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TEMPORARY METHODS FOR ASSESSING THE LOAD CARRYING CAPACITY OF AIRCRAFT PROPULSION SYSTEM LUBRICATING OILS

INTRODUCTION

This SAE Aerospace Information Report (AIR) is intended as a guide toward standard practices during a period when the ability to perform previously used lubricant load carrying test methods, such as Ryder and IAE, is severely limited. The methods presented herein are the result of communication among lubricant formulators, hardware designers, lubricant specialists, tribologists, lubricant specification writers, and lubricant users. These methods do not necessarily have a definitive correlation with the previously used test devices but rather provide a ranking relationship for oils of different load carrying classes as defined by those devices. As such, they can be used to generate data to assist in making judgments regarding qualification and batch approval of lubricants formulated with current state-of-the-art basestocks and additives which have a long service history. They should not be used for making judgments or decisions of any kind for oil formulation chemistry with no or little previous load carrying data and service experience.

The methods contained in this document consist of those which have been submitted to SAE Committee E-34 and which have been agreed by the committee to be consistent with the intended purpose.

FOREWORD

All modern aviation propulsion system lubricant specifications contain some type of a gear scuffing/scoring test to measure the lubricant's load carrying capacity, i.e., Ryder, IAE, and FZG. These tests are costly and recently have exhibited questionable reliability and availability and, in the case of the Ryder Test, complete unavailability because of a lack of a test gear source.

There are very large databases (from the past 30 plus years) for these tests and they form the basis for judging on the effectiveness of various products in controlling scuffing or scoring. For this reason, there are some strong ties to these devices. However, because of the expense of running these tests and because of the limited utility of the data generated regarding hardware design, there is little support to reestablish these tests to their former role. Although limited efforts may restore some capacity to perform these tests, the long-term perspective is to develop new methods based on the abundance of tribology research that has and is being done.

FOREWORD (Continued)

The continued use of the these gear type tests is considered at best tenuous and the development of new methods to completely replace the old methods is far term. Thus, there is a need to have test methods for the interim and that is the purpose of this document.

1. SCOPE:

1.1 Purpose:

To present methods which, according to the consensus of the aviation propulsion community represented by SAE Committee E-34, allow the continued assessment of load carrying capacity of current chemistry products during periods of limited or nonavailability of previously used standardized methods.

1.2 Field of Application:

The methods listed in this document are intended to provide a means of generating data which can be used as a guide for making decisions against the backdrop of load capacity databases (Ryder, IAE, FZG) and experiences available on chemically similar oils used for lubrication of aircraft propulsion and power drive systems.

2. REFERENCES:

2.1 Applicable Documents:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 ASTM Publications: Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 5001	Measurement of Lubricity of Aviation Turbine Fuels by the Ball-on-Cylinder Lubricity Evaluator (BOCLE)
ASTM D 5182-91	Standard Test Method for Evaluating the Scuffing (Scoring) Load Capacity of Oils

3. METHOD SELECTION:

3.1 Process for Approving Test Methods:

Methods will be submitted to Committee E-34 with data showing their relationship to a standardized load capacity test previously used for aviation propulsion system lubricants. The method should: a) Be affordable, i.e., cost no more than the currently used methods; b) Have adequate sources of test specimens; c) Separate oil performance according to the currently accepted load carrying classes as determined by databases for standardized load carrying test methods.

The Committee will review a method and supporting data and a) give tentative approval, b) give guidance for changes or for additional data to make a method acceptable, or c) reject a method as outside the scope of this document.

Use of a tentatively approved method will generate a broader database for the particular method and the committee will review the data and experience on this method at each meeting. Full approval for inclusion in the document, suggestions to improve the method or rejection of the method could result from these reviews.

This document and process will remain in effect until the committee decides there is no longer a need for alternate methods of assessing load carrying capacity of aviation propulsion system lubricants.

