SAE International

SURFACE VEHICLE STANDARD

SAE J1899 AUG2011

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Superseding J1899 AUG2005

Lubricating Oil, Aircraft Piston Engine (Ashless Dispersant)

RATIONALE

This Standard was revised based on the recommendations made at the 22 April 2010 SAE E-38 Aviation Piston Engine Fuels and Lubricants Committee meeting. The revision is part of the standard SAE five-year review process and it includes both technical and editorial changes. The name of the preparing SAE committee has changed to E-38 and is now under the SAE Aerospace Council.

1. SCOPE

This SAE Standard establishes the requirements for lubricating oils containing ashless dispersant additives to be used in four-stroke cycle, reciprocating piston aircraft engines. This document covers the same lubricating oil requirements as the former military specification MIL-L-22851. Users should consult their airframe or engine manufacturers manuals for the latest listing of acceptable lubricants.

1.1 Classification

The lubricating oils shall be furnished in the following grades as in Table 1:

TABLE 1 - VISCOSITY GRADE COMPARISON TABLE

SAE Grade	Military Grade	Commercial Grade	NATO Code Number
30	none	65	none
40	Type III	80	0 - 123
50	none	100	none
60	Type II	120	0 - 128
Multi-Grade	none	none	none

NOTE—The Military Grade designations are being phased-out in favor of the NATO Code Numbers. Commercial Grade designations are being replaced by the SAE Grade classifications.

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http://www.sae.org/technical/standards/J1899_201108

1.2 Commercial Products

Commercial products sold under this document must meet all of the requirements of Sections 3 and 4 of this document with the following exceptions:

a. Qualification samples and test results do not have to be submitted to the Naval Air Systems Command (NAVAIR), but must be retained by the manufacturer for a period of at least three years.

b. Individual products acceptance lists for commercial aviation piston engine oils will be maintained by each of the original aircraft engine manufacturers.

c. The detailed sampling and inspection procedural requirements of 4.4.2.2 through 4.4.3.2 do not apply.

d. Commercial products do not have to meet the packaging requirements of Section 5.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 Government Documents

2.1.1.1 Specifications and Standards

The listed publications and standards form a part of this specification to the extent specified herein. Unless otherwise specified, the issues of these documents shall be those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto cited in the solicitation (see 6.2). The military specifications are listed for reference only and are not current.

2.1.1.1.1 Specifications

Military

MIL-L-6082 Lubricating Oil, Aircraft Piston Engine (Non-Dispersant Mineral Oil), canceled Nov. 1995

MIL-L-22851 Lubricating Oil, Aircraft Piston Engine (Ashless Dispersant), canceled Nov. 1995

2.1.1.1.2 Standards

Federal

FED-STD-313 Material Safety Data Sheets, Preparation and the Submission of

FED-STD-791 Lubricants, Liquid Fuels and Related Products; Methods of Testing

Military

MIL-STD-290 Packaging, Packing and Marking of Petroleum and Related Products

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Document Automation and Production Service (DAPS), Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6257, http://assist.daps.dla.mil/quicksearch/.)

2.1.1.2 Other Government Publications

The following other Government publications form a part of this specification to the extent specified herein. Unless otherwise specified, the issues shall be those in effect on the date of the solicitation.

Naval Air Systems Command

NAVAIR 17-15-BF-62 Fluid Analysis Spectrometer, Atomic Emission, Operation Instructions and Maintenance Instructions

(Application for copies should be addressed to the Navy Inventory Point, Code 03334 (Publications/Forms Branch), 700 Robbins Avenue, Philadelphia, PA 19111-5098. Their customer service telephone number is (215) 697-5632.

(Copies of specifications, standards, other Government documents and publications required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting activity.)

2.2 Other Publications

The following publications form a part of this specification to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE International Standards

SAE J300 Engine Oil Viscosity Classification

SAE J1787 Measurement of the Total Ash Content of Aviation Piston Engine Oils by a Calculation Method

SAE International Aerospace Material Specifications (AMS)

SAE AMS 3217/1 Test Slabs, Acrylonitrile Butadiene (NBR-H), Medium-High Acrylonitrile, 65 - 75

SAE AMS 3217/4 Test Slabs, Fluoroelastomer (FKM), 65 - 75

SAE AMS 3217/5 Test Slabs, Fluorosilicone (FVQM), 55 - 65

2.2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM D 92	Flash and Fire Points by Cleveland Open Cup
ASTM D 93	Flash Point by Pensky-Martens Closed Cup Tester
ASTM D 97	Pour Point of Petroleum Oils
ASTM D 129	Sulfur in Petroleum Products (General Bomb Method
ASTM D 130	Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test
ASTM D 445	Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)
ASTM D 482	Ash from Petroleum Products
ASTM D 664	Acid Number for Petroleum Products by Potentiometric Titration
ASTM D 892	Foaming Characteristics of Lubricating Oils
ASTM D 1298	Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
ASTM D 1552	Sulfur in Petroleum Products (High-Temperature Method)
ASTM D 2270	Calculating Viscosity Index from Kinematic Viscosity at 40 and 100 °C
ASTM D 2273	Trace Sediment in Lubricating Oils
ASTM D 2622	Sulfur in Petroleum Products (X-ray Spectrographic Method)
ASTM D 4052	Density and Relative Density of Liquids by Digital Density Method
ASTM D 4057	Manual Sampling of Petroleum and Petroleum Products
ASTM D 4177	Automatic Sampling of Petroleum and Petroleum Products
ASTM D 4683	Measuring Viscosity at High Temperature and High Shear Rate by Tapered Bearing Simulator
ASTM D 4684	Determination of Yield Stress and Apparent Viscosity of Engine Oils at Low Temperature
ASTM D 4741	Measuring Viscosity at High Temperature and High Shear Rate by Tapered-Plug Viscometer
ASTM D 4927	Elemental Analysis of Lubricant and Additive Components—Barium, Calcium, Phosphorus, Sulfur, and Zinc by Wavelength—Dispersive X-Ray Fluorescence Spectroscopy
ASTM D 4951	Determination of Additive Elements in Lubricating Oils by Inductively Coupled Plasma Atomic Emission Spectroscopy
ASTM D 5185	Determination of Additive Elements, Wear Metals, and Contaminants in Used Lubricating Oils by Inductively Coupled Plasma Atomic Emission Spectroscopy

ASTM D 5293 Evaluation of Automotive Engine Oils Between -5 and -30 °C Using the Cold-Cranking Simulator

ASTM D 5481 Measuring Viscosity at High Temperature and High Shear Rate by Multicell Capillary Viscometer

ASTM D 5949 Pour Point of Petroleum Products (Automatic Pressure Pulse Method)

ASTM D 5950 Pour Point of Petroleum Products (Automatic Tilt Method)

ASTM D 5985 Pour Point of Petroleum Products (Rotational Method)

ASTM D 6709 Evaluation of Automotive Engine Oils in the Sequence VIII Spark-Ignition Engine (CLR Oil Test Engine)

ASTM D 6922 Determination of Homogeneity and Miscibility in Automotive Engine Oils

2.2.3 ANSI Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ANSI Z129.1 American National Standard for the Precautionary Labeling of Hazardous Industrial Chemicals

2.2.4 ASQ Publications

Available from American Society for Quality, 600 North Plankinton Avenue, Milwaukee, WI 53203, Tel: 800-248-1946 (United States or Canada) or +1-414-272-8575 (International), www.asq.org.

ASQ-Z1.4 Sampling Procedures and Tables for Inspection by Attributes (DoD Accepted)

2.2.5 Order of Precedence

In the event of a conflict between the text of this specification and the references cited herein, the text of this specification takes precedence. Nothing in this specification, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 Qualification

The lubricating oils furnished under this specification shall be products which are authorized by the qualifying activity for listing on the applicable qualified products list at the time for opening of bids (see 4.3 and 6.2.2). Detailed information on the procedures to be followed when submitting a candidate lubricating oil are available from the Naval Air Systems Command, AIR-4.4.1, Fuels and Lubricants Systems Engineer, Building 2360, 22229 Elmer Road, Unit 4, Patuxent River, MD 20670. Qualification approval will be granted upon successful completion of all specification requirements.

