Laboratory Performance Tests for AUTOMOTIVE GEAR LUBRICANTS Intended for API GL-5 Service

ASTM

STP 512A

INTERNATIONAL
Standards Worldwide

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Corrections – STP 512A

Introductory Information

Page 3	Third paragraph – Change MIL-L-2105C to MIL-L-2105D
Page 4	Table 2 – Change RGO 124 to RGO 125
Page 5	Table 3 – Title change MIL-L-2105C to MIL-L-2105D
Page 14	5.2.2 – U.S. Motors 1.1 should be KW... (delete words, should be)
Page 22	Noted Items:
	Item 2 – Change "Hub O.D." to "Hub I.D."
	Item 3 - Change "Hub I.D." to "Hub O.D."
Page 29	Asterisk at bottom of page refers to location 4, axle housing cover
Page 46	Note 3 – Change ...controlled at 220 ± 3°F
	to ...controlled at 200 ± 3°F
Page 51	11.1.2 – Reference oils ...are designated RGO 103 and RGO 105
Page 68	Note 3, 3.5.1. – Change (573m³) to (5.7L)
Page 71	5.2.4 - ...speed to 400rpm change to ...speed to 385rpm
Page 71	5.2.9 – Add statement "recharge with test oil"
Page 79	Figure 1 – Change 3/8" (1.0mm) to 3/8" (10mm)
Page 85	2.1 – Change 0.3 gallon/hour to 0.3 cubic feet/hour
Page 85	2.1 – Change "of oil..." to "of air..."
Page 86	3.1.5 – Change "gallon/hour" to "cubic feet per hour"
Page 89	5.7 – Sentence should read "Install the air-box thermocouple in the

air-box cover so that the tip is 3 inches..."

Page 89 6.2 – Change "0.3 gallon/hour" to "0.3 cubic feet/hour"

Page 92 First Line – Change "lubricant" to "lubricants"

Page 95 Heading – "Test Oil Viscosity..." change to "AST.1 D445" to "ASTM D445"

Page 95 Last Line – Change "Benzene Insolubles (uncoagulated) to "Toluene Insolubles (uncoagulated)"

Page 71 5.3.1 Line 2

...200°F (93.3°C) [for low viscosity oils e.g., grades 75W, 75W-90, 175°F (79°C)] and with...

Page 71 Note 6, Line 2

...(93.3°C); 175°F (79°C) for 75W type oils...

Page 72 5.3.6

Add second sentence "For low viscosity oils, e.g., grades 75W, 75W-90, use water spray on axle housing to control rate of temperature rise. Commence shock loading when oil temperature drops to 200°F (93°C) with a maximum rise of 5.5 to 8.3°C."

Page 75 Sequence IV

The word "Alloy" should be "Allow"

LABORATORY PERFORMANCE TESTS FOR AUTOMOTIVE GEAR LUBRICANTS INTENDED FOR API GL-5 SERVICE*

Sponsored by:
ASTM Committee D-2 on Petroleum Products and Lubricants, Subcommittee B on Automotive Lubricants, Section III on Gear Lubricants

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RELATED ASTM PUBLICATIONS

ASTM and other specifications for Petroleum Products and Lubricants, 4th Edition 1985.

FOREWARD

This report is made available for those interested in the performance of lubricating oils as a material of engineering. The procedures are part of the technical language used for describing the performance of automotive gear lubricants which will satisfy manual transmission and axle requirements of modern passenger cars and trucks.

The information contained herein has not been subjected to ASTM's full consensus balloting and review procedures, and the test methods described have no official status as ASTM Standards. The technical review of these test procedures was accomplished through simultaneous balloting by ASTM Section D02.B03 on Gear Lubricants and Subcommittee D02.B on Automotive Lubricants.

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Performance Test for Evaluating the Thermal Oxidation Stability of Automotive Gear Lubricants

INTRODUCTORY INFORMATION

INTRODUCTION

STP 512A replaces STP 512 (published in 1972). STP 512 was a compilation of the automotive gear lubricant tests used to define API services GL-4, GL-5, and GL-6. The GL-4 and GL-6 services are presently considered obsolete by API because: the test equipment originally used to define these services is no longer available; and alternate equipment/procedures have not been developed. At present, only the Gear Lubricant Service Designation API GL-5 can be completely defined. STP 512A contains 1987 versions of the original GL-5 performance tests updated under the guidance of ASTM.

Gear lubricants have changed significantly over the past four decades in response to performance demands imposed by changes in operating conditions, design and metallurgy of automotive axles and transmissions. The API Lubricant Service Designations for Automotive Manual Transmissions and Axles[1] allows matching performance requirements and lubricant quality. Each of these six Lubricant Service Designations, (API GL-1 through GL-6) states in qualitative terms the kind of service in which a gear lubricant is expected to perform satisfactorily. Both the type of gears and the operating conditions for the lubricant are included in each Service Designation.

Supplementing of the qualitative API Designations with performance definitions is needed particularly for Designations GL-4, GL-5, and GL-6 (Appendix 1). These definitions include a series of tests and associated minimum performance requirements.

Under the API, ASTM, SAE Tripartite System, a Lubricant Performance and Service Classification Maintenance Procedure - SAE J1146 November 1980 (1986 SAE Handbook 3:23.47) - is designed to keep abreast of changing requirements by redefining existing categories, adding new or declaring as obsolete lubricant categories for automotive applications. Under this system, ASTM is responsible for defining the technical language (test techniques and performance criteria), while API defines the user language and assigns the category designation. The API designations as well as other items of information are published in the SAE Handbook under "Axle and Manual Transmission Lubricants" - SAE J308 Nov. 82 (1986 SAE Handbook 3:23.20).

SCOPE

The purpose of this publication is to provide detailed procedures for the API GL-5 gear tests. A total of six independent test procedures are required to define API GL-5 Service (Table 1).

The API GL-5 Service Designation is important because it

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[1] *API Publication No. 1560 available from the American Petroleum Institute, 2101 L Street, Northwest, Washington, DC 20037.*

represents the most commonly specified and commercially available type of automotive gear lubricant. It is estimated that 80 percent of gear lubricants produced are formulated to satisfy the API GL-5 Service Designation.

API GL-5 performance tests originated with the U.S. Army Gear Lubricant Specification MIL-L-2105B. The latter was updated to encompass multigrade oils, SAE 80W-90 and 85W-140 in 1976 (MIL-L-2105C), but performance requirements were unchanged.

TABLE 1
API GL-5
Required Laboratory Tests

Test Designation	Type	Characteristics Measured
L-33	Gear test using axle components	Resistance to corrosion in the presence of moisture
L-37	Gear test using complete axle assembly	Resistance to gear distress under the conditions of low speed high torque
L-42	Gear test using complete axle assembly	Resistance to gear distress (scoring) under conditions of high speed and shock loads
L-60	Bench test using spur gears	Thermal oxidation stability
ASTM D 892*	Bench test	Foaming tendencies
ASTM D 130*	Bench test	Stability in the presence of copper and copper alloys

**These test methods are available in ASTM's Annual Book of Standards, Vol. 05.01.*

In 1987 MIL-L-2105C was replaced by MIL-L-2105D (allowing the use of re-refined base oils) without a change in performance tests. These remain as summarized in Table 1.

It should be noted that several differences exist between API GL-5 and the Military Specification MIL-L-2105D. In addition to the six API GL-5 performance tests, MIL-L-2105D also requires:

(1) Evidence of compatibility with previously approved oils (FTM 3455.1).

(2) Field testing of new additive systems and/or unique base stocks, e.g., synthetic components.

(3) Third party performance review system (SAE Lubricants Review Institute).

(4) Approval by the U.S. Army Belvoir Research, Development and Engineering Center.

API GL-4 and GL-6 Service Designations are considered to be obsolete since the equipment used in performing one or more of the required tests is no longer available. While the original type of testing cannot be performed on new oils, lubricants of these types (API GL-4 and GL-6) may be available via previously approved lubricant formulations. ASTM is currently considering new tests to describe lubricant applications requiring other than API GL-5 service oils.

MILITARY APPROVAL

Gear lubricants purchased by the U.S. Military, NATO affiliates and some federal, state and local government agencies must be approved under MIL-L-2105C. The mechanism by which lubricants are reviewed is outlined in the LRI Gear Lubricant Review Committee procedures available from SAE at the address below:

Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, PA 15096
Attention: Mr. G. Pollak

API GL-5 GEAR TESTS

The following sections detail the four test procedures for API GL-5 gear tests: Section 1 (L-33 Test Method); Section 2 (L-37 Test Method); Section 3 (L-42 Test Method); and Section 4 (L-60 Test Method).

API GL-5 BENCH TESTS

Copper Corrosion (ASTM D 130)

Copper containing mechanical components such as thrustwashers and synchronizer elements, may be found in axles and transmissions where gear lubricant use is specified. Consequently, it is important that these lubricants are equally compatible with both copper alloys and ferrous metals. ASTM D 130 - Method for Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test (Vol. 05.01) - is used in combination with appropriate limits to define the degree of copper corrosion protection provided by gear lubricants.

Foaming Tendency (ASTM D 892)

Churning and agitation of the lubricant in the axle can result in air entrainment and foaming. The consequence of excessive foaming may be leakage and depletion of lubricant supply. ASTM D 892 - Test Method for Foaming Characteristics of Lubricating Oils (Vol. 05.01) - is the procedure used to determine the lubricants ability to resist foaming in service.

REFERENCE OILS

Reference oils for each of the API GL-5 gear tests are available from the ASTM Test Monitoring Center, 4400 Fifth Avenue, Pittsburgh, PA 15213, Attn: Mr. Paul Eisaman.

The correct reference oils required for each of the API GL-5 tests are listed in Table 2.

TABLE 2-- Reference Oils and Tests

Performance Test	Reference Oil*	
	High Level	Low Level
L-33	RGO 124	RGL 122
L-37	RGO 105	RGO 103
L-42	RGO 110	RGO 108
L-60	RGO 4668	RGO 4669

**Alternate reference oils are under consideration by ASTM. For current information on API GL-5 reference oils contact ASTM Test Monitoring Center.*

PRECISION

The precision of the API GL-5 gear tests has not been established with the exception of ASTM D 892 and ASTM D 130. As additional data is generated, it is anticipated that a statistical evaluation can be determined.

PROCEDURES

MIL-L-2105C Chemical and Physical Requirements

TABLE 3 - CHEMICAL AND PHYSICAL PROPERTIES REQUIREMENTS OF MIL-L-2105C

	Values		
	Grade 75W	Grade 80W-90	Grade 85W-140
Viscosity at 100°C (212°F)			
Kinematic, cSt, min	4.1	13.5	24.0
max	-	24.0	41.0
Temperature for apparent viscosity of 150,000 cP, °C, max	-40	-26	-12
Channel point °C, max	-45	-35	-20
Flash point °C, min	150	165	180
Gravity, °API	x	x	x
Viscosity index	x	x	x
Pour point	x	x	x
Pentane insolubles	x	x	x
Sulfated ash	x	x	x
Sulfur (total)	x	x	x
Sulfur contributed by additive	x	x	x
Phosphorus	x	x	x
Nitrogen	x	x	x
Boron	x	x	x
Zinc	x	x	x
Potassium	x	x	x
Chlorine	x	x	x
Organo-metallic components	x	x	x

X=Report (determination or measurement required)

MIL-L-2105D Storage Stability and Compatibility

Lubricants must not exhibit any separation upon storage or when mixed with other lubricants, particularly those of the same performance categories. If separation occurs, the result is additive depletion with accompanying loss of performance. A modified CRC L-22 (Federal Test Method 3440) is used for evaluation of solubility.

To assess a lubricant's compatibility characteristics, the candidate oil is mixed with six reference oils representing previously approved gear lubricants. Evaluation is by a modified FTM 791b method 3430. The reference oils are supplied under code by:

Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, PA 15096
Attention: Mr. G. Pollak

MIL-L-2105D Field Test Requirements

The following are excerpts from the LRI "Procedures of the Gear Lubricants Review Committee for Review at Gear Lubricants Under Military Specification MIL-L-2105C" (October 1985).

Field test information (to demonstrate satisfactory field service performance) is required when the following are used:

(1) Unknown or new additive packages including viscosity index improvers and combinations thereof.