3.2 Methods:

The methods listed below received tentative approval for use under the terms of this document by SAE Committee E-34 on September 28, 1995.

a. Modified ASTM D 5182-91 Standard Test Method for Evaluating the Scuffing (Scoring) Load Capacity of Oils (Appendix A)

b. Rolls Royce Tribology Evaluator to Determine the Lubricating Quality of Aviation Turbine Oils (Appendix B)

PREPARED BY SAE COMMITTEE E-34, PROPULSION LUBRICANTS

APPENDIX A
MODIFIED ASTM D5182-91 STANDARD METHOD
FOR EVALUATING SCUFFING/SCORING LOAD CAPACITY
OF AVIATION PROPULSION SYSTEM OILS

The gear load-carrying capacity test will be conducted in accordance with ASTM D 5182-91 modified as follows:

The FZG test speed shall be 1760 rpm rather than 1450 rpm.

The failure criteria is reached when the summed total width of scuffing/scoring/adhesive wear damage from all 16 teeth is estimated to equal or exceed two gear tooth widths (40 mm) rather than one gear tooth width (20 mm).

APPENDIX B
ROLLS ROYCE TRIBOLOGY EVALUATOR METHOD TO DETERMINE THE LUBRICATING QUALITY OF AVIATION TURBINE OILS

B.1 SCOPE/BACKGROUND:

Lubricant load carrying performance is an important parameter when considering evaluation/approval of a lubricant type for a specific application. The test methods currently in use within the aviation propulsion industry for assessing compliance with specification requirements are the Ryder and the IAE gear tests.

The Rolls-Royce tribology evaluator is a device used to rate the relative lubricating quality of aviation turbine oils. Employing ball-on-cylinder philosophy, a nonrotating steel ball is held in a vertically mounted chuck and forced against an axially mounted steel cylinder with an applied load. The test cylinder is rotated at a fixed speed while being partially immersed in the fluid reservoir. This maintains the cylinder in a wet condition and continuously transports a film of test fluid to the ball/cylinder interface. The wear scar generated on the test ball is a measure of the fluid lubricating properties.

B.2 TYPES OF WEAR:

Using this apparatus, the two distinct types of wear mechanisms most commonly seen in oil system components, namely mild and scuffing wear, can be reproduced and studied. Only a scuffing wear test method is included in this document.

B.2.1 Mild Wear:

As the test cylinder rotates, the lubricant is continuously transported to the ball/cylinder interface. At this interface under mild wear conditions, there is an elastohydrodynamic boundary layer of lubricant which prevents contact of anything other than the surface asperities of the ball and cylinder. However, due to the difference in hardness of these asperities, abrasion and, hence, mild wear occurs. Any wear debris carried from the cylinder to the wear scar area can also be a contributory factor.

B.2.2 Scuffing Wear:

At a specific applied ball load, a transition from mild to scuffing wear can be observed. At this transition, a reduction and ultimate breakdown of boundary lubrication and film thickness occurs. This results in full metal-to-metal contact of the sliding surfaces, leading to severe adhesive wear and a large wear scar. Loadings beyond this transition will result in localized welding of the surfaces and eventual seizure. It must be noted that scuffing wear is an entirely different tribological and physical phenomenon compared to mild wear. This method is concerned with the determination of the maximum load a particular lubricant can withstand prior to the onset of scuffing type wear.

B.3 PRIMARY TEST EQUIPMENT (See Figure B1):

B.3.1 Test Ball Specification:

Material : Chrome alloy AISI 52100 steel
Hardness : 64 to 66 Rc
Surface Finish : Grade 5-10 EP (extra polish)
Dimensions : 12.7 mm diameter

B.3.2 Cylinder Specification (See Figure B2):

Material : SAE 8720 steel
Hardness : 58 to 62 Rc
Surface Finish : 0.56 to 0.71 µm rms
Dimensions : 49.25 +0.00/-0.15 mm diameter

The ball and cylinder specifications described above are identical to those listed in ASTM D 5001.

B.3.3 Cleaning Solvents:

B.3.3.1 Isooctane (2,2,4 - trimethylpentane), analar, spectro, or better grade.

B.3.3.2 Isopropyl alcohol, reagent grade or better.

B.3.3.3 Acetone, reagent grade or better.

B.4 DESCRIPTION OF APPARATUS:

Figures B3 and B4 show the system components.