3.1.1 Read-across Approvals

Read-across approvals will only be granted to different grades of oil which are composed of varying percentages of the same base stocks blended with identical additive packages (adjustments in VI improver and pour point depressant concentration will be permitted). Complete chemical and physical property test results shall be submitted for each grade of oil for which qualification is requested. Single cylinder engine tests shall be performed on the lightest and heaviest single grade oils to be blended from the same basestock materials (neutral and bright stock). All single grade oils blended from the same basestock materials and meeting SAE viscosity classification standards between the two tested products will be granted qualification approval based on similarity. The 150 h engine test will be run on an SAE 50 grade oil unless the use of another grade is acceptable to the approving agency. The flight test will be run on the appropriate single grade(s) for the environmental conditions encountered. No read-across approvals will be granted to multi-grade oils.

3.1.2 Requalification

Requalification shall be required in the event any change is made in the source or composition of the lubricant, the ingredients used, the manufacturing processes, or the plant location.

3.2 Materials

The lubricating oils shall be derived from petroleum fractions, synthetically prepared compounds or a combination of the two types of products compounded with such functional additives as dispersants, oxidation inhibitors, antifoam agents, viscosity index improvers, and pour point depressants necessary to meet specified requirements. Crude source(s) and the types of processing used in the manufacture of the base stocks shall be identified in accordance with Appendix A. Exceptions to these requirements shall be directed to the qualifying activity. If re-refined materials are used the manufacturer must demonstrate the consistency of the products to the qualifying activity.

3.3 Chemical and Physical Properties

The finished lubricating oil shall conform to the physical and property requirements specified in Tables 2A and 2B.

3.4 Sulfur

The sulfur content of the oil shall not exceed the value shown for each grade in Tables 2A and 2B. For quality conformance inspection, the sulfur content shall be within ±0.15% mass of the qualification value or within a 0.3% mass range selected by the manufacturer to bracket the qualification value.

3.5 API Gravity

The American Petroleum Institute (API) gravity of the oil shall be determined but not limited on qualification inspection. For quality conformance inspection, the gravity shall be within ±1.0 °API of the qualification value, or within a 2.0 °API range selected by the manufacturer to bracket the qualification value.

3.6 Workmanship

The lubricating oil shall be a homogeneous blend when examined visually at room temperature (25 °C ± 3 °C) in a well-lighted room or daylight. It shall exhibit no separation or fallout of the additive package. Any jelly-like substance or very viscous material observed in the bottom of the container will be considered evidence of additive fallout.

3.7 Storage Stability

3.7.1 Fourteen-day Storage Test

When stored as specified in 4.5.1.1, the oil shall show no separation.

3.7.2 Six-month Storage Test

When stored as specified in 4.5.1.2, the oil shall show no separation.

TABLE 2A - CHEMICAL AND PHYSICAL PROPERTY REQUIREMENTS FOR FINISHED LUBRICANT

Characteristic (Limits) SAE GRADE	30	40	50	60	Multi-grade	Test Method
Viscosity, mm^2/s (cSt),						ASTM D 445
@ 100 °C, Min	9.3	12.5	16.3	21.9	(1)	
@ 100 °C, Less than	12.5	16.3	21.9	26.1	(1)	
Viscosity Index, Min	100	100	95	95	100	ASTM D 2270
Flash Point, °C, Min	220	225	243	243	220	ASTM D 92
Flash Point, °C	report	report	report	report	report	ASTM D 93
Pour Point, °C, Max	-24	-22	-18	-18	—	ASTM D 97, ASTM D 5949, ASTM D 5950, ASTM D 5985
Sulfur, Mass %, Max	0.6	0.8	1.0	1.2	0.6	ASTM D 129, ASTM D 1552, ASTM D 2622, ASTM D 4951, ASTM D 5185
Viscosity, Low Temp., Pumping	—	—	—	—	(1)	ASTM D 4684
Viscosity, Low Temp., Cold Crank Sim., cP, Min	—	—	—	—	(1)	ASTM D 5293
Viscosity, High Temp., High Shear, at 150 °C, cP, Min	2.9	3.7	3.7	3.7	(1)	ASTM D 4683, ASTM D 4741, ASTM D 5481
		All Grades				
Viscosity, mm^2/s (cSt), @ 40 °C		report				ASTM D 445
Acid Number, mg KOH/g, Max[2]		1.0				ASTM D 664
Density, @ 15 °C, g/mL		report				ASTM D 4052
Gravity, @ 60 °F, °API[3]		report				ASTM D 1298, ASTM D 4052
Ash Content,[4] Mass %, Max		0.011				ASTM D 482, SAE J1787
Trace Sediment, mL/100 mL Oil, Max		0.005				ASTM D 2273
Copper Strip Corrosion,[5] Max Rating						ASTM D 130
3 h @ 100 °C		1				
3 h @ 204 °C		3				
Foaming Tendency/Stability						ASTM D 892
Seq. I						
Aerated Vol., mL, Max		50				
Vol. after 10 min, mL, Max		0				
Seq. II						
Aerated Vol., mL, Max		50				
Vol. after 10 min, mL, Max		0				
Seq. III						
Aerated Vol., mL, Max		50				
Vol. after 10 min, mL, Max		0				

1. Oil shall meet the viscosity requirements of SAE J300 for the designated grade.
2. Titrate to a pH 11 end point.
3. API gravity may be computed from the relative density measured by ASTM D 4052.
4. ASTM D 482 is required for qualification. Either ASTM D 482 or SAE J1787 may be used for quality Assurance testing.
5. Conduct the test in accordance with ASTM D 130 but at the temperature specified.

TABLE 2B - CHEMICAL AND PHYSICAL PROPERTY REQUIREMENTS FOR FINISHED LUBRICANT

Characteristic (Limits) SAE Grade		All Grades	Test Method
Compatibility with other oils[1]		pass	ASTM D 6922
Elastomer Compatibility[2]			FTM 791 Method 3604
% swelling, acceptable range:			
after 72 h			
Material	Test Temp.		
AMS 3217/1	70 °C (158 °F)	-5 to +10	
AMS 3217/4	150 °C (302 °F)	-5 to +5	
AMS 3217/5	150 °C (302 °F)	-5 to +5	
US Navy			
Silicone Rubber	121 °C (250 °F)	0 to +20	
Trace Metal Content, ppm, Max[3]			(see 4.5.2)
Iron (Fe)		5	
Silver (Ag)		2	
Aluminum (Al)		7	-
Chromium (Cr)		5	
Copper (Cu)		3	
Magnesium (Mg)		3	
Molybdenum (Mo)		4	
Nickel (Ni)		3	
Lead (Pb)		5	
Silicon (Si)		25	
Tin (Sn)		10	
Titanium (Ti)		2	
Zinc (Zn)		10	

1. Reference oils will be identified by NAVAIR at the time of candidate submission.
2. The elastomer compatibility test shall be performed in accordance with Fed Test Method Std 791 Method 3604 with the following exception: The specific materials which shall be tested and the temperature at which the test is to be conducted are those listed in this table.
3. Required for qualification and for U.S. Government procurements.

3.8 Performance Requirements

3.8.1 Single Cylinder Engine Test

3.8.1.1 The fully formulated oil shall meet the requirements of Table 3 when tested in the Sequence VIII spark-ignition engine test run in accordance with ASTM D 6709 except as modified herein. The test shall be run with the oil gallery temperature controlled at 135 °C ± 1 °C (275 °F ± 2 °F).

