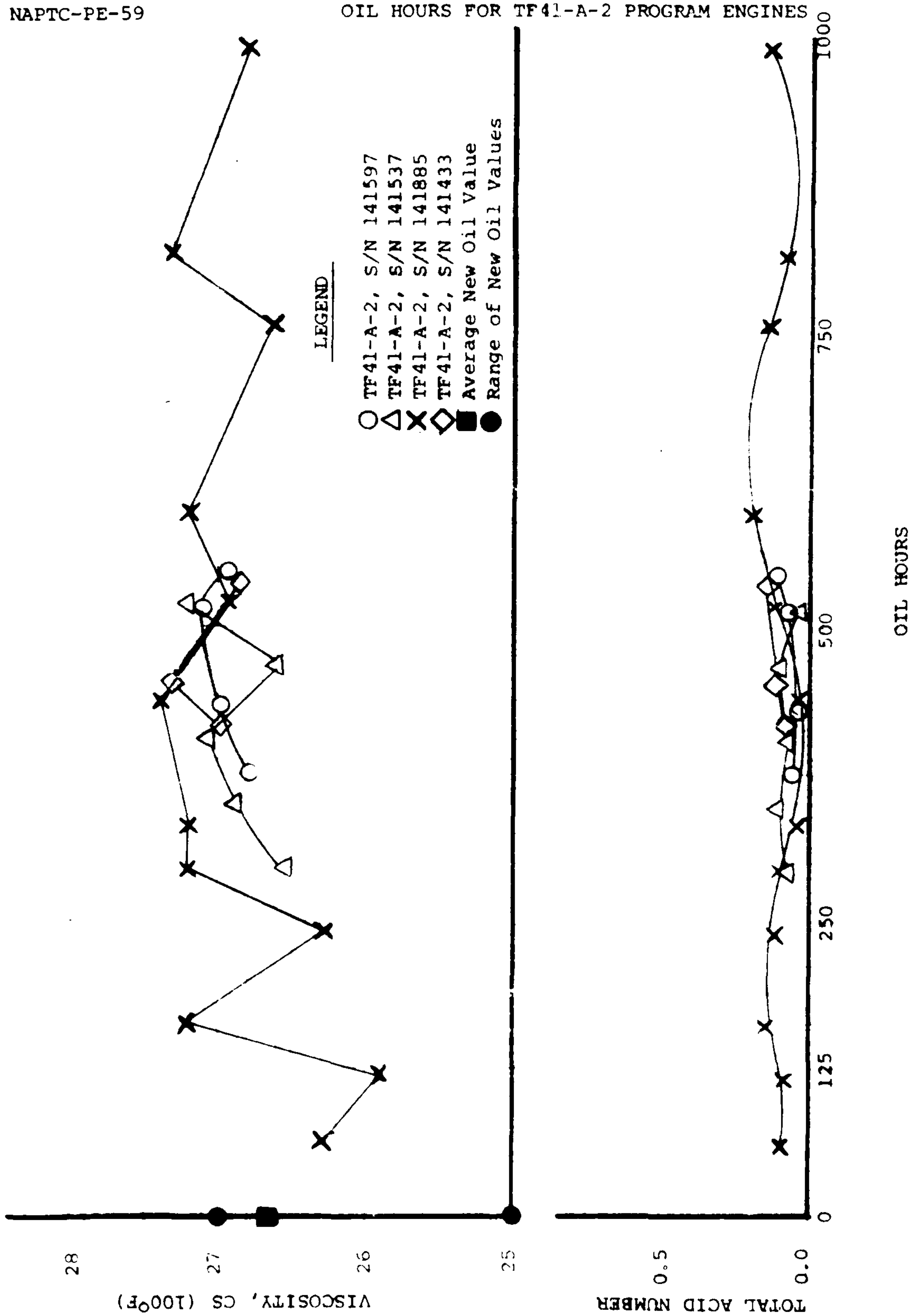

FIGURE 3: VISCOSITIES AND 400°F CORROSION-OXIDATION TEST DATA
VERSUS
OIL HOURS FOR TF41-A-2 PROGRAM ENGINES

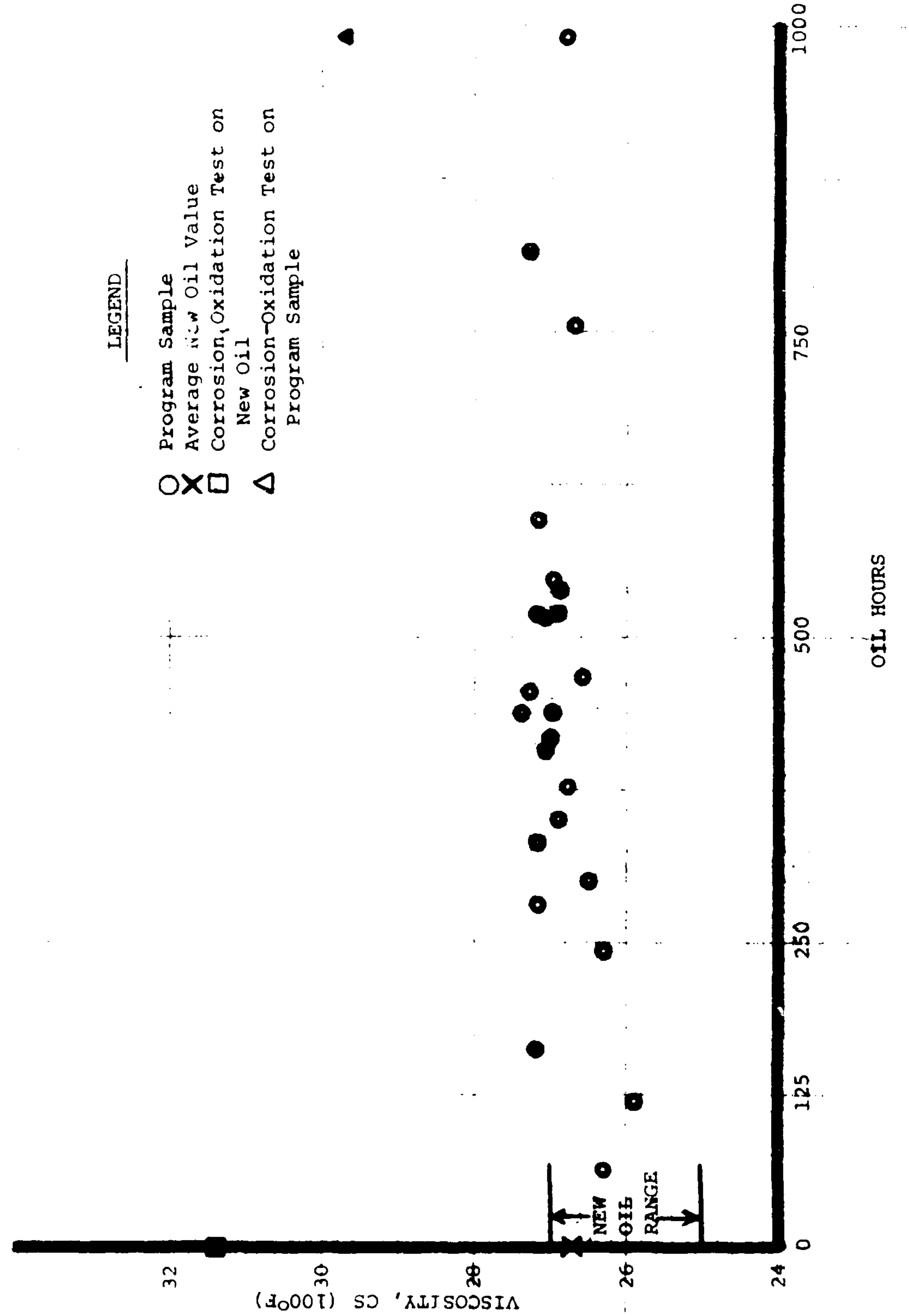

TABLE I

TF41-A-2 ENGINE LUBE SYSTEM PROBLEM AREAS

Problem	Cause	Reference
Heavy shaft wear and failure of main oil pressure pump.	overloaded pump bearings	2, 3
High pressure turbine sump oil leakage.	HPT seal wear.	2, 3, 4
Spline wear in accessory G/B.	poor lubrication	2, 5
High pressure turbine bearing failures.	severe rub, sealing problems	2
Scavenge line failures.	inadequate clamping	2 , 3, 4
Oil pressure fluctuations.	instrumentation malfunctions	3, 4
High pressure turbine seal wear and failure.	design, installation problems	3, 4
Low oil quantity indications.	instrumentation malfunctions	4
Number 1 bearing skidding	bearing design	6
Numbers 1, 6 and 7 piston ring seal oil leakage	installation problem	6
High speed G/B gear wear.	design deficiencies	6

TABLE II

CORROSION-OXIDATION STABILITY TEST RESULTS FOR

A NEW OIL AND A USED OIL FROM TF41-A-2 PROGRAM ENGINES

(72 HOURS AT 400°F)

	MIL-L-23699B Specification Limit for New Oils	New 0-9B Oil	Used Oil 989 Hours