(2) New processes for recovery, reconstitution and/or treatment of base stocks, or new types of base stocks or combinations thereof.

(3) More than a combined total of 2 mass % of low temperature flow improvers ("pour point depressants").

No changes in field test requirements are anticipated to accompany MIL-L-2105C to MIL-L-2105D change.

Additional information may be obtained by contacting the Gear Lubricant Review Committee Secretary at SAE World Headquarters (address below).

Related Documents

Document	Source
MIL-L-2105C or MIL-L-2105D	Department of the Army U.S. Army Belvoir R. & D. Center Attention: STRBE-VF Ft. Belvoir, VA 22060-5606
API 1560	American Petroleum Institute 2101 L Street, Northwest Washington, DC 20037
SAE J308 and LRI Procedures	Society of Automotive Engineers 400 Commonwealth Drive Warrendale, PA 15096

APPENDIX 1

API GL-4, GL-5, GL-6 Performance Criteria

GEAR PERFORMANCE	GL-4 MIL-L-2105	GL-5 MIL-L-2105C	GL-6
1. Gear Scoring Resistance Under Conditions of High Speed Shock Load	A) CRC L-19* or FTM 6504T B) Equal or Better than RGO-105	L-42 Gear/Pinion Coastside Scoring Equal or Better than RGO-110	Vehicle Rear Axle Score Test (Ford Drag Start Procedure 001) No Scoring After 500 Drag Starts
2. Resistance to Gear Distress Under Conditions of High Torque, Low Speed	CRC L-20 No tooth disturbance such as rippling, ridging, pitting or severe wear.	L-37 No tooth disturbance such as rippling, ridging, pitting or severe wear.	No Requirement
3. Corrosion Resistance in the Presence of Water	A) CRC L-13 or FTM 5313.1 B) CRC L-21 No evidence of rusting	L-33 No evidence of rusting after 7 days exposure on any working surface. Maximum of 0.5 $in.^2$ (3.2 cm^2) rust on cover plate (1% of surface area)	Ford BJ 10-3 Water Tolerance Merit rating of 8 or greater 0 (poor) 10 (clean)
4. Thermal and Oxidation Stability	No Requirement	L-60 Vis Increase 100% max Pentane Insol. 3% max Toluene Insol. 2% max	L-60 Vis Increase 100% max Pentane Insol. 3% max Toluene Insol. 2% max
5. Lubricant Stability in Motored Axle Test	No Requirement	No Requirement	Ford BJ 15-1 Stability - No Abrasive deposits Seal Life - No Cracking or leakage Viscosity Change - ±5% max

* Equipment no longer available. Impossible to conduct test per original procedure.

APPENDIX 1 (continued)

API GL-4, GL-5, GL-6 Performance Criteria

	GEAR PERFORMANMCE	GL-4	GL-5	GL-6
6.	Antifoaming Characteristics	CRC L-12 Readings taken immediately after 5 min aeration Sequence 1, 75°F (23.9°C)-21.97 fl oz (650 ml) Sequence 2, 200°F (93.3°C) 21.97 fl oz (650 ml)	ASTM D 892 Reading taken immediately after 5 min aeration Sequence 1 - 0.67 fl oz (20 ml) max Sequence 2 - 1.7 fl oz (50 ml) max Sequence 3 - 0.67 fl oz (20 ml) max	ASTM D 892 0.8 fl oz (25 ml) max immediately after aeration and 0 ml after standing in Sequence 1, 2 and 3
7.	Copper Corrosion	ASTM D-130 3b max after 1 h @ 250°F (121.1°C)	ASTM D 130 3 max after 3 h @ 250°F (121.1°C)	ASTM D 130 3a max after 3 h @ 250°F (121.1°C)
8.	Channeling Characteristics	No Requirement	FTM 3456.1 Modified SAE 75 - -49°F (-45°C) max SAE 80W90 95°F -31°F (-35°C) max SAE 85W140 68°F -40°F (-20°C) max	-25°F (-31.7°C)
9.	Separation Characteristics	FTM 3440, modified		
	Solubility measure separated material after centrifuging of oil stored for 30 days at room temperature - 84.9°F ± 49°F (29.4°C ± 9.5°C)	0.25% wt max of original non-petroleum material in sample	0.25 wt max of original non-petroleum material in sample	No Requirement
	Compatibility Same as solubility except mixed 50/50 with each of six ref. oils (available from SAE)	0.50% wt max of original non-petroleum material in sample	0.50% wt max of original non-petroleum material in sample	No Requirement

SECTION 1 (L-33 TEST) -- Performance Test for Evaluating the Moisture Corrosion Tendencies of Automotive Gear Lubricants

The test method described herein has no official status as an ASTM Standard.

L-33 TEST

(formerly CRC L-33 Test and FTMS 791B Method 5326.1)

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1. SCOPE

1.1 This test method describes a test procedure for evaluating the rust and corrosion inhibiting properties of a gear lubricant while subjected to water contamination and elevated temperature in a bench-mounted hypoid differential housing (carrier) assembly. The customary test is a seven-day test; an abbreviated test of one day may also be run.

1.2 This test method may involve hazardous materials, operations, and equipment. This test method does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this test method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. APPLICABLE DOCUMENT

2.1 *SAE Recommended Practice* - J923 Axle Nomenclature and Terminology

2.2 *Definitions* - Stain vs. rust: The LRI Gear Lubricants Review Committee and ASTM (Section D.02 B.03) have adopted the following criteria to differentiate between stain and rust. "If the deposit or discoloration is transparent, it is considered to be stain rather than rust. However, if scale or pitting is observed, then the candidate lubricant has failed the test."

3. SUMMARY OF METHOD

3.1 This procedure utilizes a Dana Corporation Model 30 hypoid differential housing (carrier) assembly, Part No. 27770-1X, 4.10 ratio, standard differential with uncoated drive gear and drive pinion (ring and pinion).

3.2 Prior to each test, the new differential housing assembly is completely disassembled and cleaned, the cover sandblasted, all internal parts and surfaces coated with test oil, and the unit reassembled. It is then installed on the test rig; next, an oil temperature monitoring probe and a drive shaft are connected, then a cooling fan and heat lamps are placed into position near the test unit.

3.3 *Motoring Phase*

Motoring Phase - The test unit is charged with 2.5 pt (1.2 L) of test oil, then driven by an electric motor at 2500 rpm pinion speed in an unloaded condition (no axle shafts are used for the test). Next, 1.0 fl oz (30 mL) of distilled water is added and a pressure relief valve, set at 1 psi (approx. 7 kPa) is installed in the oil fill opening (all other test unit openings are already sealed). When the lubricant temperature reaches 180 ± 1°F (82.2°C ± 0.6°C) the relief valve is blocked and the motoring phase continues for four hours at this controlled temperature.

3.4 *Storage Phase*

At the completion of the motoring phase, the motoring is stopped; drive shaft, heat lamp and fan are removed. Next, an aluminum box with double walls and fan for air circulation and heat elements with temperature controller is placed over the test unit. The storage phase requires 162 h or approximately seven days at 125 ± 1°F (51.7°C ± 0.6°C) (the test unit remains in a static position).

NOTE 1 - A test with a shortened storage phase is only 18 h (special one-day test) may be run as a screening test.

3.5 At the end of the storage phase, the test is completed; the differential assembly is then disassembled and rated for rust and corrosion, sludge, and other deposits.

4. SIGNIFICANCE

4.1 *Method*

4.1.1 *Function* - The test method simulates a type of severe field service in which corrosion-promoting moisture in the form of condensed water vapor has accumulated in the axle assembly. This may happen as a result of volume expansion and contraction of the axle lubricant and the accompanied "breathing in" of moisture-laden air through the axle vent.

4.1.2 *Correlation* - This test method was developed specifically to provide a correlation to field experience. The correlation achieved will provide moisture corrosion of the type found in actual field service although formal correlation programs have not yet been run.

4.2 *Validity of Tests*

4.2.1 *Procedural Compliance* - Test validity is dependent on compliance with all requirements of this test

method.

4.2.2 *Test Stand Calibration* - A test is considered officially valid for presentation against specification only when conducted on a test stand previously calibrated by evaluation of the reference test oil. Reference test requirements are described in paragraph 10.1.

4.3 *Use*

4.3.1 *Specification and Research Activity* - This test method is used formally in specifications for gear oils. In support of research activity, the method is used to assess and compare performance levels of experimental lubricant formulations.

5. APPARATUS

5.1 *Laboratory Ambient Conditions*

5.1.1 *Test Stand Operating Area* - The ambient laboratory atmosphere is to be free of dirt, dust, and other contaminants as required by good laboratory standards. There are no specific temperature requirements for the operating area.

5.1.2 *Build-up Area* - It is recommended that the atmosphere in the test unit build-up area be filtered and maintained at uniform temperature and low humidity to prevent accumulation of dirt or rust on test parts.

5.1.3 *Parts Rating Area* - The rating of all test parts is conducted against a white background using a lamp with two 15-watt cool-white fluorescent bulbs.

5.1.4 *Parts Cleaning and Sandblasting Area* - Adequate ventilation must be provided in areas where solvents are used. Adequate safety equipment must be provided for sandblasting operations.

5.2 *Test Stand and Laboratory Equipment*

5.2.1 *Test Stand Configuration* - The differential housing (carrier) assembly is mounted on the test stand so that the housing (carrier) cover attaching face is in the vertical plane; and at a height that allows the temperature sensing probe to be located in the bottom of the housing (carrier).

NOTE 2 - Complete L-33 test stand information is provided in Appendix X-2.

5.2.2 *Drive System*

CAUTION - Rotating test stand equipment presents a physical hazard and safety guards should be used. In addition test operators should continuously be aware of this danger.

The drive system design is not precisely specified; however, the following equipment has been found to be suitable to turn the drive pinion at the specified 2500 ±25 rpm:

- U.S. Motors 1.1 should be Kw (1.5 hp), enclosed, 3600 rpm, 0.87 in. (2.22 cm) dia. shaft.

- Slide Motor Base, "Dyn-Adjust" No. 20-C.

- Dodge "Taper Lock" pulleys No. 40L100 (driven) and #28L100 (Drive).

- Dodge "Timing" Belt No. 480L100.

- Additional components such as shafts, couplings, and bearing blocks are also necessary to connect the above components to drive the carrier pinion, but are left to the option of the testing laboratory.

5.2.3 *Vapor Pressure Control System* - The differential's internal vapor pressure is controlled during the warm-up portion of the motoring phase by a James, Pond and Clark Co. pressure relief valve, Model No. 259B-2PP set for 1 psi (approx. 7 kPa) connected to the housing (carrier) cover with a 3/4 in. NPT stainless steel 90 street ell.

5.2.3.1 Housing (Carrier) Cover Gasket - The housing (carrier) cover gasket must be cut from manila file folder material; test development has shown this material to be optimum because it is not prone to water absorption and therefore minimizes rusting corrosion at the cover plate/housing interface.

5.2.3.2 Housing (Carrier) Axle Tube Opening Seals - Since the differential is tested without axle shafts or axle tubes, the housing (carrier) openings must be sealed. Fig. 2 shows construction dimensions for fabricating a pair of seals to be installed in the axle housing (carrier) openings before introducing test oil prior to starting the test.

5.2.4 *Temperature Control System, Motoring Phase* - During the motoring phase, the bulk oil temperature is sensed by a Rosemount Inc. Platinum Resistance Temperature Sensor (Model 78S01N0200) or equivalent and indicated by a Honeywell Recorder/Controller (Model 452CIL-33-L1-75) or equivalent. As needed to control bulk oil temperature at 180±1°F (82.2±6°C), the controller switches on: a pair of 250 watt heat lamps which are directed toward the differential or; a household-type electric cooling fan having 12 in. (30.5 cm) diameter blades. Fig. 1 shows the location of the heat lamp pair and the cooling fan. Fig. 3 shows the location of the temperature sensor in the differential housing (carrier).

5.2.5 *Storage Box and Temperature Control System, Storage Phase* - During the storage phase of the test, a double-walled aluminum box covers the differential housing (carrier) assembly, and the bulk oil temperature is controlled at 125±1°F (51.7±.6°C). A Fenwall Thermoswitch Catalog No. 17752 or equivalent regulates heat input from four 110V, 500W strip heaters, Chromolox Catalog No. S2450 or equivalent. A small fan motor of 25 watts, Dayton Electric Model 4K102 or equivalent turns a fabricated impeller to provide air circulation within the box. Fig. 4 shows construction and electrical details of this equipment.