TABLE 3 - SEQUENCE VIII ENGINE TEST REQUIREMENTS AT 40 H (END OF TEST)[1]

End of Test Characteristic	Limit Single Grade	Limit Multigrade	Test Method
BEARING			
Bearing Weight Loss (Uncorrected), Total, mg, Max	500	500	ASTM D 6709
USED OIL			
Viscosity, % Change, Max @ 40 °C [2]	-15 to +10	< / = +10	ASTM D 445
Viscosity, @ 100 °C	—	[3]	ASTM D 445
Acid Number, Change, Max[4]	2.0	2.0	ASTM D 664

1. The engine test is to be run in accordance with ASTM D 6709 with an oil gallery temperature of 135 °C ± 1 °C (275 °F ± 2 °F).
2. Viscosity change of the 40 h sample shall be as shown for the specified grade.
3. Stripped viscosity of the 10 h sample shall remain in original SAE grade.
4. Titrate to a pH 11 end point.

3.8.1.2 The test fuel shall be Soltrol 10 plus 0.779 to 0.806 mL/L (2.95 to 3.05 mL/US gallon) tetraethyllead (TEL) in place of the KA24E unleaded fuel. The air-to-fuel ratio is to be 14.0:1 as calculated by exhaust gas analysis. (refer to ASTM D 6709, paragraph 7.6).

3.8.1.3 The test need not be conducted using an ASTM Test Monitoring Center (TMC) calibrated test stand and power section (refer to ASTM D 6709, paragraph 10). In place of TMC reference oils a substitute aviation piston engine reference oil shall be used to validate test operation for individually authorized qualification programs as follows:

3.8.1.3.1 Immediately prior to performing a candidate lubricant test run a separate aviation reference oil test shall be conducted. The oil used in the reference test shall be identified by the Naval Air Systems Command, Fuels and Lubricants Systems Engineer (AIR-4.4.1), and will be based on discussions with the candidate oil supplier. The reference lubricant shall be a retained sample of an originally qualified product (or a recent production batch of the manufacturers qualified lubricant) conforming to the SAE Standard for which candidate approval is sought. The results obtained with the reference oil must be reported to the Naval Air Systems Command immediately following completion of the reference test and before conducting the candidate oil test. The results obtained with the reference oil must correlate with the ASTM D 5119 or ASTM D 6709 data previously obtained on that approved formulation.

3.8.1.3.2 Laboratory operators should be aware of the impact of conducting non-standard Sequence VIII test on their TMC calibration status (refer to ASTM D 6709, paragraph 10.1.3.3).

3.8.1.4 The final lab test report shall be the same format as that used for the normal ASTM D 6709 test, paragraph 13, but shall also include the following supplemental report items for Aviation Piston Engine Oil approval:

- Viscosity at 40 °C and 100 °C on the 20, 30 and 40 h oil samples.
- Stripped viscosity (per ASTM D 6709, Annex A14) at 40 °C on the 40 h oil sample for single grade products.
- Stripped viscosity (per ASTM D 6709, Annex A14) at both 40 °C and 100 °C on the 10 h and 40 h oil samples for multi-grade products.
- Acid Number per ASTM D 664-2001 on the new oil, 10, 20, 30 and 40 h oil samples.
- Post-test photographs of the bearing (top and bottom halves) and of the piston skirts (thrust and non-thrust) sides.

3.8.2 Engine Test

All candidate lubricating oils shall demonstrate satisfactory performance in a 150 h engine endurance test run on a Lycoming Engines TIO-540-J2BD engine in accordance with Appendix B. Results of this engine test shall be acceptable to the qualifying activity. For read-across approvals, only one engine test is required as defined in 3.1.1.

3.8.2.1 Engine Test Exclusion

At the discretion of the qualifying activity, this engine test requirement may be waived. Manufacturers requesting this waiver shall provide sufficient data to the qualifying activity to either verify that the candidate oil formulation does not represent a significant change from an existing qualified formulation or demonstrate the performance of the oil in an equivalent manner.

3.8.3 Flight Test

After satisfactory completion of the 150 h engine test requirement, all candidate oils shall demonstrate satisfactory performance when flight tested as specified in Appendix C. Flight tests shall be performed in accordance with current Federal Aviation Administration (FAA) advisory material. If the terms of 3.8.2.1 apply, the flight test shall not be required.

3.9 Material Safety Data Sheets

When applying for qualification, the manufacturer shall submit to the qualifying activity Material Safety Data Sheets prepared in accordance with FED-STD-313 (see 6.4).

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facility suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.1.1 Responsibility For Compliance

All items shall meet all requirements of Sections 3 and 5. The inspection set forth in this document shall become a part of the contractor's overall inspection system or quality program. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of assuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of manufacturing operations, is an acceptable practice to ascertain conformance to requirements; however, this does not authorize submission of known defective material; either indicated or actual, nor does it commit the Government to accept defective material.

4.2 Classification of Inspections

The inspection requirements specified herein are classified as follows:

a. Qualification inspection (see 4.3).

b. Quality assurance inspection (see 4.4).

4.3 Qualification Inspection

The qualification inspection shall consist of a review of and concurrence with the manufacturer's test results (see 4.3.2) by NAVAIR. Additional testing of the qualification inspection sample shall be performed by NAVAIR to confirm compliance with the requirements of Tables 2A and 2B.

4.3.1 Qualification Inspection Sample

All qualification and NAVAIR testing shall be conducted on the same homogeneous batch of oil. The NAVAIR qualification inspection test samples shall consist of a 3.8 L (1 gal) sample of each grade of blended base oil without additives and a 38 L (10 gal) sample of each grade of the finished oil for which qualification approval is sought. Material Safety Data Sheets completed in accordance with FED-STD-313 shall also be included with the test samples. At the direction of the Naval Air Systems Command, AIR-4.4.1, these samples should be forwarded to the AIR-4.4.1 test laboratory at an address to be specified at the time of sample submission. The sample should be plainly identified by a securely attached durable tag or label marked with the following information:

QUALIFICATION INSPECTION SAMPLE
LUBRICATING OIL, AIRCRAFT PISTON ENGINE,
ASHLESS DISPERSANT

Type of Sample: _____ (basestock or finished oil)
Name of Manufacturer _____
Product Code Number _____
Batch Number _____
Date of Manufacture _____
Submitted by _____ (name) on _____ (date)
for qualification inspection in accordance with SAE J1899 under authorization of (reference authorizing letter) (see 6.2.2).

FIGURE 1 - QUALIFICATION INSPECTION SAMPLE

4.3.2 Test Results

The manufacturer shall present a certified copy of the test report to NAVAIR. The report shall contain complete test data showing the results of all tests required by this specification with the exception of the trace metal content. Photographs of the test parts from the Single Cylinder engine test shall be included along with data on the test oil's viscosity (measured at 40 °C and 100 °C) and Acid Number at 0, 10, 20, 30, and 40 h into the test (including the stripped viscosity at 40 °C and 100 °C of the 10 h and 40 h samples as specified in paragraph 3.8.1.4 for the appropriate grade.) The test report shall also include complete formulation data, including the brand name and manufacturer of each of the additives used, the concentration of each additive in the finished oil, the percentages of neutral, bright stock, or other components used in the blending of the product, as well as the crude oil sources and type of processing used in the manufacture of those base stock components. The manufacturer shall also specify the manufacturing blending tolerances for each of the additives and base stock components used in the formulation.

4.3.3 Requalification

Requalification shall be required when any reformulation or change is made in source of manufacture, purity, origin, or composition of the lubricating oil base stock(s) or additives. Requalification is also required for any changes in the manufacturing process or plant locations of the finished product, its additives or base stock(s). No changes shall be made unless approved by the qualifying activity (see 6.2.2).