Initial Viscosity (100°F)	25 min.	26.79	26.99
Initial TAN	0.5 max.	0.13	0.09
Percent Viscosity Change (100°F)	-5 to +25	17.3	9.9
TAN Change	3.0 max.	2.32	0.62
Contamination mg/100 ml	50 max.	3.1	0.9
Metal Weight Change (mg)			
Steel	±0.2	+0.03	-0.05
Silver	±0.2	+0.01	0.00
Aluminum	±0.2	+0.02	0.00
Magnesium	±0.2	+0.03	-0.01
Copper	±0.4	+0.06	-0.01

TABLE III

HIGH TEMPERATURE DEPOSITION TEST RESULTS FOR A NEW OIL

AND A USED OIL FROM A TF41-A-2 PROGRAM ENGINE

(525°F LOWER TUBE TEMPERATURE)

Non-Specification Test

	New 0-9B Oil	Used Oil 815 Hours	Range of MIL-L-23699B Results
Deposit Rating	1.0	2.0	0 - 34
Deposits (mg)	2	4	0 - 18
Filter Deposits (mg)	-	22	50 - 126
Oil Consumption (ml)	68	95	68 - 150
Percent Viscosity Change	18.6	14.1	10.9 - 23.9
TAN Change	0.92	0.54	0.68 - 1.41
Initial Viscosity (100°F)	26.33	27.33	25.81 - 28.14
Final Viscosity (100°F)	31.22	31.19	31.05 - 32.94

REFERENCES

1. AUTHORIZATION: NAVAIR Work Unit Assignment Number NAPTC-316-4R6-113 - Analysis of Service Performance of Lubricating Oils.