5.2.6 *Sandblasting Equipment and Material*

CAUTION - Sandblasting presents a physical hazard; equipment manufacturer's precautions should be consulted and followed.

Sandblasting of the differential housing cover is specified and requires that sand of the following specification be used:

American Foundryman's Society grain fineness No. 26 Moh hardness of 7

99.8% SiO_2

Wedron Sand No. 4098 available from Wedron Silica Company, 50 Line Road, P.O. Box 119, Wedron, Illinois 61557 has been found to be satisfactory.

Sandblasting must produce a uniform surface on the cover plate and approximately 1 qt (.95L) of sand is necessary and must be applied using 100 psi (700 kPa) pressure with a 0.125 in. (3.2 mm) diameter nozzle.

6. REAGENTS AND MATERIALS

6.1 *Distilled Water*

6.2 *Stoddard Solvent*

CAUTION - Combustible. Vapor harmful. See Annex A3.

6.3 *Acetone*

DANGER - Extremely flammable. Vapors may cause flash fire. See Annex A3.

6.4 *Rust Prevention Oil - Mobil Arma 245*

CAUTION - Combustible mixture. Harmful or fatal if swallowed. See Annex A3 or equivalent.

6.5 *Rust Prevention Paper*

NOx Rust Vapor Wrapper or equivalent.

6.6 *Build-up Lubricant*

Test Oil will be used in all cases for test unit build-up.

7. OIL BLEND SAMPLING REQUIREMENTS

The test sample must be representative of the lubricant formulation being evaluated and must be uncontaminated.

8. TEST OIL SAMPLE

Minimum Sample Quantity - 1.0 gal (3.7L) of test oil is required for each test. The housing (carrier) capacity is 2.5 pt (1.2L); the remaining oil is used for coating test parts during build-up assembly.

9. PREPARATION OF APPARATUS

9.1 *Test Stand Preparation*

9.1.1 *Cleaning of Reused Fittings, Seals, etc.* - Clean, as necessary, all reusable parts including: axle tube opening seals, pressure relief valve and elbow, and the platinum resistance temperature sensor and its fittings.

9.2 *Differential Housing (Carrier) Assembly Build-Up*

9.2.1 *Cleaning and Preparation of Parts*

9.2.1.1 Disassembly - Completely disassemble the

differential housing (carrier) assembly, remove all parts including pinion and side gears from the differential case.

9.2.1.2 Carrier Housing Modification - Refer to Fig. 3, drill and tap the housing (carrier) to accept the platinum resistance temperature sensor.

9.2.1.3 Cleaning - Spray each component individually with Stoddard Solvent and allow to air dry.

CAUTION - Combustible. Vapor harmful. See Annex A3.

Be sure that all grease used in manufacturer's assembly is removed from bearings and lip seals. Do not use compressed air to force dry, as it may contain enough moisture to initiate rusting.

9.2.1.4 Inspection - Carefully inspect all parts for rust. Ensuring that all parts are rust-free. End-of-test inspection and rating make no allowances for parts rusted before start of test.

9.2.1.5 Rust Removal - With the exception of bearings, which must be replaced if rust is found, rust may be removed by sandblasting (see paragraph 5.2.6).

CAUTION - Sandblasting presents a physical hazard; equipment manufacturer's precautions should be consulted and followed.

After sandblasting, the parts must again be cleaned as shown in paragraph 9.2.1.3. If sandblasting was necessary to remove rust, this information must be noted on the data summary (see Annex A1).

9.2.1.6 Housing Cover Plate Preparation - The housing cover plate inside surface must be uniformly sandblasted (see paragraph 5.2.6). After sandblasting, pour Stoddard solvent over the coverplate surface and allow to air dry. Do not use compressed air to force dry, as it may contain enough moisture to initiate rusting. Next, rinse with acetone and allow to air dry.

DANGER - Extremely flammable. Vapors may cause flash fire. See Annex A3.

9.2.1.7 Test Oil Coating - Coat all interior carrier surfaces, and all internal parts with test oil; a new paint brush may be helpful. Pour approximately one-half liter of test oil over

the cover plate after it has been sandblasted and washed. Be sure to coat all of the surface then allow excess oil to drain.

9.2.2 *Assembly of Test Unit*

NOTE 3 - Do not touch any test parts with bare hands-- Fingerprints can cause rusting.

9.2.2.1 Drive Pinion Shaft Installation - Assemble the drive pinion shaft with its bearings and install in the housing (carrier). Determine pinion turning torque; break torque should be 7 to 10 lb.in. (0.8 to 1.1 N.m), turning torque should be 5 lb.in. (0.6 N.m) or less. The torques may be adjusted by adding or removing shims from pinion shaft. Record final break and turning torques on the test data sheet (Annex A1).

NOTE 4 - For proper shim selection when changes are necessary, refer to Spicer Axle Division Bulletin No. 5304-1, pages 27 through 41.

9.2.2.2 Differential Case Installation - Assemble the differential pinion, side gears, shafts and thrust washers etc. in the differential case. Then install the differential case assembly in the differential carrier housing.

Determine pinion turning torque for the assembled test unit; break torque should be 12 to 18 lb.in. (1.35 to 2 N.m), turning torque should be 7 to 13 lb.in. (0.8 to 1.4 N.m.) These torques may be adjusted by adding or removing shims at the differential case bearings. Record final break and turning torques on the test data sheet (Annex A1).

NOTE 5 - For proper shim selection when changes are necessary, refer to Spicer Axle Division Bulletin No. 5304-1, pages 27 through 41.

9.2.2.3 Cover Plate, Seals, Temperature Probe Installation - Install the cover plate and a new manila gasket (see paragraph 5.2.3.1). Insert the two axle tube opening seals (Fig. 2) until they touch the differential case bearings but do not tighten them. Install the platinum resistance temperature probe.

9.3 *Installation of Test Unit*

Install the assembled test unit on the test stand. Connect the driveshaft and temperature probe. Install the cooling fan and heat lamp pair as shown in Fig. 1.

10. CALIBRATION

10.1 *Test Stand Calibration*

10.1.1 Test stands are calibrated using reference oils. Two reference oils are currently used: one giving mild results or minimal moisture corrosion; the second severe results or substantial moisture corrosion. Reference testing requires both oils be tested for each stand:

- When a test stand is moved or commissioned;
- When a test stand is out of service for a period of four months or more;
- Each 20th test;
- Each six months after the last satisfactory reference test.

10.1.2 Two reference oils are used and are available from:

Mr. Paul Eisaman
ASTM Test Monitoring Center
4400 Fifth Ave.
Pittsburgh, PA 15213

10.1.3 All tests are consecutively numbered, either on a laboratory basis or stand basis; if on a stand basis, the stand used must be identified. Each sealed unit in which the 162-hour storage phase is conducted would be considered a test unit and as such would have its own sequential numbering system.

10.2 *Instrumentation Calibration*

10.2.1 *Drive Speed* - Calibration of drive speed should be done on a periodic basis according to good engineering judgement.

10.2.2 *Temperature* - Calibration of the temperature controller/recorder is required each four months. Calibration accuracy must ensure that the actual test operating temperatures are within the limits specified for temperature control.

10.2.3 *Pressure Relief Valve* - The pressure relief valve should be operationally checked on a periodic basis.

11. TEST PROCEDURE

11.1 *Pre-Test, Start and Motoring Phase*

11.1.1 Charge 0.3 gal (1.2L) of test oil to the test unit through the cover plate fill hole. Install the 90 Street elbow and loosely install the pressure relief valve.

11.1.2 Adjust the temperature controller to 180±1°F (82.2±.6°C).

11.1.3 Record time and the oil initial temperature on the data log (Annex A1) then immediately start the driving motor.

CAUTION - Rotating test stand equipment presents a physical hazard and safety guards should be used, as well as having a conscious awareness of this danger.

11.1.4 Remove the pressure relief valve and add 1 fl oz (30±0.5 mL) of distilled water to the test unit at the elbow. Reinstall, then tighten the pressure relief valve. Also tighten the axle tube opening seals. Measure and record drive pinion rpm.

11.1.5 Monitor oil temperature and when the oil temperature reaches 180±1°F (82.2±.6°C) install a pipe plug in the open end of the relief valve to completely seal the test unit. This prevents escape of any additional water vapor. Record the time on the data log.

11.1.6 Motor the test unit for four hours at 180±1°F (82.2±.6°C).

11.2 *Storage Phase*

11.2.1 When the motoring phase has been completed, record the time on the data log then stop the driving motor.

11.2.2 Disconnect the drive shaft, remove the heat lamps and cooling fan from the test unit to allow the storage box to be put in place.

11.2.3 Place the storage box over the test unit and switch on the internal circulating fan.

11.2.4 Experience has shown that when the storage box internal heating system is switched "on" just as the test oil temperature falls to approximately 140°F (60°C); the test oil temperature will

smoothly fall to the desired control temperature of 125±1°F (51.7±.6°C). Record on the data log the time when the test oil temperature reaches 125±1°F (51.7±.6°C). This is the start of the storage phase.

11.2.5 Continue the storage phase for a total of 162 h or approximately seven days.

NOTE 6 - A test with a shortened storage phase of only 18 h (one-day test) may be run as a screening test if desired. The procedure for this shortened one-day test is identical to that for the standard seven-day test except for the length of the storage phase time.

11.3 *End of Test Procedure*

11.3.1 When the storage phase has been completed; record the time on the data log, then switch off the storage box heating unit and circulating fan.

11.3.2 Remove the storage box.

11.3.3 Disconnect the temperature probe then remove the test unit from the test stand.

11.3.4 Drain and discard the used test oil, then completely disassemble the differential carrier assembly, remove all parts including pinion and side gears from the differential case.

11.3.5 Lightly spray all parts with Stoddard solvent to remove used test oil; spray air pressure cannot exceed 43.5 psi (300 kPa). Allow test parts to stand until solvent dries. The cover plate only may be blown with dry compressed air to avoid stain lines caused by solvent action.

12. DETERMINATION OF TEST RESULTS

Rating should be conducted under the lighting conditions shown in paragraph 5.1.3. Deposits on rated items will fall under one of two categories:[1] (1) Rust or corrosion; (2) Stain and Sludge or other. Rust or corrosion deposits will be assigned a level value, either 0, 1, 2, 5, or 10, using these definitions:

---

[1] *When differentiation between rust or corrosion vs. stain is difficult, the technique shown in Appendix X1 should be used.*

None = 0
Trace = 1 = not more than six spots, each 1 mm diameter or less.
Light = 2 = in excess of above and up to 1% of considered surface.
Moderate = 5 = in excess of above and up to 5% of considered surface.
Severe = 10 = covering more than 5% of considered surface.

The following items[2] will be rated as described above:

1 - Differential case pinion contact thrust surfaces
2 - Differential case side gear thrust surface and Hub O.D.
3 - Differential gears (side gears) thrust surface and Hub I.D.
4 - Axle Housing cover
5 - Drive gear (ring gear) tooth contact surfaces
6 - Drive pinion tooth contact surfaces
7 - Drive pinion roller surfaces
8 - Drive pinion cup contact surfaces
9 - Differential case roller surfaces
10 - Differential case cup contact surfaces

By filling in values on the rating sheet then applying the appropriate weighting values shown, a final deposit merit value will be obtained. Also note the presence, location and amount of additional deposits i.e., stain and sludge or other in the "Remarks" section on the rating sheet.

13. FINAL TEST REPORT

The final test report will include the Data Summary (Annex A1), rating sheet (Annex A2), and one black and white photograph of the cover plate showing the cover plate approximately 7 by 7¼ in. (17.8 by 18.4 cm) and including the test number.

NOTE 7 - To preserve test parts in storage or for shipment: after completion of all rating and documentation photographs, a rust preventative oil such as Mobil Arma 245 should be used to coat all parts; then wrap in corrosion inhibiting paper such as NOx rust vapor wrapper.

CAUTION - Combustible mixture. Harmful or fatal if swallowed. See Annex A3.