4.4 Quality Assurance Inspection

Quality assurance inspection shall consist of all the tests in Table 4. Oil manufacturers shall retain a copy of each batch test report in their files for at least three years. A copy of the test report on each batch of oil produced for the U.S. Government shall be forwarded to Naval Air Systems Command.

4.4.1 Lot Formation

4.4.1.1 Bulk Lot

A bulk lot is considered as an indefinite quantity of homogeneous mixture of material in a single isolated container or manufactured by a single plant run (not exceeding 24 h) through the same processing equipment, with no change in ingredient material.

4.4.1.2 Packaged Lot

A packaged lot is considered as an indefinite number of 208 L (55 gal) drums or smaller unit packages of identical size and type filled with a homogeneous mixture of material manufactured by a single plant run (not exceeding 24 h) through the same processing equipment, with no change in ingredient material.

4.4.2 Sampling

4.4.2.1 Sampling for Verification of Product Quality

Each bulk and packaged lot of material shall be sampled at random in accordance with ASTM D 4057 or ASTM D 4177 for verification of product quality as specified in 4.4.

4.4.2.2 Sampling for Examination of Filled Containers

Each packaged lot of containers shall be sampled in accordance with ASQ-Z1.4, for leakage, fill, closure, and preparation for shipment (packaging, packing, marking) in accordance with Section 5.

4.4.2.3 Sampling for Examination of Sedimentation of Filled and Sealed Containers

Samples of filled and sealed 0.95 L (1 qt) containers shall be taken at such periodic levels as to be representative of each day of operation. The number of samples to be taken each day shall be in accordance with ASQ-Z1.4, when tested against the sedimentation requirement of Table 4.

4.4.3 Inspection

4.4.3.1 Inspection of Material

Inspection shall be performed in accordance with Method 9601 of FED-STD-791.

4.4.3.2 Examination of Filled Containers

Examine samples taken in accordance with 4.4.2.2 for compliance with MIL-STD-290 with regard to fill, closure, sealing, leakage, packaging, packing, and marking requirements. Reject any container having one or more defects or under the required fill. If the number of defective or unfilled containers exceeds the acceptance number for the appropriate plan of ASQ-Z1.4, reject the lot represented by the sample.

TABLE 4 - QUALITY ASSURANCE TEST REQUIREMENTS FOR FINISHED LUBRICANT

Characteristic (Limits) SAE Grade	30	40	50	60	Multi-Grade	Test Method
Viscosity, mm^2/sec (cSt),						ASTM D 445
@ 100 °C, Min	9.3	12.5	16.3	21.9	(1)	
@ 100 °C, Less Than	12.5	16.3	21.9	26.1	(1)	
Viscosity Index, Min	100	100	95	95	100	ASTM D 2270
Flash Point, °C Min	220	225	243	243	220	ASTM D 92
Sulfur, Mass % Max(2)	0.6	0.8	1.0	1.2	0.6	ASTM D 129, ASTM D 1552, ASTM D 2622, ASTM D 4951, ASTM D 5185
Pour Point, °C Max	–24	–22	–18	–18	—	ASTM D 97, ASTM D 5949, ASTM D 5950, ASTM D 5985
Viscosity, Low Temp., Cold Crank Sim.	—	—	—	—	(1)	ASTM D 5293
	---------- All Grades ----------					
Viscosity, mm^2/sec (cSt), @ 40 °C	Report					ASTM D 445
Acid Number, mg KOH/g, Max(3)	1.0					ASTM D 664
Density @ 15 °C, g/mL	Report					ASTM D 4052
Gravity @ 60 °F, °API(4)	Report					ASTM D 1298, ASTM D 4052
Ash Content(5)						ASTM D 482,
Mass % Max	0.011					SAE J1787
Trace Sediment						ASTM D 2273
ml/100 mL Oil, Max.	0.005					
Copper Strip Corrosion, Max Rating						ASTM D 130
3 h @ 100 °C	1					
Foaming Tendency/Stability						ASTM D 892
Sequence 2						
Aerated Volume, mL, max	50					
Volume after 10 min, mL, max	0					
Trace Metal Content, ppm, Max						See 4.5.2(6), ASTM D 5185
Iron (Fe)	5					
Silver (Ag)	2					
Aluminum (Al)	7					
Chromium (Cr)	5					
Copper (Cu)	3					
Magnesium (Mg)	3					
Nickel (Ni)	3					
Lead (Pb)	5					
Silicon (Si)	25					
Tin (Sn)	10					
Titanium (Ti)	2					
Zinc (Zn)	10					
Molybdenum (Mo)	4					

1. Oil shall meet the viscosity requirements of SAE J300 for the designated grade.
2. See 3.4 for conformance limit range
3. Titrate to a pH 11 end point.
4. API gravity may be computed from the relative density measured by ASTM D 4052, see 3.5 for conformance limit range.
5. ASTM D 482 is required for qualification. Either ASTM D 482 or SAE J1787 may be used for Quality Assurance Testing.
6. Required for U.S. Government procurements only. ASTM D 5185 may be used for commercial products.

4.5 Test Methods

Tests shall be performed in accordance with the applicable methods listed in Tables 2A, 2B, 3, and 4, and Appendices B and C.

4.5.1 Storage Stability

4.5.1.1 Fourteen-Day Storage Test

A clean, capped, or stoppered 0.95 L (1 qt) glass bottle shall be half filled with test oil and stored on alternate days ±1 h at 5 °C ± 1 °C (40 °F ± 2 °F) and -18 °C ± 1 °C (0 °F ± 2 °F) by daily transferring from one cold box to another. Examine the sample for evidence of additive separation immediately after removal from the 5 °C storage. Note optical clarity and invert the bottles to see if deposits adhere to the bottom. Also slowly pour 10 to 15 mL of cold oil over the lip of the bottle and observe carefully any unevenness in fluid texture. Deposits or suspended material may be present even though the sample is optically clear, because of similar refractive indices. The test cycle shall be repeated for 14 days except for weekend periods where the sample may remain at one temperature condition for up to 72 continuous hours.

4.5.1.2 Six Month Storage Test

A 1-gallon sample of the test oil shall be stored in a clean, capped, or stopper wide-mouth glass container for a period of 6 months at 25 °C ± 3 °C (77 °F ± 5 °F) away from light. At the end of the storage period the oil shall then be examined visually for separation of components.

4.5.2 Trace Metal Content

For initial qualification and Government procurements the trace metal content of the oil shall be determined with a Joint Oil Analysis Program (JOAP) approved atomic emission spectrometer. Using JOAP spectrometric calibration standards, the spectrometer shall be standardized as specified in NAVAIR 17-15-BF-62. Immediately after standardizing the spectrometer, five determinations for trace metal content shall be determined on the oil. The average of the five determinations shall be reported. Samples requiring trace metal content determinations may be sent to: Department of Defense, Technical Support Center, Joint Oil Analysis Program, 85 Millington Avenue, Pensacola, FL 32508-5020. For commercial procurements trace metal content may be measured using ASTM D 5185.

5. PACKAGING (FOR MILITARY PROCUREMENTS)

5.1 Preservation and Packing

For acquisition purposes, the packaging requirements shall be as specified in the contract order (see 6.2.1.1).

5.2 Marking

All unit, intermediate, and shipping containers shall be marked in accordance with the contract order. All unit and intermediate packs of toxic and hazardous chemicals and materials shall also be labeled in accordance with the applicable laws, statutes, regulations, or ordinances, including Federal, State, and Municipal requirements. In addition, unit or intermediate containers, including unit containers that serve as shipping containers, such as pails and drums, shall be marked with the applicable precautionary information detailed in ANSI Z129.1.

6. NOTES

This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.

6.1 Intended Use

The lubricating oil covered by this specification is intended for use in four cycle piston aircraft engines and covers the same lubricating oil requirements as the former military specification MIL-L-22851. Users should consult their engine manufacturers manuals for the latest listing of acceptable lubricants.