A speed controlled motor (0.25 kW), coupled directly to a reduction gearbox, provides the rotational drive to the test cylinder. The gearbox reduces the maximum shaft speed from 1850 to 440 rpm producing a maximum sliding speed of 44 in/s. A flexible drive coupling is incorporated between the motor and the test section to minimize the effect of any shaft misalignment.

The load arm and support are arranged with a moment such that the ball load is three times that applied to the arm.

Oil heating is provided via two 110 V/500 W cartridge heaters inserted into the reservoir. A Eurotherm controller is utilized to allow bulk oil temperatures of up to 200 °C ± 2 °C.

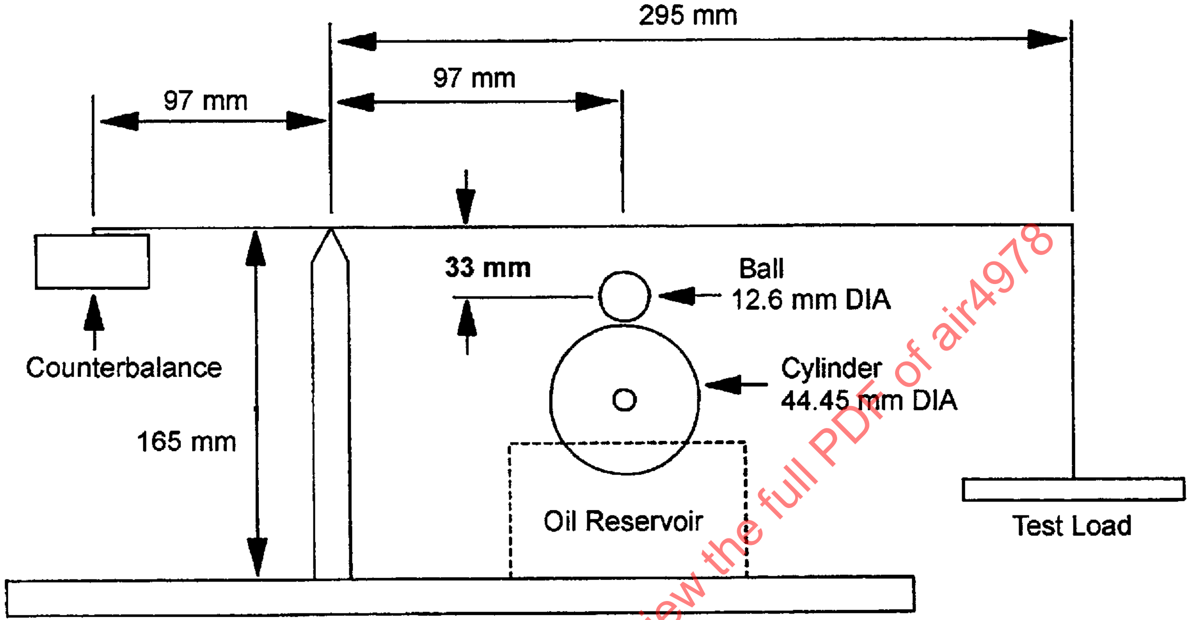
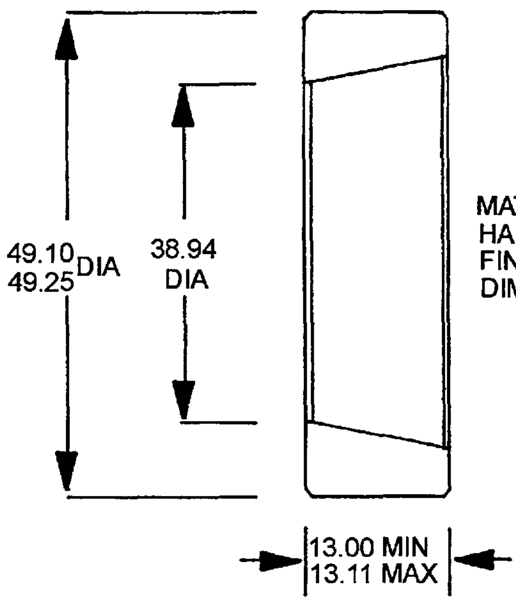