---

[2] *Locations of the rated areas are shown in Fig. 5 and Appendix X3.*

14. PRECISION AND BIAS

Precision and bias of this test have not yet been formally established. However, it is generally considered that the repeatability of the L-33 Moisture Corrosion Test is very good for gear lubricants which exhibit good anti-corrosion characteristics, but the repeatability of this test when conducted with a gear lubricant possessing marginal or poor anti-corrosion characteristics is poor.

NOTE 8 - See Appendix X-4 for Reference Oil Data.

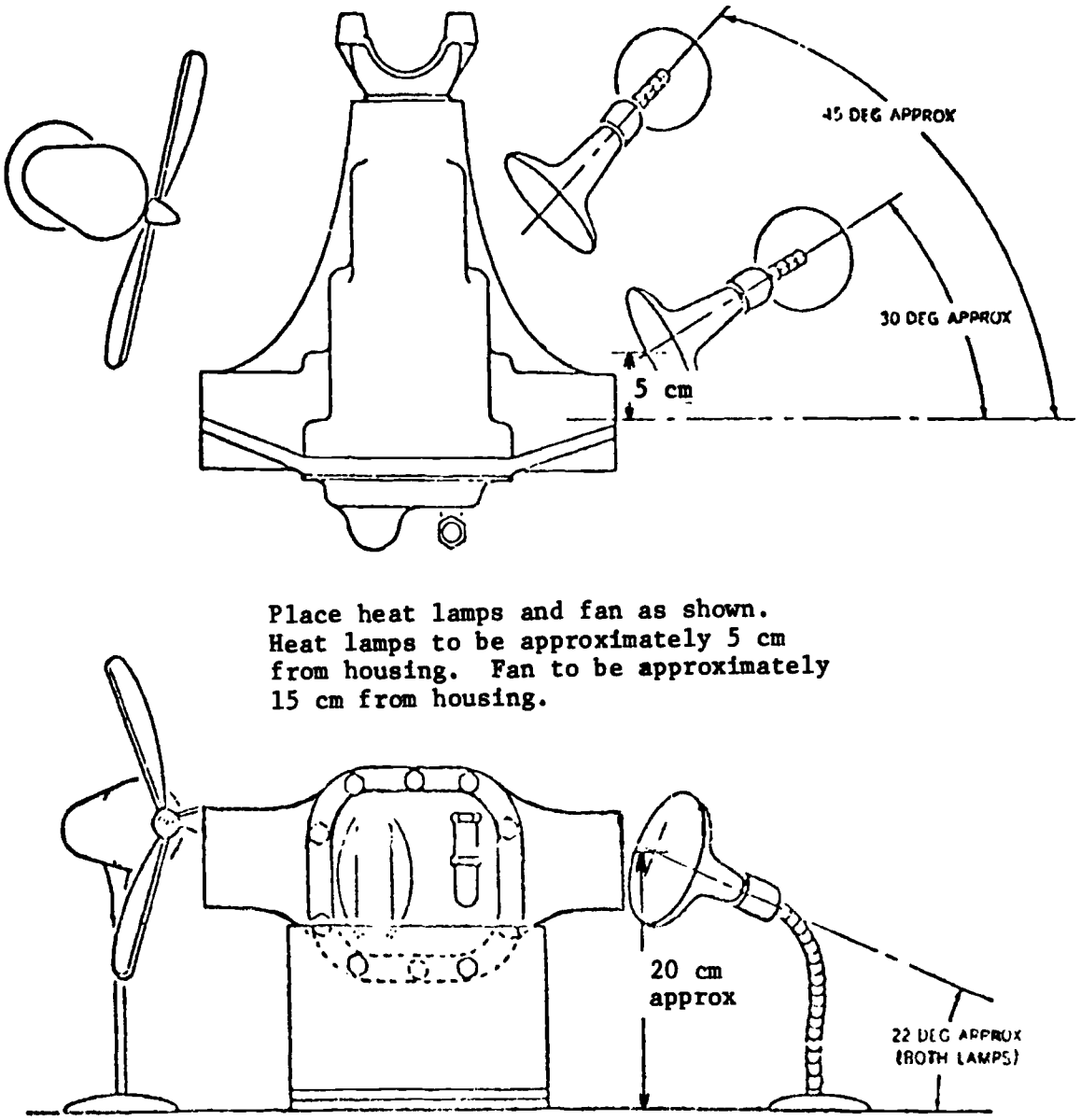
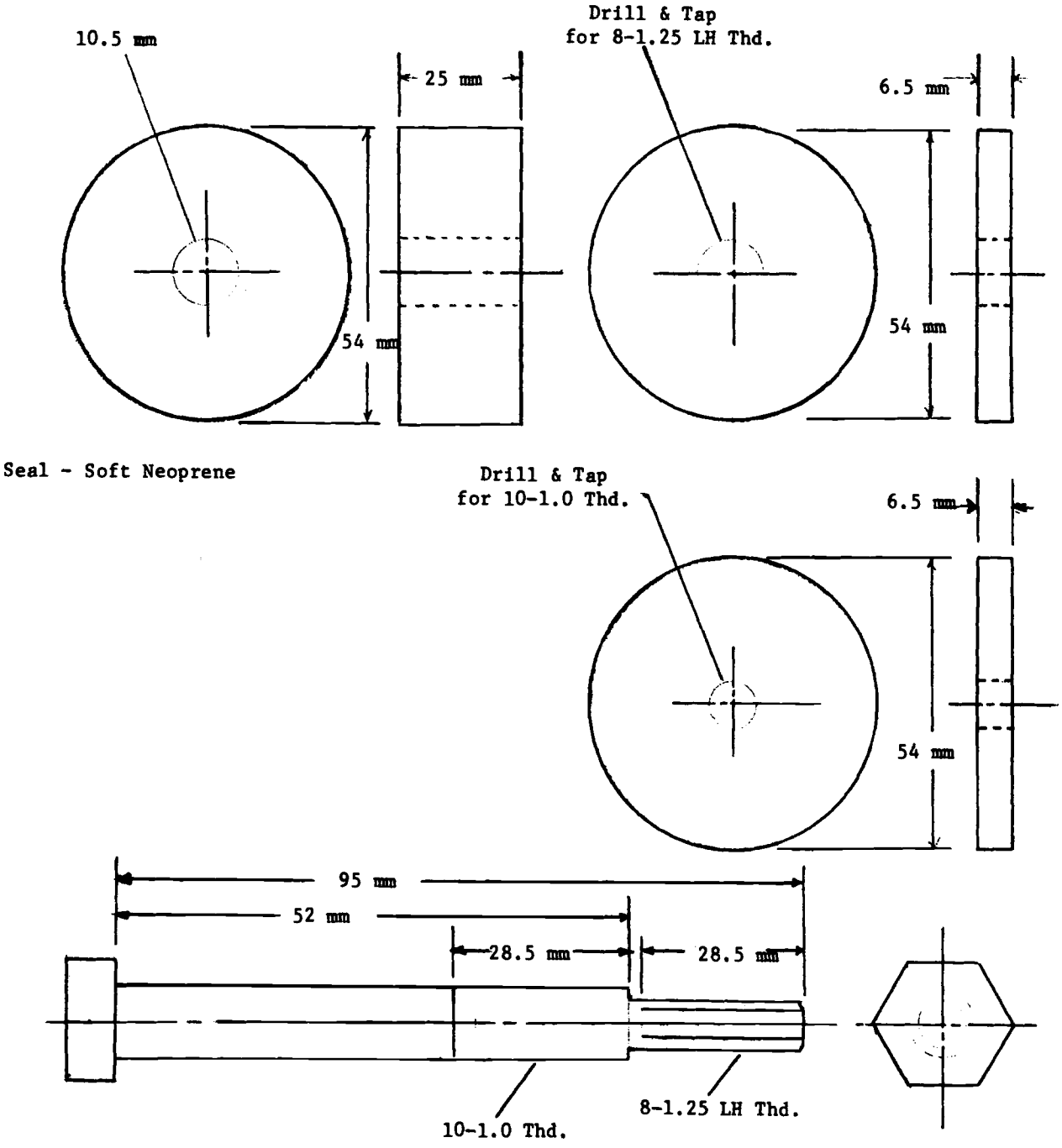


FIG. 1 - Heat Lamp and Fan Arrangement



Bolt and Washers - Stainless Steel

FIG. 2 - Axle Seals

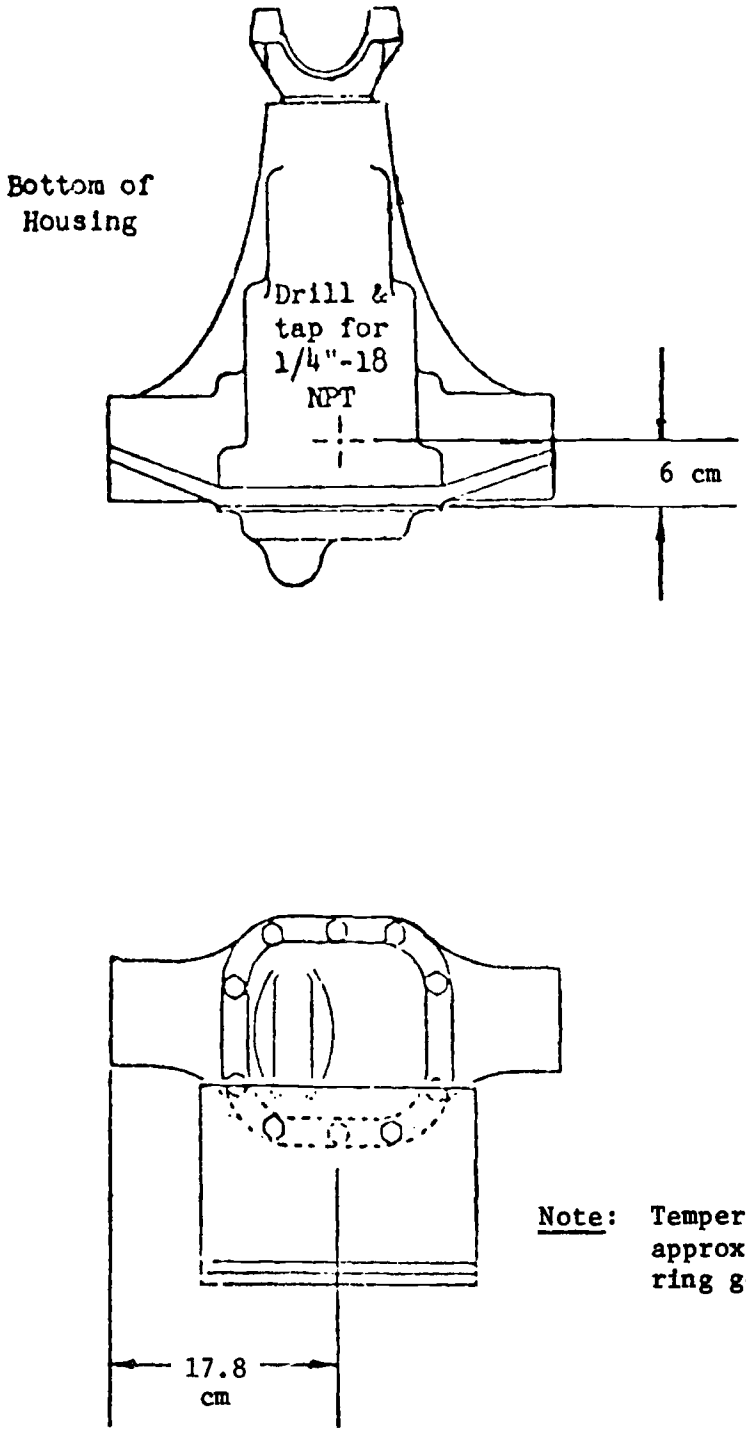
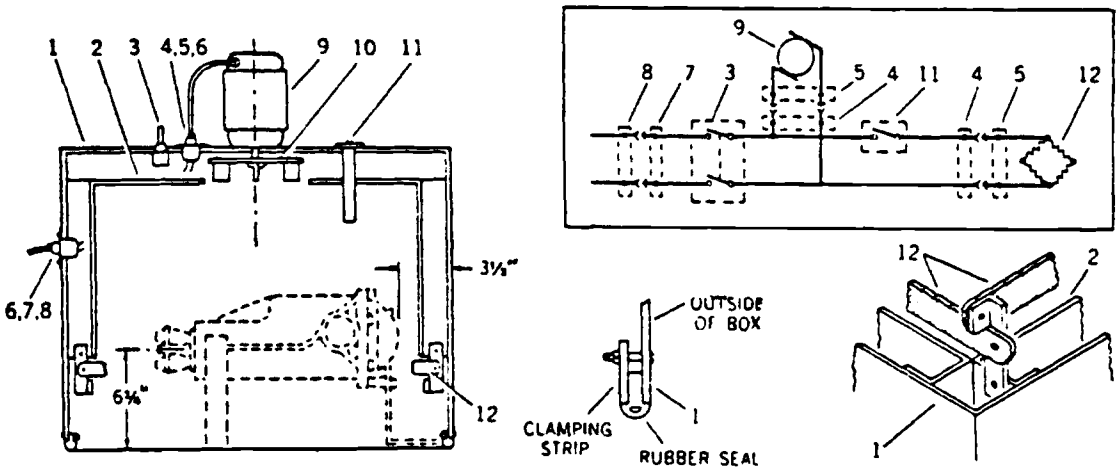