6.2 Military Procurements

6.2.1 Ordering Data

6.2.1.1 Acquisition Requirements

Procurement documents should specify the following:

a. Title, number, and date of this specification;

b. Grade of lubricating oil required (see 1.2);

c. Type and size of containers required (see 5.1);

d. Level of packing required (see 5.1);

e. Quantity desired;

f. Submittal of test results (see 4.4).

6.2.2 Qualification

With respect to products requiring qualification, awards shall be made only for the products which are, at the time set for opening of bids, qualified for inclusion in applicable Qualified Products List whether or not such products have actually been so listed by that date. The attention of the contractors is called to these requirements, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification in order that they may be eligible to be awarded contracts or purchase orders for the products covered by this specification. The activity responsible for the Qualified Products List is Commander, Naval Air Systems Command, AIR-4.4.1, Fuels and Lubricants Systems Engineer, Building 2360, 22229 Elmer Road, Unit 4, Patuxent River, MD 20670. Information pertaining to qualification of products may be obtained from that activity.

6.2.3 International Standardization Agreement*

Certain provisions of this specification are the subject of an international standardization agreement with NATO (STANAG 1135). When amendment, revision, or cancellation of this specification is proposed which will affect or violate the international agreement concerned, the preparing activity shall take appropriate reconciliation action through international standardization channels, including department standardization offices, if required.

6.3 Revisions

Revisions or changes to this document must have concurrence from the Naval Air Systems Command.

6.4 Material Safety Data Sheets*

Contracting officers will identify those activities requiring copies of completed Material Safety Data Sheets prepared in accordance with FED-STD-313. The pertinent Government mailing addresses for submission of data are listed in paragraph 4 of FED-STD-313.

6.5 Marginal Indicia

A change bar (I) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY THE SAE E-38 AVIATION PISTON ENGINE FUELS AND LUBRICANTS COMMITTEE

APPENDIX A - BASE STOCK CRUDE OIL SOURCE AND PROCESSING DESCRIPTIONS

A.1 When applying for qualification, refiners shall provide the following information about the crude oil and the processing used in the manufacture of each base stock blended into their product:

a. Name of original base stock refiner or processor;

b. Location of refinery or processing plant, by city and state (U.S.), province (Canada), or country;

c. General crude source shall be identified as follows:

ACI—Alaskan Cook Inlet

ANS—Alaskan North Slope

DE—Diester (Including Manufacturing Source)

GE—Germany

MC—Mid Continent

ME—Middle East

MW—Mid West

MXA—Maya

MXO—Mexican

NA—North Africa

NS—North Sea

PA—Pennsylvania

PAO—Polyalpha Olefin (Including Manufacturing Source)

PE—Polyol Ester (Including Manufacturing Source)

VEN—Venezuelan

WC—West Coast

WCA—Western Canada

WT—West Texas

OC—Other (Please provide brief description)

d. General crude refining processes (nonsynthetics only) shall be defined as follows:

SD—Straight Distillation

VD—Vacuum Distillation

SR—Solvent Refining

MH—Mild Hydrogenation

SH—Severe Hydrogenation

HP—Hydrocracked

OP—Other (Please provide brief description)

APPENDIX B - ENGINE TEST REQUIREMENTS FOR SAE J1899/MIL-L-22851 AVIATION PISTON ENGINE LUBRICANT

B.1 REFERENCES (LATEST APPLICABLE PUBLICATION APPLIES)

a. Society of Automotive Engineers Standard, SAE J1899, Lubricating Oil, Aircraft Piston Engine (Ashless Dispersant).

b. Code of Federal Regulations (CFR) 14, Federal Air Regulation Part 33.49 Endurance test, Subpart D Block Test, Reciprocating Aircraft Engines.

c. Overhaul Manual, Lycoming Engines Direct Drive Engine, Publication Number 60294-7.

d. Operator's Manual, Lycoming Engines TIO-540 Series Aircraft Engines, Publication Number 60297-23.

e. Parts Catalog, Lycoming Engines TIO-540-J2BD Engine, Publication Number PC315.

f. Overhaul Manual for Aircraft Systems Turbochargers, Publication Number TP20-0128.

g. Service Table of Limits and Torque Value Recommendations, Lycoming Engines, Publication Number SSP1776.

h. Overhaul Manual for Aircraft System Valves and Controllers, Publication Number TP20-0129.

i. Hartzel Overhaul Manual Number 117D (for Hartzel Propeller Model HC3Y-2UF/FC8486-6R),

j. Code of Federal Regulations (CFR) 14, Federal Air Regulation Part 33.57 General Conduct of Block Tests.

B.2 ENCLOSURES

a. TIO-540-J2BD Engine Instrumentation Data (Tables B1 and B2).

b. Figures B1 and B2.

1. Objective: To conduct an engine test that will evaluate the quality of aviation piston engine oils (described in B.1a) prior to being subjected to flight test evaluations.

2. Introduction:

   a. Qualified oils under SAE J1899 are synthetic or petroleum base lubricating oil blends containing additives to impart oxidative stability and dispersant properties. Laboratory and bench tests are performed under B.1a to determine the chemical and physical properties of the lubricants.

   b. Flight evaluations are also performed according to B.1a to determine the oil's performance under actual engine operating conditions.

   c. This directive identifies the equipment, procedure, and requirements for a full scale piston engine test to evaluate aviation engine lubricating oils.

B.3 APPROACH

a. The engine used in this test is the Lycoming Engines TIO-540-J2BD or an equivalent model with the approval of the Naval Air Systems Command (NAVAIR). It shall be run in the 150 h endurance test described in B.1b without the turbocharger test requirements and along with the exceptions and amendments described herein.

    1. Prior to the engine test, the engine is to be assembled using original manufacturer parts.

    2. All the critical parts are to be measured during the initial build-up. These dimensions shall be compared with the respective post test engine dimensions to determine the amount of wear which has occurred.

    3. Engine hardware shall also be visually inspected after the test and the presence of carbonaceous deposits shall be described and recorded.

    4. The test may be run at ambient pressure altitude in place of the critical altitude and 8000 ft pressure altitude requirement as noted in reference B.1.b.

    5. It is not necessary to load each accessory drive and mounting attachment as noted in reference B.1.b.

    6. NOTE: A TIO-540-J2BD Engine test run in strict compliance with reference B.1.b may be used to qualify lubricant without these listed exceptions.

b. Lubricant properties shall be examined periodically throughout the test to determine oil degradation.

c. All measured items shall meet the requirements contained herein.

TABLE B1 - TIO-540-J2BD ENGINE INSTRUMENTATION DATA[1]

Parameter	I.D. Tags	Range	Limit
Temperature (°F)			
Oil, In (gallery)	TIS	0–400	245 Max[2]
Oil, Out (to cooler)	TOO	0–500	Record
Air, Compressor Inlet	TAI	0–200	32–104
Air, Compressor Outlet	TATE	0–500	400 Max
Air, Test Cell	TATC	0–200	32–104
Exhaust Gas, Turbocharger Inlet	TETI	0–2000	1650 Max
Cylinder Head (at each Cyl.)	TCH (1–6)	0–800	500 Max
Fuel Inlet	TFI	0–200	100 Max
Pressure			
Oil, Engine Gallery	POEG	0–200	55–95[2][3]
Oil, Pump Exit Engine (psig)	POPE	0–300	Record[2]
Oil, Filter Outlet (psig)	POFO	0–200	Record[4]
Air, Dry Manifold, Std. Location (in Hg)	PAM	0–100	49.0 Max[2]
Air, Barometric, Test Cell (in Hg)	PBTC	0–40	Record[5]
Fuel, at Engine Fuel Pump Inlet (psig)	PFUP	0–200	-2 to +65
Flow			
Fuel (lb/h)	FF	0–300	250 Max
Speed (rpm)			
Engine	ERPM	0–4000	2575 Max
Other			
Test Time, h	TET	0–200	150
Test Time, h	TOT	0–200	

1. The test instrumentation shall be calibrated before each test so that reported data shall have static accuracy within the following limits:
   Temperature within 2 °F
   Pressure within 2%
   Flow within 2%
   Speed within 2%
2. Measured at the location specified in B.6d.
3. Values stated are for normal operation after engine warm-up. The minimum idle pressure is 25 psig and the maximum warm-up pressure is 115 psig.
4. The oil filter outlet pressure should not drop more than 18 psi below the oil pump exit pressure.
5. Barometric pressure.