2. LETTER: Naval Air Propulsion Test Center, PE72:FF:ss NAPTC-316-4R6-113/13 Serial No. F918 of 27 February 1973 to Commander, Naval Air Systems Command (AIR-5364); Subject: Evaluation of Lube Oil Service Performance at NARF Jacksonville and NAS Cecil Field; report on

3. LETTER: Naval Air Propulsion Test Center, PE72:AJD:er NAPTC-316-4R6-113/34 Serial No. F1036 of 5 October 1973 to Commander, Naval Air Systems Command (AIR-5364); Subject: Investigations Performed by the Joint Air Force-Navy TF41 Oil System Team; report on

4. LETTER: Naval Air Propulsion Test Center, PE72:FF:er NAPTC-316-4R6-113/43 of 19 October 1973 to Commander, Naval Air Systems Command (AIR-5364); Subject: Evaluation of Lube Oil Performance in the TF41 Engine at NAS Lemoore; report on

5. LETTER: Naval Air Propulsion Test Center, PE72:FF:er NAPTC-316-4R6-113/15 Serial No. F1038 of 14 September 1973 to Commander, Naval Air Systems Command (AIR-5364); Subject: Evaluation of Lube Oil Service Performance at NARF Alameda; report on

6. LETTER: Naval Air Propulsion Test Center, PE72:FF:vyh NAPTC-316-4R6-113/59 Serial No. F924 of 25 February 1975 to Commander, Naval Air Systems Command (AIR-5364); Subject: Evaluation of Lube Oil Service Performance at NARF Jacksonville and NAS Cecil Field; report on