FIG. 3 - Temperature Probe Location



1. Outer box (62x62x45 cm) aluminum, welded seams
2. Inner baffle (53x53x46 cm) , aluminum, welded seams
3. Toggle switch (Cutler-Hammer No. 7560-K5, or equivalent)
4. Plug, female (Amphenol No. 61F, or equivalent)
5. Connector, male (Amphenol No. 61M11, or equivalent)
6. Shells (Amphenol No. 61-61, or equivalent)
7. Plug, male (Amphenol No. 61M, or equal)
8. Connector, female (Amphenol No. 61F11, or equivalent)
9. Fan motor, 25 watts (Dayton Elec. Co. Model 4K102, or equivalent)
10. Fan impeller, aluminum, 15.25 cm 6 blades (3.8x3.2 cm)
11. Thermoswitch (Fenwall Cat. No. 17752, or equivalent)
12. Heating element, 110-V, 500-W (Chromolox strip heaters No. S2450, or equivalent)

FIG. 4 - Controlled Temperature Storage Box

Annex A1

Data Summary

L-33 Moisture Corrosion Test

Test Laboratory _____ Date Test Started _____

Test Number _____Stand No. _____ Date Test Completed _____

Test Fluid _____ Test Fluid No. _____

Test Operator _____

Test Duration _____ Day(s)

Turning Torques: Pinion, lb. ft (N.m) Break _____ Turn _____

Full Assembly, lb. ft (N.m) Break _____ Turn _____

Warm-Up: Time Start _____ Finish _____

Temperature Start _____ Finish _____

Motoring Phase: Time Start _____ Finish _____

- Average Pinion Speed, RPM Start _____ Finish _____

- Oil Temperature, °F (°C) Avg. ___Max. ___ Min. __

Storage Phase: Time Start _____ Finish _____

- Oil Temperature, °F (°C) Avg. ___Max. ___ Min. __

Remarks: _____

_____

_____

_____

Annex A2
Rating Sheet

Test Laboratory _____ Date Test Started _____
Test No. _____ Stand No. _____ Date Test Completed _____
Test Fluid _____ Test Fluid No. _____
Rated by _____ Date _____

RUST/CORROSION

Location	Rust Levels (1)	
Differential Case:		
1. At Pinion Contact	_____	
2. At Differential Gear Contact	_____	
3. Differential Gears (Side Gears)	_____*	
4.Axle Housing Cover	_____	
5. Drive Gear (Ring Gear)	_____	
6. Drive Pinion Bearings:	_____	
Bearing		
7. Drive Pinion Rollers	_____	
8. Drive Pinion Cups	_____	
9. Differential Case Rollers	_____	
10. Differential Case Cups	_____	
Sum of Deposit levels	_____	_____
Severity Factor	2.50	0.50
Weighted Factor (Severity Factor times numerical total of deposit level)	_____	_____

Final Rust/Corrosion/Merit Rating (Sum of Weighted Values _____

REMARKS: (Note presence, location and amount of additional deposit-stain, sludge, etc.)

(1) Rust Level (Enter 0, 1, 2, 5, or 10):
None = 0
Trace = 1 = not more than six spots, each 1 mm diameter or less
Light = 2 = in excess of above and up to 1% of considered surface.
Moderate = 5 = in excess of above and up to 5% of considered surface.
Severe =10 = covering more than 5% of considered surface.

* 1% of considered surface = 0.50 $in.^2$ (3.23 cm^2).

At the LRI Gear Lubricants Review Committee Meeting No. 37, February 14, 1985, this definition was developed - "If the deposit or discoloration is transparent, it is considered to be stain rather than rust. However, if scale or pitting is observed, then the candidate lubricant has failed the test and the Committee Recommendation will be 'Not Acceptable'."

Annex A3

L-33 Moisture Corrosion Test

A3. PRECAUTIONARY STATEMENTS

A3.1 *Stoddard Solvent*

CAUTION - Combustible. Vapor harmful.
Keep away from heat, sparks and open flame.
Keep container closed.
Use with adequate ventilation.
Avoid breathing vapor or spray mist.
Avoid prolonged or repeated contact with skin.

A3.2 *Acetone*

DANGER - Extremely flammable. Vapors may cause flash fire.
Keep away from heat, sparks, and open flame.
Keep container closed.
Use with adequate ventilation.
Vapors may spread long distance and ignite explosively.
Avoid build-up of vapors and eliminate all source of ignition, especially non-explosion proof electrical apparatus and heaters.
Avoid prolonged breathing of vapor or spray mist.
Avoid contact with eyes and skin.

A3.3 *Mobil Arma 245*

DANGER - Combustible material.
Harmful or fatal if swallowed.
Keep away from heat and open flame.
Use only with adequate ventilation.
Avoid prolonged or repeated skin contact.
Avoid prolonged breathing of mist or vapor.
If swallowed, do not induce vomiting. Call physician immediately.

A3.4 *85% Concentrated Phosphoric Acid (H_3PO_4)*

DANGER - Harmful if swallowed. Do not get in eyes, on skin, on clothing.
Avoid breathing vapor or mist.
Keep in tightly closed container.
Loosen closure cautiously.
Wash thoroughly after handling.
Flood spill area with water spray.

A3.5 *Formula 30 Alcohol*

WARNING - Flammable. Keep away from heat, sparks and open flame.
Use with adequate ventilation.

Appendix X1

L-33 Moisture Corrosion Test

(Rust vs. Stain as Distinguished Through Profilometer Traces)

To resolve questions about rust versus stain on the surfaces, the following procedure is recommended.

1. Wash the surfaces in question with a rust remover consisting of:

   20 vol. % of 85% concentrated phosphoric acid (H_3PO_4)

   DANGER - Harmful if swallowed. See Annex A3.4

   40 vol. % Formula 30 Alcohol

   WARNING - Flammable. See Annex A3.5

   40 vol. % Distilled water

2. Run a profilometer over the surface in question. A relatively smooth profilometer trace will indicate no major change in the surface demonstrating stain; major changes in the trace will demonstrate rust.

Fig. X1 and X2 are exaggerated pits characterizing rust; Fig. X3 and X4 demonstrate stain.

This procedure is recommended only for questionable cases as it may be impractical to use in all cases.