TABLE B2 - 150 H TEST OPERATING CONDITIONS, TIO-540-J2BD[1]

Test Period	Cumu-lative Time, h	Cycles/ Period	Cycle Time, h	BHR	RPM	Manifold Pressure[2]	Fuel Flow lb/h	Oil Temp. °F	Cyl. Head Temp. °F
1	0 to 30	10	0.08	350	2575	43.0	240–250	140–245	350–475
			0.08	210	2200	record	86–90	140–245	350–475
2	30 to 50	4	2.5	350	2575	43.0	240–250	215–225	350–475
			2.5	210	2200	record	86–90	215–225	350–475
3	50 to 70	10	1.5	350	2575	43.0	240–250	215–225	350–475
			0.5	263	2340	record	130–135	140–245	350–475
4	70 to 90	10	1.5	350	2575	43.0	240–250	235–245	500 Min[3]
			0.5	245	2290	record	120–125	140–245	350–475
5	90 to 110	10	1.5	350	2575	43.0	240–250	235–245	500 Min[3]
			0.5	228	2240	record	102–109	140–245	350–475
6	110 to 130	10	1.5	350	2575	43.0	240–250	235–245	500 Min[3]
			0.5	210	2180	record	86–90	140–245	350–475
7	130 to 150	10	1.5	350	2575	43.0	240–250	235–245	500 Min[3]
			0.5	175	2050	record	79–84	140–245	350–475

1. The engine is to be shut down a minimum of 0.5 h between each cycle.
2. The engine is to be shut down a minimum of 0.5 h between each cycle.
3. Starting at cycle 7, the hottest cylinder head shall maintain a minimum temperature of 500 °F. The temperature of the remaining cylinder heads shall be within 50 °F of the hottest cylinder head for the remainder of the test at all maximum power conditions.