FIGURE B1 - Rolls-Royce Tribology Evaluator



MATERIAL: STEEL SAE *8270 SPECIAL MODIFIED
HARDNESS: 58 - 62 Rc
FINISH: 22 - 28 RMS
DIMENSIONS: mm

FIGURE B2 - RRTE Test Cylinder

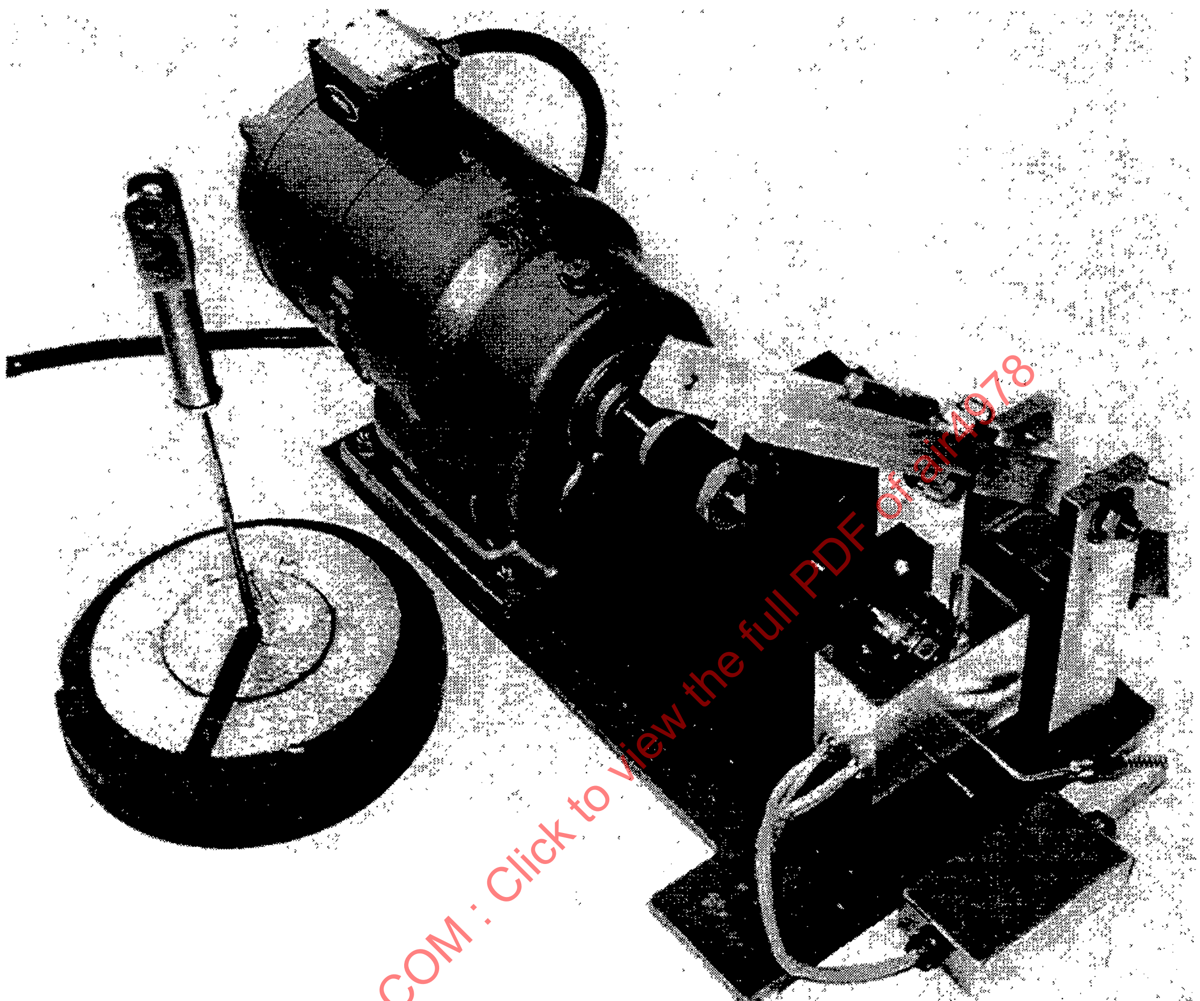


FIGURE B3

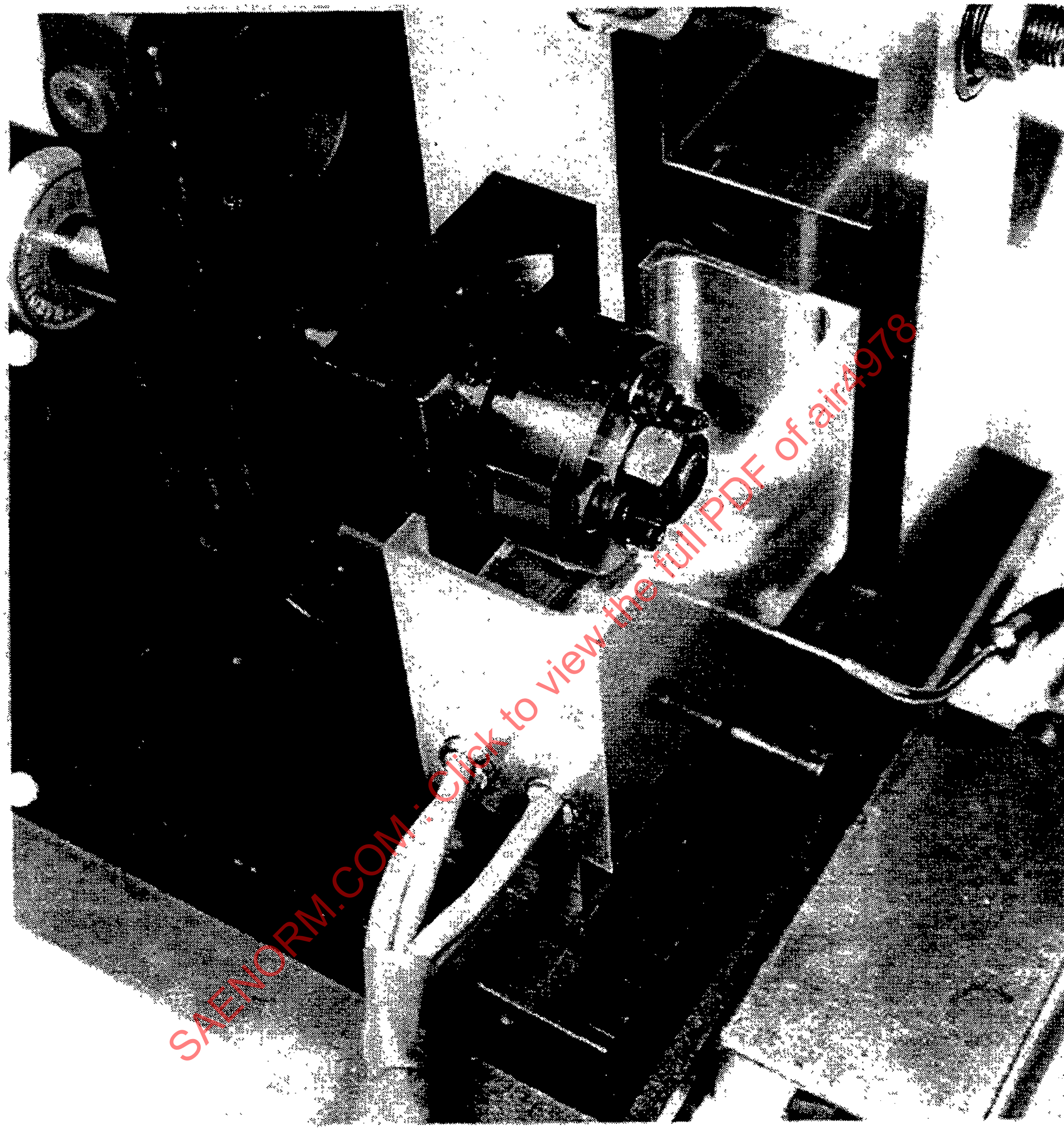


FIGURE B4

B.5 SUMMARY OF OPERATING CONDITIONS:

TABLE B1

Parameter	Scuffing Wear Mode	Mild Wear Mode
Test duration	1 min ± 0.05 min	30 min ± 0.1 min
Test temperature	150 °C ± 2 °C	100 to 200 °C ± 2 °C
Ball load	24 to 60 kg	3 to 39 kg
Cylinder speed	220 rpm ± 5 rpm	220 rpm ± 5 rpm
Sliding speed	22 in/s ± 0.5 in/s	22 in/s ± 0.5 in/s
Sample volume	48 ml ± 1 ml	48 ml ± 1 ml

B.6 PREPARATION OF APPARATUS:

Great care must be taken to adhere strictly to cleanliness requirements and to the specified cleaning procedures. During handling and installation procedures, protect cleaned test parts (cylinder, balls, reservoir, etc.) from contamination by wearing clean cotton gloves.

B.7 CLEANING OF APPARATUS AND TEST COMPONENTS:

B.7.1 Test Rings, As Received:

B.7.1.1 Strip the wax protective coating from the test rings by manually wiping them with a lint-free cloth soaked in acetone.

B.7.1.2 Using a steam bath, boil the test rings in acetone for a period of 20 min.

B.7.1.3 Drain off any remaining liquid and top up with fresh acetone. Boil for a further 20 min period.

B.7.1.4 Remove test rings from vessel and rinse thoroughly with acetone. Dry with a lint-free cloth and store in a desiccator.

B.7.2 Test Balls, As Received:

B.7.2.1 Remove the oil coating from each ball by wiping with an acetone soaked lint-free cloth.

B.7.2.2 Follow steps 7.1.2 through 7.1.4.

B.7.3 Oil Tank, Ball Chuck, and Ring Mandrel Assembly Components:

B.7.3.1 Rinse each component with isooctane.

B.7.3.2 Clean in an ultrasonic bath for 15 min in isopropyl alcohol.

B.7.3.3 Remove and rinse with isooctane.

B.7.3.4 Dry and store in a desiccator prior to use.

B.8 SCUFFING TEST:

B.8.1 Assembly and Test Procedure:

B.8.1.1 Rinse motor output shaft with isooctane and wipe with disposable wiper.

B.8.1.2 Assemble mandrel/cylinder components as shown in Figure B5. Finger tighten the four allen headed bolts, ensuring the keyway on the lockplate is aligned with the keyway on the mandrel.

B.8.1.3 Slide mandrel spacer and motor shaft and insert keyway.

B.8.1.4 Locate mandrel/cylinder assembly on the motor shaft keyway and attach outer washer and main locknut (see Figure B5).

B.8.1.5 Torque mandrel allen bolts in a progressive diagonal manner to a setting of 25 in/lb ± 3 in/lb.

B.8.1.6 By inserting the locking bar into the hole in the motor shaft, torque the main locknut to a setting of 50 in/lb ± 5 in/lb.

B.8.1.7 Rotate the motor shaft at test speed to check for satisfactory smooth running (periodically check the eccentricity of the assembly using a dial test indicator).

B.8.1.8 Install a clean test ball by first placing the ball in the retaining nut. Screw the retaining nut onto the threaded chuck located on the load arm and tighten securely.

B.8.1.9 Lower the load arm by sliding the counterbalance forward. With the test ball firmly in contact with the test cylinder check the load arm horizontal via the attached spirit level. The indicator bubble shall be centered in the middle of the two lines. If necessary, adjust the retaining nut screw to achieve a level load arm.

B.8.1.10 Having installed a fresh cylinder, it is necessary to adjust the relative lateral position of the load arm.

B.8.1.11 For subsequent tests, reset the cylinder position a distance of approximately 2 mm across from the edge of the previous wear track. When testing lubricants of known low load carrying greater than 2 mm between tracks is recommended.

B.8.1.12 Install the clean reservoir and support with spacing platform. Using a clean graduated 50 ml measuring cylinder, transfer 48 ml ± 1 ml of test lubricant to the reservoir.

B.8.1.13 Place thermocouple in lubricant immediately behind the cylinder. Ensure thermocouple tip is fully submerged.

B.8.1.14 Start rotation of cylinder by switching motor drive to ON. Set potentiometer on speed control unit to maintain 220 rpm ± 5 rpm.