Appendix X1

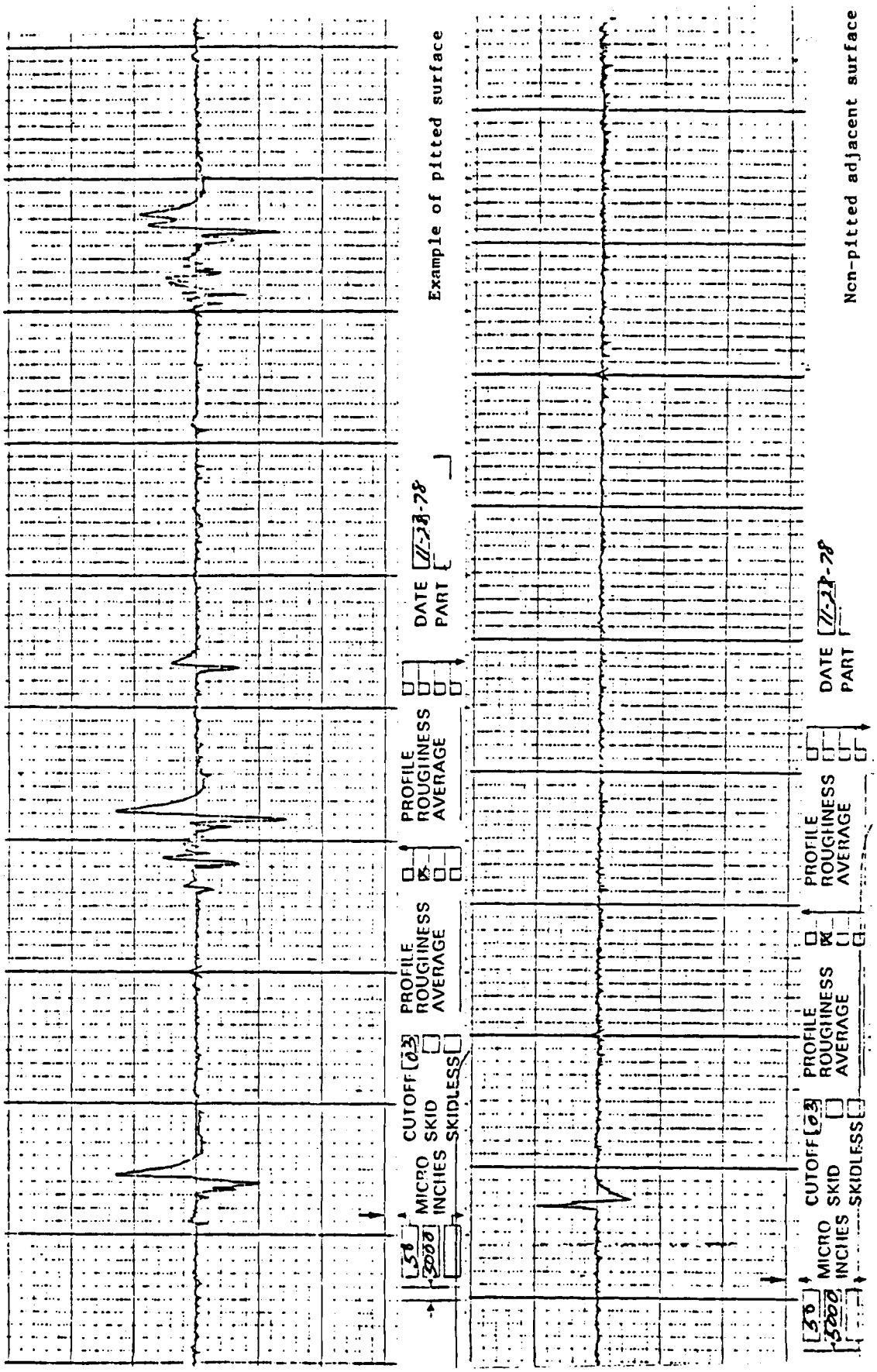


FIG. X1-1 – Bearing Race Surface Finish – Pitted Carrier Bearing

Appendix X1

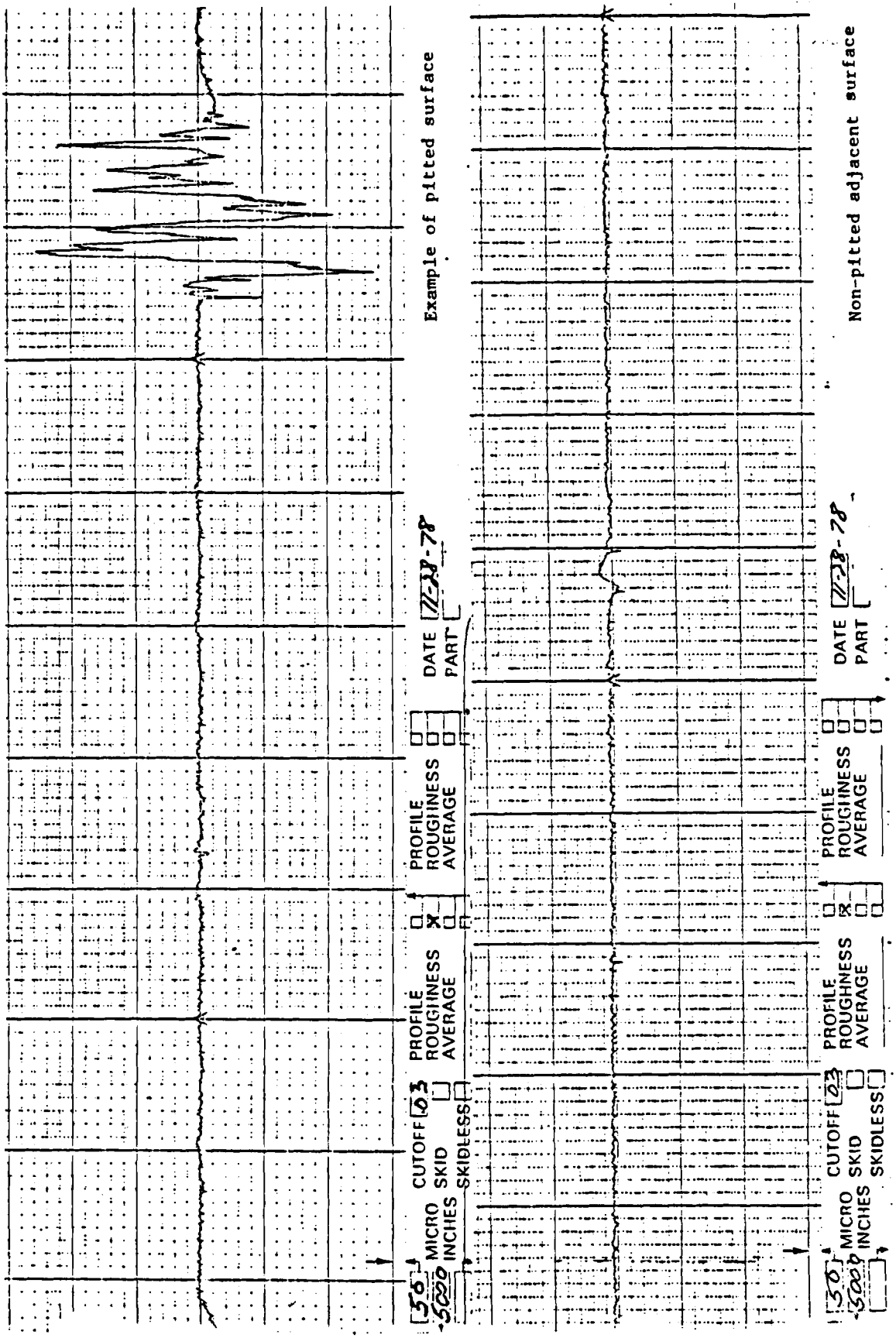


FIG. X1-2 - Bearing Surface Finish - Pitted Pinion Bearing

Appendix X1

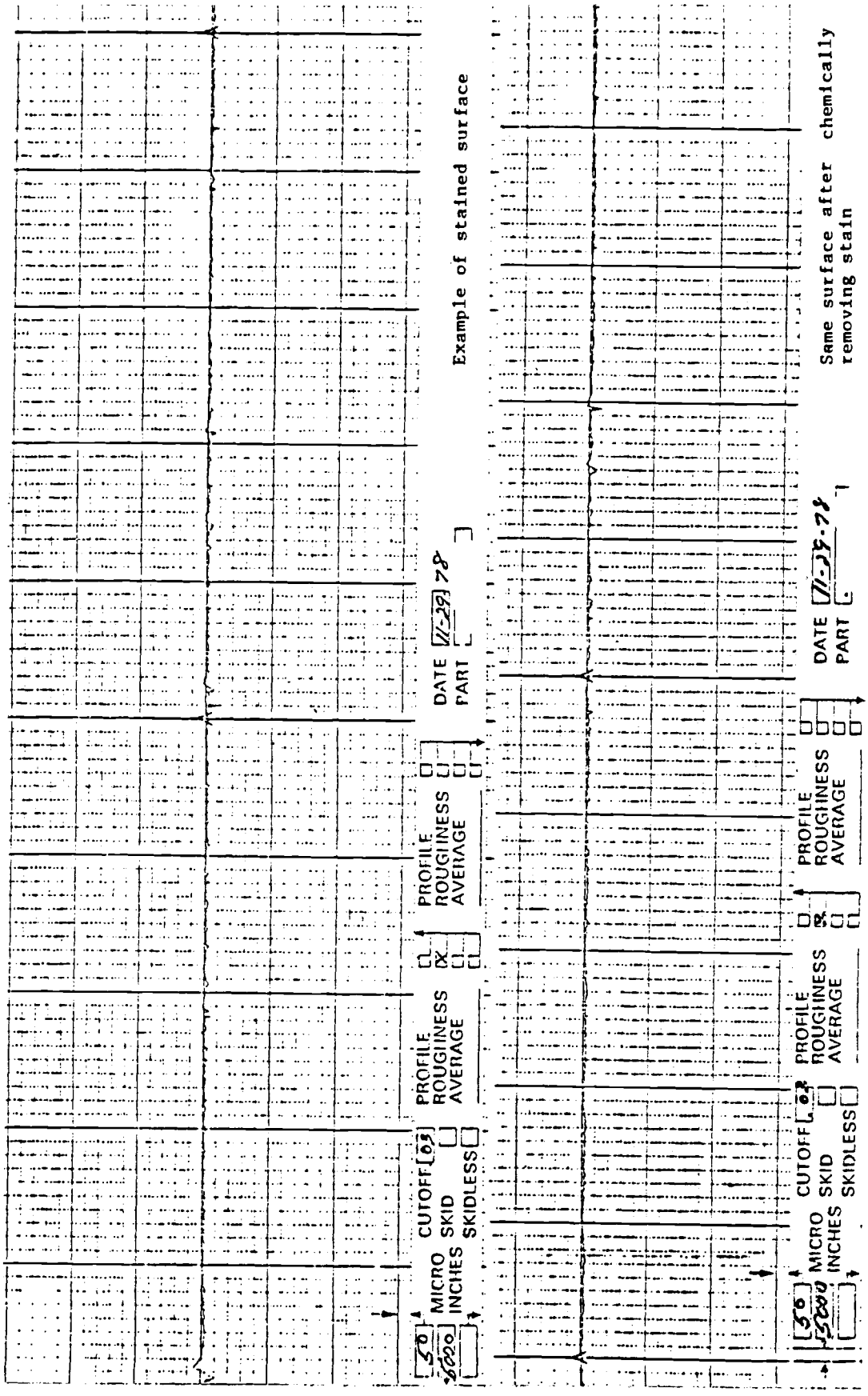


FIG. X1-3 - Bearing Surface Finish - Pinion Bearing Race

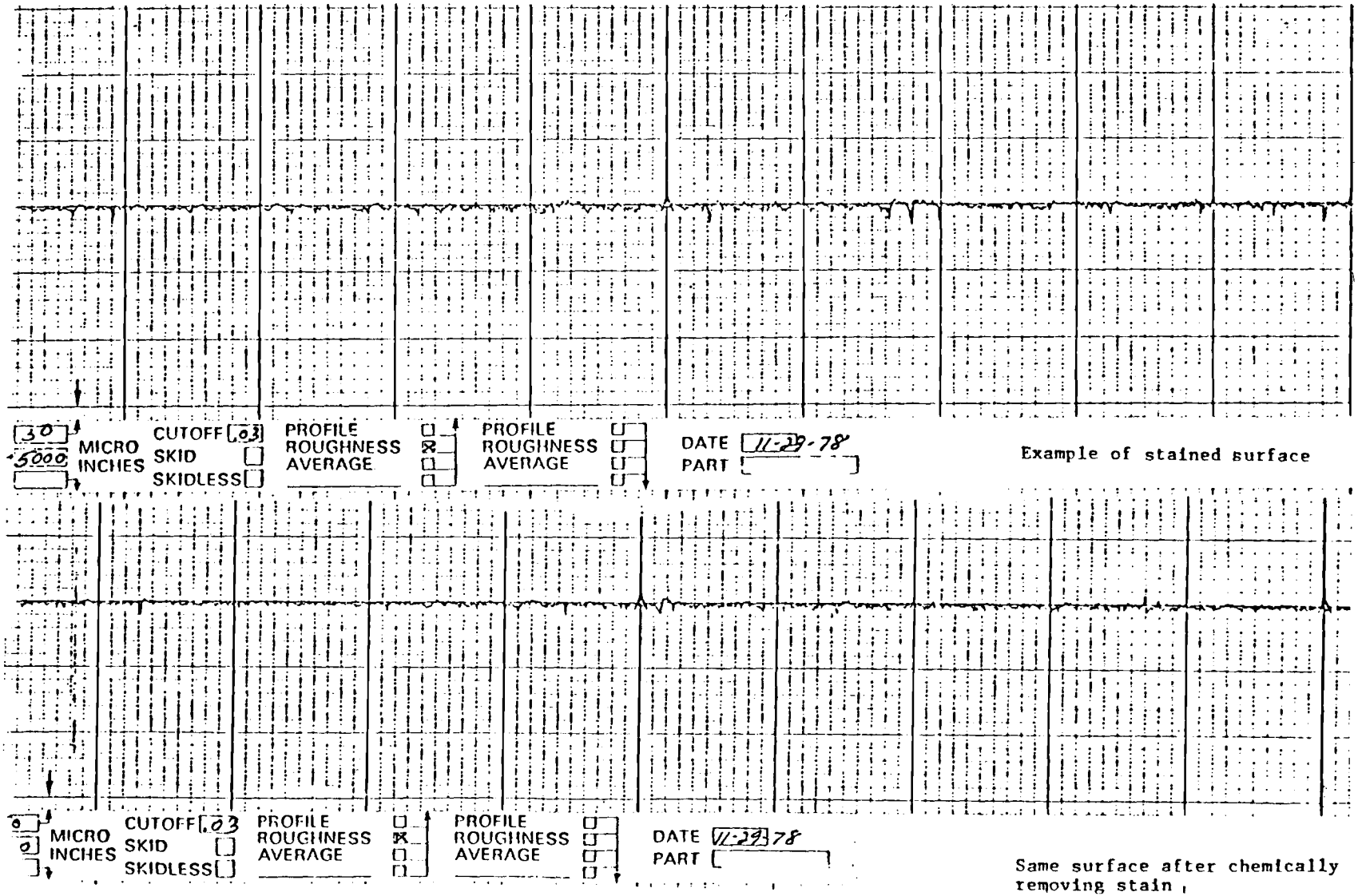


FIG. X1-4 - Bearing Surface Finish - Pinion Bearing Race

Appendix X2

Complete Test Stand

The following manufacturer offers a complete test stand for running the L-33 test, contact:

FLC Instruments, Inc.
2055 Comprehensive Drive
Aurora, Illinois 60505
Attention: Mr. Oscar M. Muskopf
Telephone: (312) 851-7660

Other sources for equipment of this type may be available. For additional information contact:

Autoresearch Laboratories, Inc.
6735 S. Old Harlem Ave.
Chicago, Illinois 60638

or

Southwest Research Institute
6220 Culebra Road
P.O. Drawer 28510
San Antonio, Texas 78284