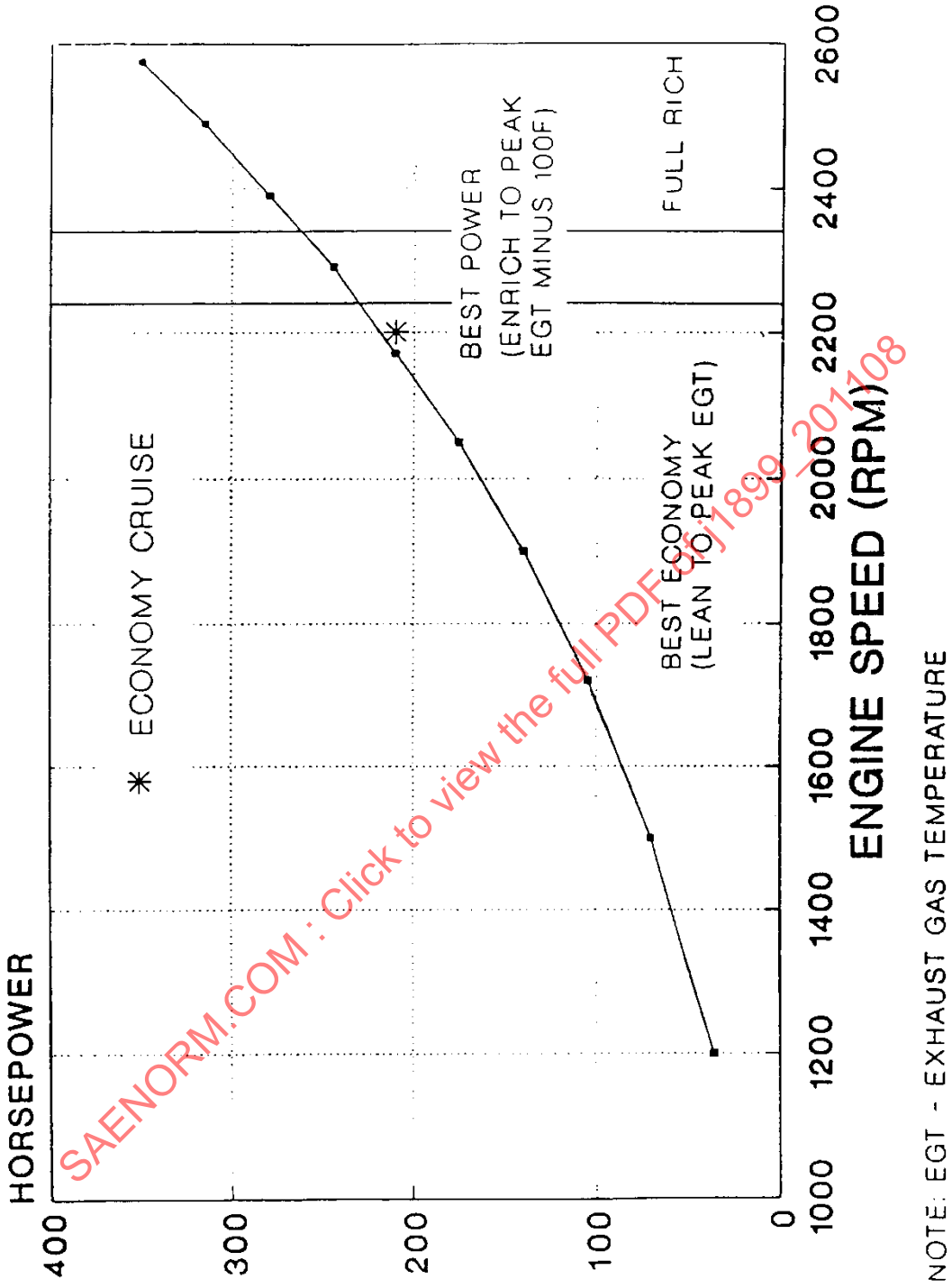

FIGURE B1 - HORSEPOWER VERSUS ENGINE SPEED

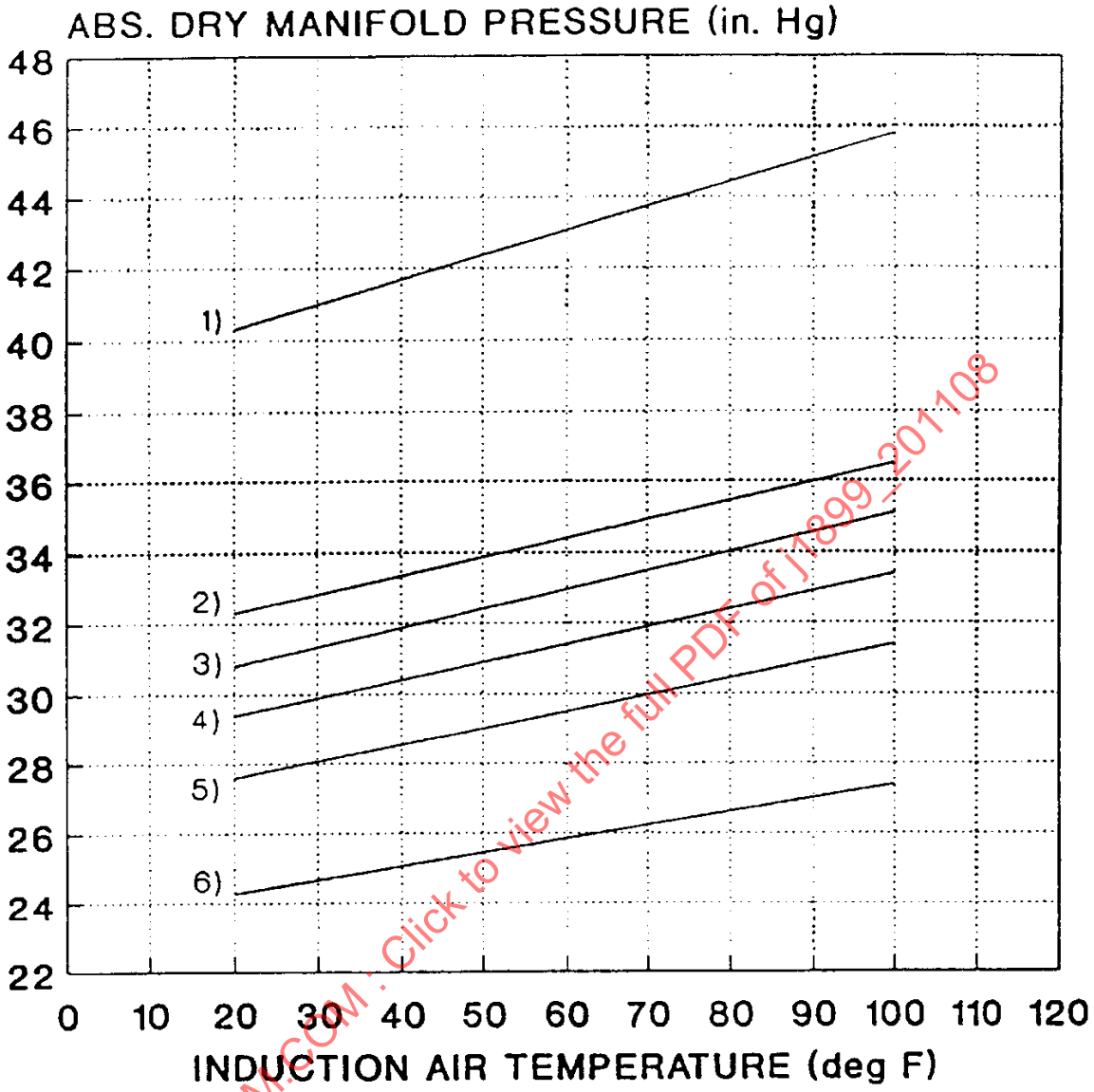

FIGURE B2 - POWER CHART AT SEA LEVEL

B.4 EQUIPMENT

a. Engine:

1. The TIO-540-J2BD engine is manufactured by Lycoming Engines, Williamsport, Pennsylvania. It is an internal combustion, air cooled, turbocharged piston engine.

2. It is equipped with a continuous flow type fuel injection system and shall run on aviation grade gasoline with a minimum octane rating of 100LL.

3. The engine is a six-cylinder opposed design with a displacement of 8873.6 cm^3 (541.5 in^3). At maximum power it shall develop 350 Horsepower at sea level through critical altitude (4626 m [15 000 ft]).

4. The engine is provided with a wet sump oil system having a capacity of 11.36 L (12 qt).

5. Accessories supplied with the engine are the fuel pump, the starter, and the alternator. Two additional accessory drives are supplied on this model engine and need not be loaded during the test. The alternator, while normally supplied with the engine, need not be installed for this test.

b. Test Stand: The test stand shall consist of an aircraft type dynafocal engine mounting system, Piper model number 01272-2, identical to that used on the Piper PA31-350 (manufactured by Piper Aircraft Corp., Vero Beach, Florida) or equivalent. This system shall then be attached to a suitable test bed.

c. Power Absorber:

1. This engine drives a propeller directly off the engine crankshaft. For this test setup a flight propeller shall be used to absorb engine power. The propeller shall be a three-blade variable pitch type, Hartzell model number HC3YR-2UF/FC8468-6R manufactured by Hartzell Propeller Inc., Piqua, Ohio, or equivalent representative propeller in a fixed position. Used in conjunction with this propeller shall be the Hartzell propeller governor model number F624Z or equivalent. This propeller and governor are similar to those used on the Piper PA31-350.

2. With this type of installation auxiliary air may be required to cool the engine to the specified limits. The flight propeller alone may not provide sufficient cooling air to the engine in a test cell environment.

3. Alternate means of absorbing engine power, e.g., club propellers or dynamometers are acceptable for this test method.

d. Instrumentation:

1. The test location shall be equipped with the necessary instrumentation and associated hardware to record the required data. The minimum required instrumentation is listed in Table B1. Also listed are the ranges and the limits of these parameters. The system shall acquire data from thermocouples, pressure taps, flow meters, and tachometer. The instrumentation shall also be equipped with suitable alarms and controls to permit safe operation.

2. Data shall be recorded periodically throughout the entire test. This includes the break-in, pre and post test calibration, and oil consumption runs along with the endurance test run. The data shall be recorded either by hand or by data acquisition system.

e. Fuel: All testing shall be conducted using grade 100LL aviation fuel manufactured to ASTM D 910 Standards.

f. The test installation shall incorporate a suitably sized air-oil separator connected to the oil breather exit of the engine.

B.5 LOCATION

The testing source for the engine test is not limited. However, to obtain concurrent FAA approval the engine test must comply with the instrumentation calibration requirements defined in reference B.1b. Also see Section B.9.b of this specification.

B.6 PROCEDURE

B.6.1 Introduction

a. The engine shall be run using the power settings outlined in B.1b. The test shall run for a total of 150 h. A daily engine log shall be maintained summarizing all the daily activities.

b. Prior to performing the 150 h endurance test a break-in, an oil consumption run, and a pretest calibration run shall be performed. The time spent on these sequences shall not be included as part of the 150 h of test time. All nontest time accumulated during the 150 h endurance test plus the pre- and post-test run time and any miscellaneous running should not exceed 20 h. All miscellaneous running time shall be documented.

c. After 150 h of testing has been completed the engine shall be subjected to a post-test calibration run. At this time any change in engine performance which has occurred during the test shall be determined and recorded.

d. Prior to starting any sequence (break-in, pre- and post-test calibration, and oil consumption runs) the engine shall be run at a lower setting to allow the oil to reach a temperature of 60 °C (140 °F) as recommended in Section 9 of B.1c. The start-up, warm-up, and ground check procedures outlined in Section B.1d shall be used at the beginning of any run listed in this procedure. This shall also be done at the start of each cycle of the endurance run and at start-up after the engine has been shut down (e.g., shutdown for maintenance, etc.). This warm-up time shall not be included in the 150 h endurance test time.

e. At the end of any sequence or cycle or in the event of a premature shutdown, the engine shall be stopped according to the shutdown procedure in B.1d. The only time this procedure may be omitted is if the engine shall sustain serious damage if it is run, even at an idle condition, for any length of time (e.g., complete loss of oil or oil pressure, etc.).

f. For all engine running procedures listed below, the engine speed shall be maintained within ±3% of the specified values and the manifold pressure within ±0.5 in of Hg. The test cell environment shall stay at ambient conditions.

g. For all sequences run prior to the actual endurance test, an oil filter shall be used in the oil system. At the completion of the pretest calibration run this filter shall be replaced with a new oil filter.