APPENDIX A

LUBRICATION SYSTEM TF41-A-2 ENGINE

The TF41 engine has a dry sump type lubrication system. The oil tank and fuel cooled oil cooler (FCOC) are engine furnished components. The aircraft manufacturer provides the differential pressure transmitter, cockpit oil pressure indicator, differential warning switch, low oil pressure light, and wiring for these components. A thermo-electric generator oil level transmitter is provided in the oil tank, and a connector cable to the engine main electrical connector is provided for remote indication of oil level. The matching cockpit indicator and power source converter are not engine furnished.

The engine has 6 sumps from which oil must be scavenged, and these sumps are as follows:

1. HS gearbox.
2. LP-IP compressor front bearing.
3. Internal gearbox.
4. HP thrust bearing.
5. HP turbine bearing.
6. LP turbine bearing.

The oil pump assembly consists of the following:

1. One pressure element.
2. Six scavenge elements - one for each of above listed sumps.
3. Relief valve (oil pressure pump relief valve) with a setting of 300 psi differential across pressure element.
4. Pressure regulating valve (engine relief valve) with a nominal setting of 35 psi differential between oil filter outlet pressure and internal gearbox pressure.
5. A spill jet in parallel with pressure regulating valve.
6. One chip detector.

The HS gearbox has one scavenge oil strainer and a chip detector. The oil flow from the oil tank to the pressure pump passes through a strainer. These two strainers are identical.

The fuel cooled oil cooler (FCOC) is an oil to fuel type heat exchanger. The FCOC incorporates an oil bypass valve set to open 65 psi differential. This valve is normally closed,but will open if oil pressure drop across FCOC exceeds 65 psi.

Capacity of the oil tank is as follows:

1.	Usuable oil	2.73 U.S. gallons
2.	Unusable oil	0.80 U.S. gallons (static) 0.5 gallons (running)
3.	Total oil capacity	3.53 U.S. gallons
4.	Expansion space	0.85 U.S. gallons (static) 1.15 gallons (running)
5.	Total tank capacity	4.38 U.S. gallons

NOTE: Approximately 0.3 gallons of oil goes out of the oil tank and into oil lines and sumps during engine running. When engine is shut down, this oil returns to the tank.

The oil tank is a gravity fill type with a twist-off cap for access. The oil tank filler assembly incorporates a scupper drain. A sight glass on the left side of the tank allows for visual checking of the amount of oil in the tank.

The oil tank incorporates the following:

1. De-aerator tray for scavenge oil (returned to tank) to flow over. Thus allowing air in the scavenge oil to be separated from the oil.

2. Upper ball valve which permits oil tank to be vented to the HS gearbox during normal operation, but prevents oil drainage from tank into HS gearbox during inverted flight.

3. Lower ball valve which allows tank to be vented to the HS gearbox during inverted flight. With scavenge pumps operating in inverted flight, the air pressure within the oil tank would tend to build up. Excessive air pressure within the tank will not occur because air pressure would move the ball off its seat which would permit the tank to be vented.

4. Oil sampling valve which allows for oil samples to be taken for spectrographic analysis.

5. Flexible oil pickup.

6. A thermo-electric generator oil level transmitter.

NOTE: A connector cable to the engine main electrical connector is engine-furnished for remote indication of level. The matching cockpit indicator and power source converter are NOT engine-furnished.

The oil filter assembly incorporates the following:

1. Wire wound filter element which provides a filtration of approximately 75 microns.

2. Drain valve which, when open drains oil from both sides of the filter element.

Thread type oil filters are utilized in some of the oil feed passages. These filters prevent "chunks" of solid matter from small oil feed passages and oil jet nozzles. The exterior of these filters are threaded. Longitudinal slots are cut through the threads but do not extend the full length of the filter. Oil entering a slot from one end must flow thru threads to adjacent slots which allow oil flow out the other end. The LS and HS gearboxes do not have thread filters, but all oil delivered to the main bearings of the engine must flow thru a thread filter.