Appendix X3 - L-33 Rated Surfaces

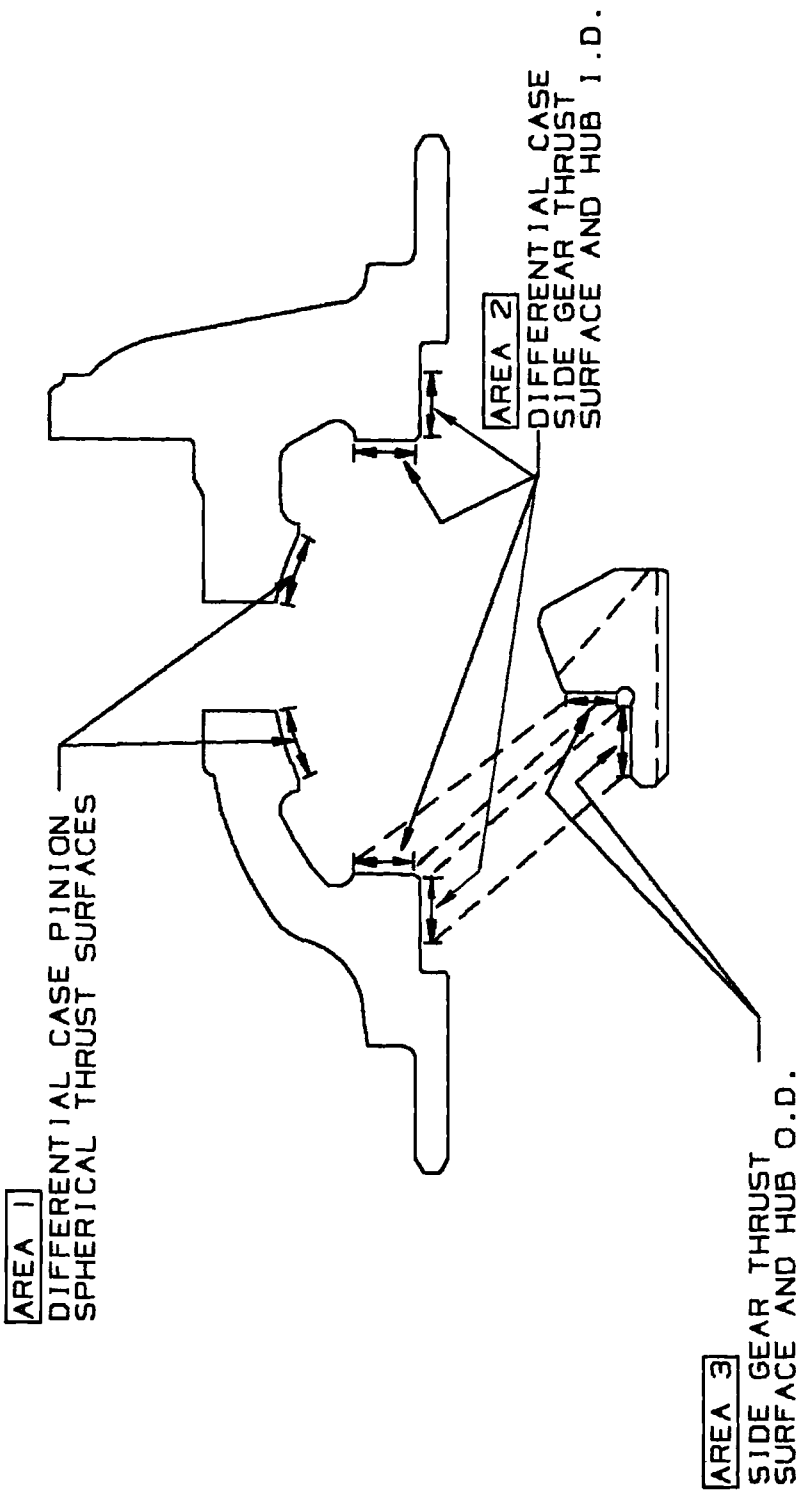


FIG. X3-1 - Differential Case

Appendix X3 - L-33 Rated Surfaces

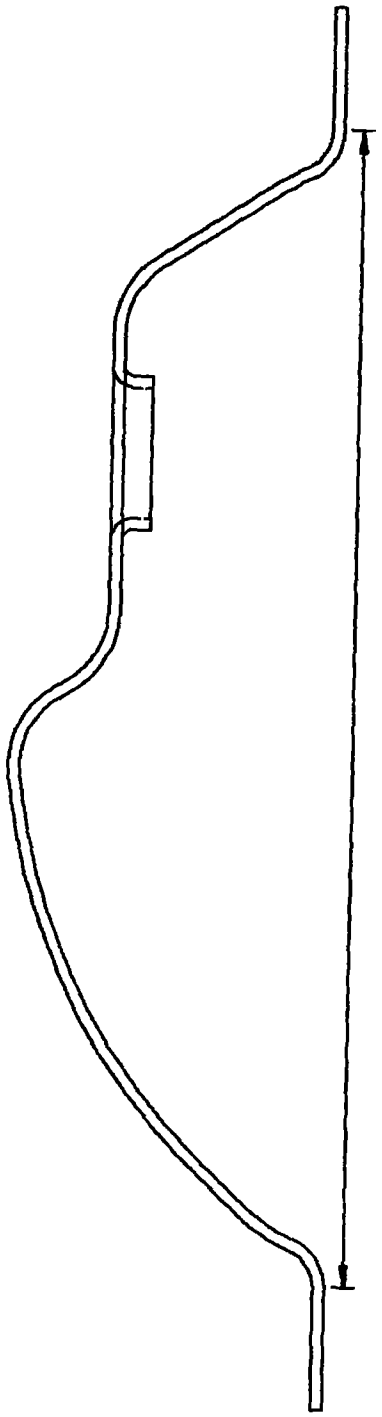
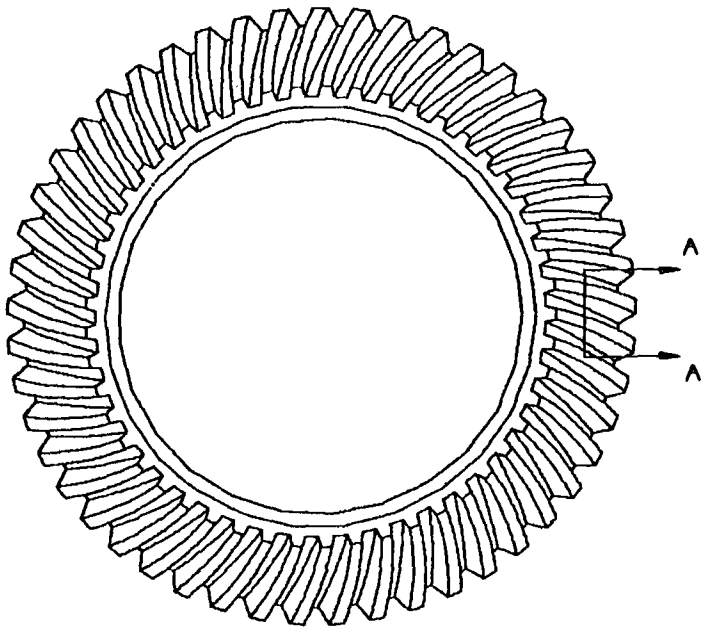
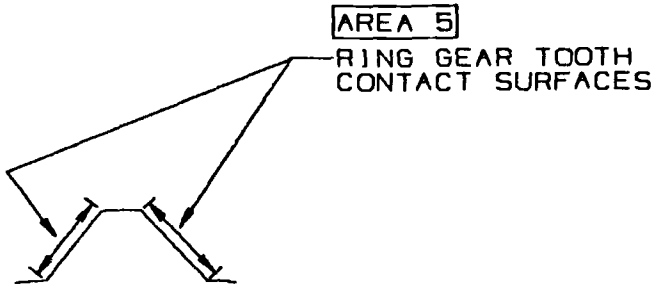
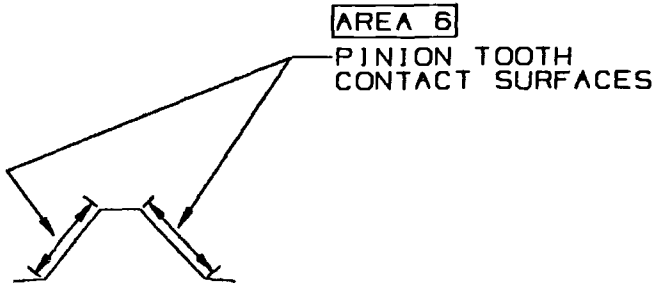