B.6.2 Break-In Run

a. The engine shall be run for a 3 h break-in period according to the procedure outline in B.6.2b. This sequence shall be run at ambient pressure with the mixture setting adjusted to full rich. Record the data once at each power setting. The oil used during this run shall be a SAE J1899 product as required by reference B.1d (with supplemental information contained in the latest version of Lycoming Engines Service Instruction 1014). The J1899 product selected from Service Instruction 1040 shall not contain an antiwear additive such as tri-cresyl-phosphate (TCP).

b. The break-in run shall be conducted as follows:

1. 0.25 h at 1200 rpm.
2. 0.25 h at 1500 rpm.
3. 0.25 h at 1720 rpm.
4. 0.25 h at 1900 rpm.
5. 0.33 h at 2050 rpm.
6. 0.33 h at 2170 rpm with a manifold pressure of 32 in of Hg.
7. 0.33 h at 2290 rpm with a manifold pressure of 36 in of Hg.
8. 0.33 h at 2390 rpm with a manifold pressure of 38 in of Hg.
9. 0.33 h at 2490 rpm with a manifold pressure of 41 in of Hg.
10. 0.33 h at 2575 rpm with a manifold pressure of 43 in of Hg.
11. Adjust the turbocharger density controller as per Lycoming Service Instruction Number 1187.
12. Shut down the engine according to the shutdown procedure in B.1d.

During the break-in run, the engine temperatures, pressures, and speeds shall remain within the normal operating limits specified by the manufacturer for the power setting selected. If a fixed pitch (club propeller) type of power absorber is used, the break-in run manifold pressure for condition (j) shall be met. For all other conditions the test profile manifold pressure shall be monitored but not controlled.

c. Drain the used break-in oil from the engine, oil lines, and oil cooler. Remove the oil filter and replace it with a new one. Fill the crankcase with a clean charge of the candidate oil and proceed to the oil consumption run.

B.6.3 Oil Consumption Run

a. This sequence shall be run for 2 h at maximum continuous power and speed (2575 rpm with a manifold pressure of 43 in of Hg), at sea level pressure, and have an oil temperature of 93 °C ± 6 °C (200 °F ± 10 °F). During this run record data every 15 min. After the engine has been shut down and the oil has drained down into the engine sump (approximately 1/2 h), add enough test oil to bring the level to the full mark. Determine the oil consumption from the amount of oil added and record this quantity. The oil consumption shall not exceed 0.95 L per hour (1.0 qt per hour), if this value is exceeded the engine shall be rejected for testing.

b. Drain the used oil from the engine, oil lines, and the oil cooler. Fill the engine with a clean charge of candidate oil to flush out any residual break-in lubricant. Proceed to the pretest calibration run.

B.6.4 Pretest Calibration Run

a. Prior to endurance testing a calibration run shall be conducted. The engine shall not be used if its performance does not meet the required power settings listed in B.6.4c. With the data obtained from the calibration run described as follows, construct a propeller load curve for the engine to be used in testing. This propeller load curve shall also be used as a record of the engine's performance prior to running the endurance test.

b. The pretest calibration run shall be conducted using three different power settings. Each of these settings shall be held for a minimum of 10 min and the data shall be recorded when all the parameters have stabilized. The engine speed, manifold pressure, and fuel mixture shall be held constant for each power level.

c. The propeller pitch stops shall be set according to the propeller manufacturer's recommendations or as necessary to achieve an engine speed of 2575 rpm and a manifold pressure of 40 in of Hg. This shall enable the engine to run at all the settings listed in B.6.4d with the propeller blades at the fixed pitch position. The propeller blade pitch angle, obtained at the 30 in station, shall be measured and recorded. Run the engine at the speeds indicated in B.6.4d and record the manifold achieved. Construct a propeller load curve using the manifold pressures achieved at these engine speeds.

d. The following instrument settings shall be used for the pretest calibration run:

   1. All power levels below shall be run with the fuel mixture at the settings specified in Figure B1;

   2. 2575 rpm at 40 in of Hg manifold pressure;

   3. 2400 rpm and record manifold pressure;

   4. 2200 rpm and record manifold pressure;

   5. Shut down the engine according to the shutdown procedure in B.1d.

e. If an alternate power absorber is used, a similar propeller load curve shall be constructed to measure engine power. The alternate device selected shall allow the engine to operate at the speeds and manifold pressures specified by the manufacturer for the ambient conditions present. These values and limits are contained in B.1d. If the engine's performance does not meet the minimum acceptable limits, it will not be considered acceptable for use.

f. Drain the used oil from the engine, oil lines, and the oil cooler. Replace the slave oil filter with a new test oil filter. Install a fresh charge of test oil and proceed to the endurance test.

B.6.5 FAR 33.49 Endurance Test

a. The test procedure listed below is similar to that as described in B.1b. The test consists of seven portions for which the engine is run at various power settings. The total test duration is 150 h as indicated in Table B2.

b. Use Figure B2 as a guideline to set the manifold pressure and engine speed to achieve the desired power settings. Figure B1 shows the recommended fuel mixture setting for the desired engine speed and horsepower. Holding the engine speed and the manifold pressure constant, adjust the fuel mixture as necessary to obtain the setting shown in Figure B1. The fuel flow shall remain within the specified limits shown in Figure B2.

c. During 50 h of the endurance test at least one cylinder shall be operated at or above the limiting cylinder head temperature, 260 °C (500 °F). The other cylinders shall not be lower than 28 °C (50 °F) below the limiting cylinder head temperature. This 50 h of test time shall be conducted with the engine set at maximum continuous power and speed. For test method consistency this phase shall take place during the last 50 h of testing at the maximum continuous power setting. Start at test portion 4 cycle 7, as given in B.6.5d.

d. The 50 h of test time mentioned above shall also be run with the oil inlet temperature maintained within ±3 °C (±5 °F) of the limiting oil inlet temperature, 118 °C (245 °F). Adjust the cooling equipment for the engine is necessary to achieve this temperature. If it is necessary the oil lines and sump may be insulated. The remainder of the test shall be conducted with the oil inlet temperature of 104 °C ± 3 °C (220 °F ± 5 °F).

e. The test procedure shall be run as follows with a minimum of 1/2 h separation between cycles. The delay between cycles is to permit evaluation of the lubricant's resistance to the formation of carbonaceous materials during static hot soak conditions. Test data is to be recorded once during the last 5 min of each power setting in portion 1. In portions 2 through 7 record the data at approximately 15 min intervals during each power setting. Allow the engine to run for at least 10 min after a setting change (in portions 2 through 7) before taking an instrument reading. (All horsepower values are corrected to sea level standard day conditions at the stated speed.)

1. Portion 1, 0 to 30 h (10 cycles):
   Each test cycle shall include the 0.16 h (10 min) sequence as follows, repeated 18 times in a 3 h period:

   a. 0.08 h at maximum continuous power with maximum continuous speed (350 horsepower at 2575 rpm).

   b. 0.08 h at economy cruise (210 horsepower at 2200 rpm).

2. Portion 2, 30 to 50 h (4 cycles):
   Each test cycle is 5 h run as follows:

   a. 2.5 h at maximum continuous power with maximum continuous speed (350 horsepower at 2575 rpm).

   b. 2.5 h at maximum best economy cruising power (210 horsepower at 2200 rpm).

3. Portion 3, 50 to 70 h (10 cycles):
   Each test cycle is 2 h run as follows:

   a. 1.5 h at maximum continuous power with maximum continuous speed (350 horsepower at 2575 rpm).

   b. 0.5 h at 75% maximum continuous power with 91% maximum continuous speed (263 horsepower at 2340 rpm).

4. Portion 4, 70 to 90 h (10 cycles):
   Each test cycle is 2 h run as follows:

   a. 1.5 h at maximum continuous power with maximum continuous speed (350 horsepower at 2575 rpm).

   b. 0.5 h at 70% maximum continuous power with 89% maximum continuous speed (245 horsepower at 2290 rpm).

5. Portion 5, 90 to 110 h (10 cycles):
   Each test cycle is 2 h run as follows:

   a. 1.5 h at maximum continuous power with maximum continuous speed (350 horsepower at 2575 rpm).

   b. 0.5 h at 65% maximum continuous power with 87% maximum continuous speed (228 horsepower at 2240 rpm).