PRESSURE OIL FLOW

Filtered pressure oil is delivered to the following:

1. LP-IP compressor front bearing.
2. LP-IP compressor front bearing squeeze film passage.
3. LP-IP compressor rear bearing.
4. HS gearbox drive gearshaft ball and roller bearings. This drive shaft splines into HP compressor rotor front shaft.
5. HP compressor front bearing.
6. LP thrust bearing.
7. HP thrust bearing.
8. HP turbine bearing.
9. LP turbine bearing.
10. LS gearbox.
11. Internal gearbox.
12. HS gearbox.
13. Spill jet.
14. Pressure regulating valve.
15. Differential pressure transmitter.
16. Differential warning switch.

Pressure oil delivered to Items 1 thru 9 is used to lubricate and cool the listed component.

Pressure oil to the LS gearbox is used to lubricate parts within the LS gearbox and the N_L tachometer generator.

Pressure oil to the internal gearbox is used to lubricate the HS gearbox bevel gearing and bearings on the driven HS gearbox drive gear.

Pressure oil delivered to the HS gearbox is used to lubricate the following thru 10 oil jet nozzles:

1. Main drive gear - driven gear bevel mesh.
2. Main driven gear front roller bearing.

3. Main driven gear rear roller bearing.
4. Main driven gear ball thrust bearing.
5. Main driven gear - main spur gear mesh.
6. Hydraulic pump mesh.
7. A/C boost pump idler mesh.
8. LP fuel pump idler mesh.
9. Main fuel control drive quill.
10. Breather bearing.

Pressure oil delivered to the spill jet flows thru the jet into the common (combined) scavenge oil return passage to the oil tank. The function of the spill jet is to bypass some of the excess capacity of the oil pump. Pressure oil pump is designed with an excess capacity to take care of possible future lubrication requirements.

The pressure regulating valve (engine relief valve) has pressure oil delivered to it, and it senses internal gearbox pressure. This valve has a nominal setting of 35 psi differential between these two pressures. When the differential between these two pressures exceeds 35 psi., the valve is moved off its seat to allow pressure oil to flow into the common (combined) scavenge oil return passage to the oil tank.

The differential pressure transmitter and differential warning switch are both aircraft furnished components which sense oil feed pressure and internal gearbox pressure. The differential pressure transmitter provides the necessary signals to the cockpit indicator for the indication of engine oil pressure. The differential pressure switch controls a cockpit light. If the light is on, it indicates that the differential oil pressure is low. The setting of the differential pressure switch is 11 $\pm$ 1 psi.

The O.D. of the LP-IP compressor front bearing is less than the I.D. of the LP compressor front support. The annulus between these two parts is filled with squeeze film oil. An external oil pipe delivers feed oil (pressure oil) to the LP compressor front support for LP-IP compressor front bearing squeeze film oil. This oil flows thru an attenuator and thread filter thru a tube in one of the LP1 compressor vanes to the annulus around the outer race of this bearing. Because of the annulus and squeeze film oil, the LP-IP compressor rotor can rotate around its mass center rather than its geometric center of rotation. The squeeze film oil also serves as a hydraulic damper to absorb and minimize any vibration at this location.

An external oil pipe delivers oil to the intermediate case near the LS gearbox mounting pad. Internal passages in the intermediate case deliver oil to the LS gearbox and to a duel oil jet nozzle. This nozzle provides for the lubrication of the HS gearbox drive and driven gear mesh, and the bearings which retain and support the driven HS gearbox drive gear. The oil to this oil jet nozzle flows thru a threaded oil filter.

An external oil pipe delivers oil to a bearing service tube in a strut of the diffuser. This tube delivers oil thru the flange area of the HP thrust bearing outer race into a HP turbine bearing service tube within the JP turbine bearing support. This service tube delivers oil thru a threaded oil filter to two nozzles. One oil jet nozzle delivers oil to the HP turbine bearing. The other oil jet nozzle delivers oil onto the front surface of the HP turbine bearing oil seal.

An external oil pipe delivers oil to a tube behind the lower right strut of the LP turbine bearing support which in turn delivers oil to LP turbine bearing housing cover. This cover delivers oil thru a threaded filter to an oil jet nozzle which directs oil such that centrifugal force directs it to the LP turbine bearing. This cover also directs oil to the rear oil feed tube via a transfer tube. The transfer tube fits into a bushing in the aft end of the rear oil feed tube. At this point oil is transferred from stationary to rotating components.

The rear oil feed tube delivers oil to the oil feed tube and filter assembly, which in turn delivers it to the bearing oil pipe.

The oil feed tube and filter assembly, located within the LP compressor drive shaft, consists of a tube with identical thread type filters on either end. Oil must flow thru the thread filters before it can exit thru holes in the tube.

The rear end of the oil feed tube has two holes thru which oil may pass. Flow thru the forward hole is directed by centrifugal force to the LP thrust bearing. Centrifugal forces cause the oil which lubricates the LP thrust bearing to flow into the HP thrust bearing cavity and sump. Flow thru the aft hole is directed such that centrifugal force causes the oil to flow thru the HP turbine bearing and HP compressor rear shaft helical splines. This oil, on its way to the HP thrust bearing lubricates the LP turbine spherical seat and coupling nut and the rear helical splines in the LP compressor drive shaft.

The front end of the oil feed tube has two holes thru which oil may pass. Flow thru the aft hole is directed such that it flows thru holes in the LP compressor drive shaft to the interior of the HS gearbox drive shaft (splined in HP compressor front shaft) where it splits with some of the oil flowing forward and some of it flowing aft. Centrifugal force causes the forward flowing oil to lubricate the ball and roller bearings on the HS gearbox drive shaft. Centrifugal force causes the rearward flowing oil to lubricate the HP compressor front bearing. Flow thru the forward hole is directed such that centrifugal forces causes the oil to flow to the LP-IP compressor rear bearing. On the way to this bearing, oil lubricates the spherical seat and coupling nut and the forward helical splines in the LP compressor drive shaft.

The bearing oil pipe has a thread type filter. Oil flows thru this filter and pipe to annular passage formed by the bearing oil pipe flange and LP1 compressor wheel coupling. The coupling has holes which direct oil from the annular passage to interior of LP2 compressor wheel. Centrifugal force directs oil thru holes in the LP2 compressor wheel to the LP-IP compressor front bearing.

SCAVENGE OIL FLOW

Oil delivered to the LS gearbox drains via external plumbing into the HS gearbox. The HS gearbox scavenge pump pumps oil over a magnetic chip detector, thru a strainer, thru the pump, thru a separate scavenge oil pipe, and to the oil tank. There are three indexing passages between the oil pump assembly and the HS gearbox. These indexing passages are:

1. Scavenge pump inlet from HS gearbox.
2. Scavenge pump outlet to HS gearbox.
3. Scavenge pump outlet to oil pump and then external scavenge oil pipe to the oil tank.

The remaining five sumps have oil scavenged from them by their respective scavenge pump. These five pumps deliver their output into a common or combined scavenge oil passage within the oil pump. A pipe delivers oil from this passage to the oil tank.

The reason for having two scavenge oil return pipes from the oil pump assembly to the oil tank is that the HS gearbox sump is lower than the other five sumps and when the engine is not running, the five sumps and their pipes would drain into the high speed gearbox.

All scavenge oil returned to the oil tank flows over the de-aerator tray which permits air trapped in the scavenge oil to separate from the oil.

Scavenge oil pressure at the inlet of the internal gearbox is sensed by the differential pressure transmitter, differential warning switch, and the pressure regulating (engine relief) valve.

A thermal bulb, a component of the cold start system, is installed at the inlet of the HP thrust bearing scavenge oil pump.

INTERNAL SCAVENGE OIL PUMP

An internal scavenge pump in the high speed gearbox is to scavenge oil from the lower front area during nose down flight attitude. The internal pump is mounted on the forward side of the bearing diaphragm. It is driven by a quillshaft splined into the main oil pump drive shaft. Oil, scavenge from the lower portion of the gearbox, is directed to the output of the main pump high speed gearbox scavenge element via a steel tube.