FIG. X3-2 - Cover Plate





SECTION A-A



SECTION B-B

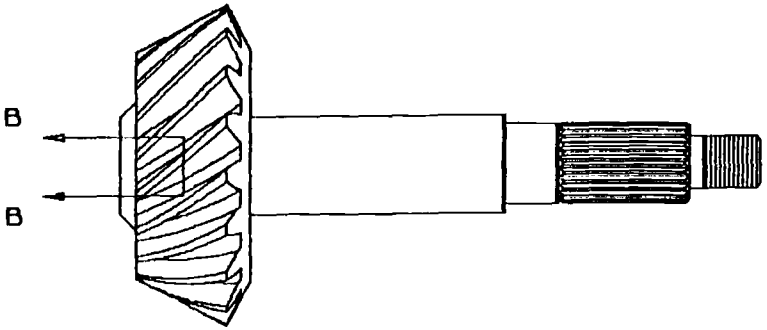


FIG. X3-3 -Ring Gear and Drive Pinion

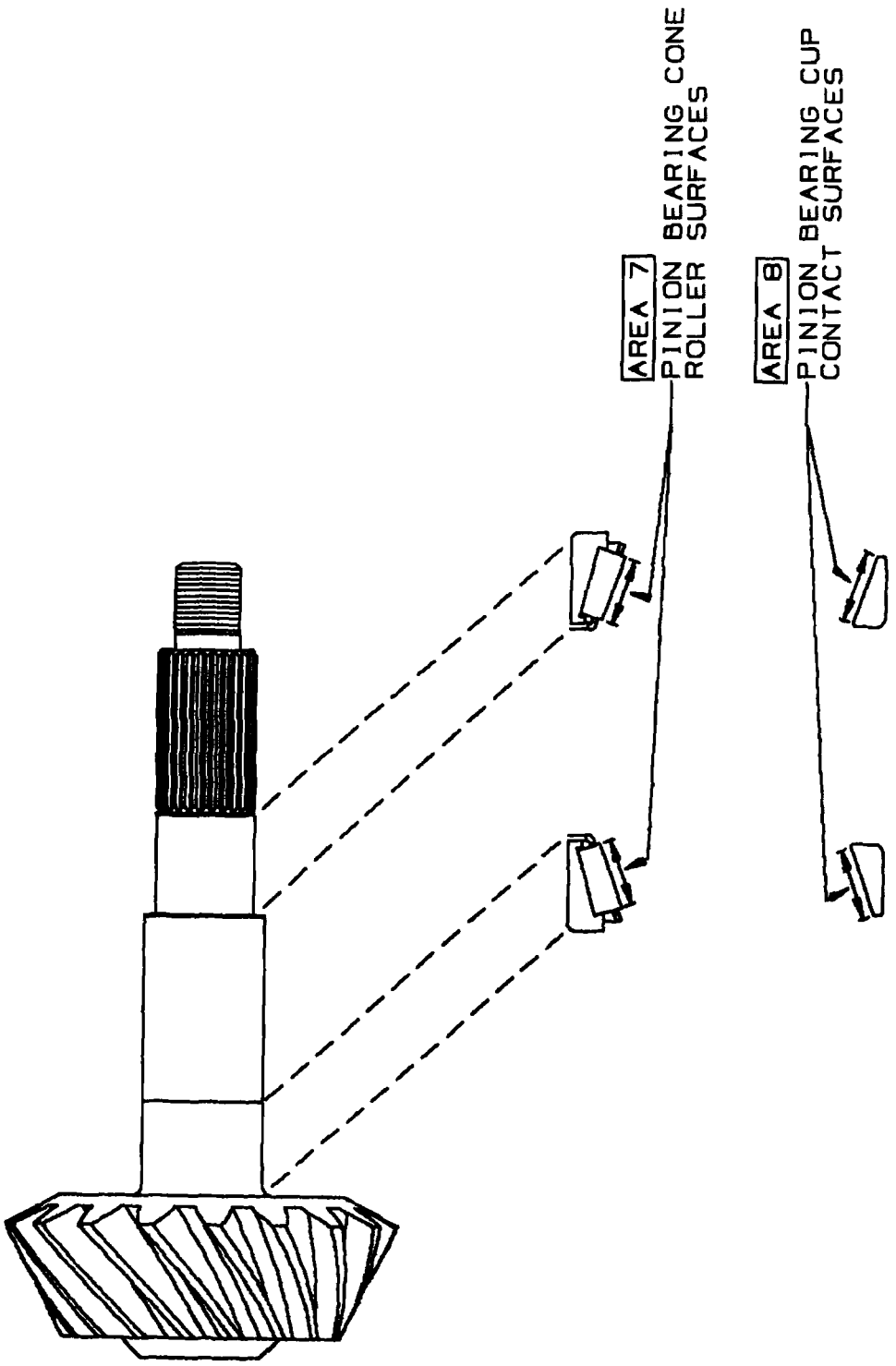


FIG. X3-4 - Drive Pinion Roller Bearings

Appendix X3 - L-33 Rated Surfaces

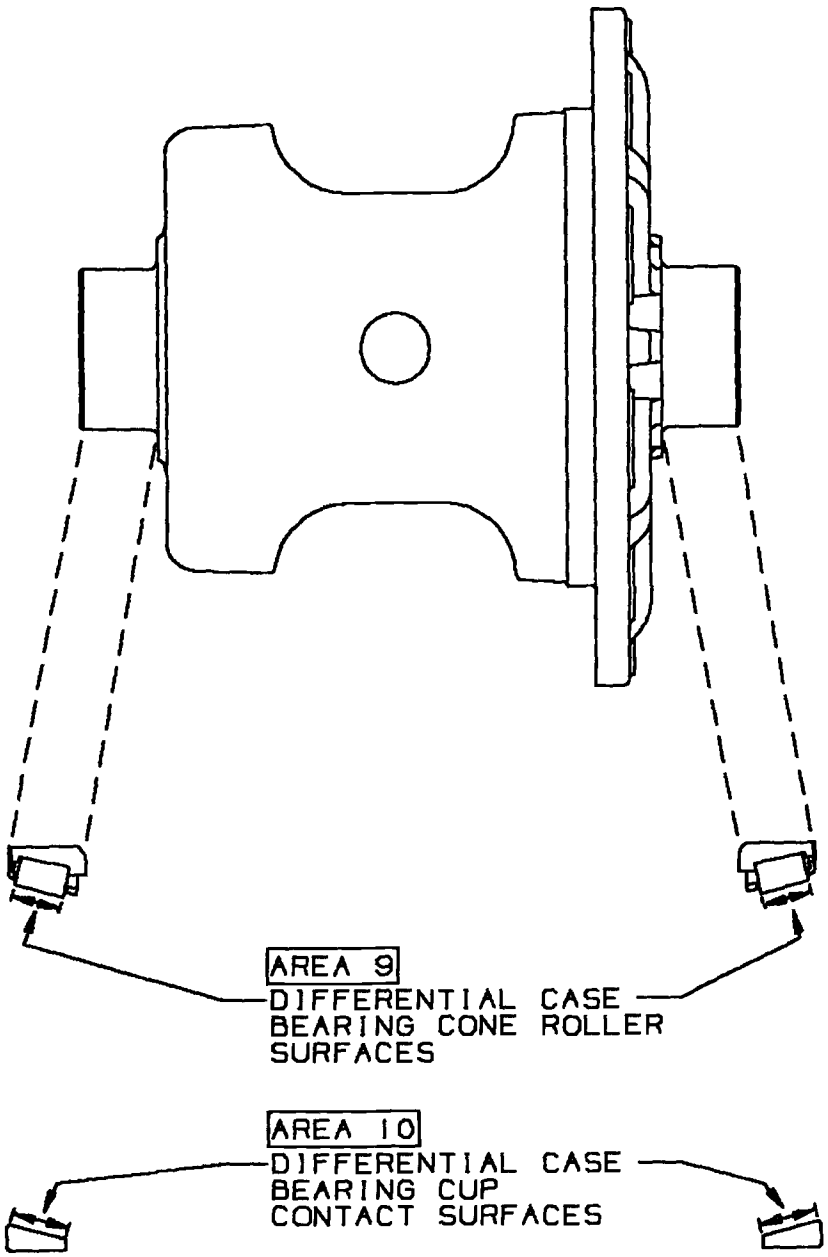


FIG. X3-5 - Differential Case Roller Bearings

FIG. X3-5 - Differential Case Roller Bearings

Appendix X4

Summary of L-33 Reference Tests Using 1982 Reference Oil Blends

	Location Weighted Factor			
Location/ Oil	Critical (Functional Surfaces)	Cover Plate	Final Merit Rating	Overall Assessment
RGO 122-82	7.50	1.00	8.50	Fail
	2.50	1.00	3.50	Fail
	2.50	0.50	3.00	Fail
	2.50	0.00	2.50	Fail
RGO 124-82	0.00	0.50	0.50	Pass
	0.00	0.00	0.00	Pass
	0.00	0.00	0.00	Pass

SECTION 2 (L-37 TEST) -- Performance Test for Evaluating the Load Carrying Capacity of Automotive Gear Lubricants Under Conditions of Low Speed and High Torque

The test method described herein has no official status as an ASTM Standard.

L-37 TEST

(formerly CRC L-37 Test and FTMS 791B Method 6506.1)

---

1. SCOPE

1.1 This test method describes a test procedure for evaluating the load carrying, wear, and extreme pressure properties of a gear lubricant in an axle under conditions of high-speed, low-torque and of low-speed, high-torque operation.

CAUTION - This test method may involve hazardous materials, operations, and equipment. This test method does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this test method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. APPLICABLE DOCUMENT

SAE Recommended Practice - J923 Axle Nomenclature and Terminology.

3. SUMMARY OF METHOD

3.1 This test procedure uses a Dana Model 60 hypoid differential housing (carrier) assembly, Part No. 060AA100-2, 5.86 ratio, standard differential with uncoated drive gear and drive pinion (ring and pinion). Prior to each test, the entire axle assembly is cleaned; no disassembly is allowed.

NOTE 1 - A test may be run using coated[1] drive gear and drive pinion. For this purpose, the test unit is a Dana Model 60 assembly Part No. 060AA100-4, 5.86 ratio, standard differential.

3.2 *Sequence 1* - High-speed, low-torque operation: The test unit is charged with 6 pt (2.8 L) of test oil, then run for 100 min at 440 wheel rpm and 4730 lb.in (535 N.m) torque per wheel. During this time, the axle sump temperature is maintained at 297±3°F (147.2±1.7°C). For purposes of cooling, a water spray over the differential housing is used. At the end of the 100 min breakin an optional visual inspection is permitted.

---

[1] *Manganese phosphate coating.*

NOTE 2 - For purposes of evaluating lower viscosity lubricants (i.e., SAE 75W types), the test lubricant temperature is controlled at 220±3°F (104.4±1.7°C).

3.3 *Sequence 2* - Low-speed, high-torque operation: Run the test axle for 24 h at 80 wheel rpm, 20,900 lb.in (2.35 KN.m) torque per wheel and an axle sump temperature 275±3°F (135±1.7°C).

NOTE 3 - For purposes of evaluating lower viscosity lubricants (i.e., SAE 75W types),. the sump temperature is controlled at 220±3°F (104.4±1.7°C).

3.4 At the end of the low-speed, high-torque phase, the test is completed; the ring and pinion are removed and rated for various forms of gear distress.

4. SIGNIFICANCE

4.1 *Method*

4.1.1 *Function* - This test method simulates a type of severe field service in terms of hypoid gear tooth loading and sliding velocities.

4.1.2 *Correlation* - This test method was developed specifically to provide a correlation to field experience. The correlation achieved will provide severe axle durability conditions of the type found in actual field service although formal correlation programs have not yet been run.

4.2 *Validity of Tests*

4.2.1 *Procedural Compliance* - Test validity is dependent on compliance with all requirements of this test method.

4.2.2 *Test Stand Calibration* - A test is considered officially valid for presentation against specification only when conducted on a test stand previously calibrated by satisfactory evaluation of the reference test oils. Reference test requirements are described in paragraph 11.1.

4.3 *Use*

4.3.1 *Specification and Research Activity* - This test method is used formally in specifications for automotive gear oils. In support of research activity, the method is used to assess and compare performance levels of experimental

lubricant formulations.

5. APPARATUS

5.1 *Laboratory Ambient Conditions*

5.1.1 *Test Stand Operating Area* - The ambient laboratory atmosphere is to be free of dirt, dust, and other contaminants as required by good laboratory standards. There are no specific temperature requirements for the operating area.

5.1.2 *Parts Rating Area* - The rating of all test parts is conducted against a white background using a lamp with two 15-watt cool-white fluorescent bulbs.

5.1.3 *Parts Cleaning Area* - Adequate ventilation must be provided in areas where solvents are used.

5.2 *Test Stand and Laboratory Equipment*

5.2.1 *Test Unit* - The test unit consists of a new complete hypoid truck axle assembly less axle shafts, Dana Model 60, 5.86 to 1 ratio (Dana Part No. 060AA100-2 non-coated gears or 060AA100-4 ring and pinion coated). No change in any of the tooth contact or bearing adjustments are made.

5.2.2 *Test Stand Configuration* - The complete assembly is mounted in the test stand with pinion and axle shaft centerlines horizontal. The cover plate and vent are provided as specified below.

5.2.2.1 Axle Vent - The axle is vented to atmosphere throughout the entire test. The vent is arranged so that no water can enter the housing. The vent consists of a suitable tube fitting screwed into a drilled and tapped hole in the right hand axle tube.

5.2.2.2 Axle Cover - The axle cover has a 3.5 in. (8.9 cm) inspection port installed as in Fig. 1. This is to allow overfilling of the axle as well as to provide a means for inspecting the axle after break-in as detailed in paragraph 12.1. In addition, a thermocouple, as described in 5.2.3.1 below is also installed.

5.2.3 *Temperature Control Systems* - The test setup includes a means of maintaining the lubricant at a specified temperature. This includes a

thermocouple, a temperature recording instrument, and a cooling bath.

5.2.3.1 Thermocouple - a thermocouple, preferably a hairpin type, is installed in the rear cover plate in such a manner that the junction is on the centerline of the housing, 1 in. (2.5 cm) from the tooth side of the ring gear and 1 in. (2.5 cm) from the bottom of the housing. This thermocouple actuates a temperature recording instrument and controls an automatic cooling bath.

NOTE 4 - A shielded type thermocouple may be used provided its accuracy is equivalent to that of the hairpin type.

5.2.3.2 Temperature Recording Instrument - A temperature recording instrument (Leeds & Northrup Micromax, Model S-40000, or equivalent) is provided for recording the temperature of the lubricant in the axle housing.

5.2.3.3 Cooling Bath - A water bath is provided for controlling the temperature of the lubricant in the axle housing. The bath consists of an electrically operated water-control valve, and spray nozzles arranged as shown in Fig. 2 to spray cooling water over the rear cover of the axle housing. The water control valve starts and stops the flow of water, and is actuated by the thermocouple through the temperature recording instrument.

NOTE 5 - If a pan is used to direct waste water to the drain, take care that any water that collects in the pan does not touch the bottom of the housing.

5.2.4 *Dynamometers* - Two axle dynamometers (Midwest Dynamatic, Model 3232, or equivalent) with suitable control equipment are used. The control equipment has sufficient sensitivity of adjustment and control to permit maintenance of a uniform ring gear torque to with 2% and a uniform speed to within ±1 rpm. Each dynamometer has a revolution counter so that the number of revolutions of the ring gear during the test may be recorded.

5.2.5 *Power Source* - The power source consists of an eight-cylinder, 350 $in.^3$ (5.7L) truck engine (Chevrolet LS-9, P/N 14005253, or equivalent) with standard ignition and carburetor. Install

new spark plugs and tune up engine prior to each test based on shop manual and good engineering practice.

5.2.6 *Transmission and Coupling* - The engine is coupled to the test unit through a 10 in. (25.4 cm) truck clutch (GM P/N 3906680, or equivalent), a 4 speed transmission (M-20 1978 GM transmission P/N 474074, or equivalent), and a special drive shaft [4 in. (10.1 cm),.095 in. (.26 cm) wall thickness], and universal joints.

6. MATERIALS

6.1 *Sealing Compound* - Sealing compound, where necessary, is to be Permatex No. 2 or equivalent.

6.2 *Cleaning Solvent* - Stoddard solvent, or equivalent.

CAUTION- Cleaning solvent is both toxic and flammable. Do not breathe its fumes or allow it to come in contact with the skin. Keep flames away from the cleaning solvent.

7. PRECAUTIONS

7.1 When setting up and running this test, all general laboratory good safety practices are to be adhered to.

7.2 Rotating test stand equipment presents a physical hazard, and safety guards should be used, and the operator should be aware of this danger.

8. OIL BLEND SAMPLING REQUIREMENTS

The test sample must be representative of the lubricant formulation being evaluated and must be uncontaminated.

9. TEST OIL SAMPLE

9.1 *Minimum Sample Quantity* - One gal (3.7L) of test oil is required for each test. The housing capacity is 6 pt (2.8 L). The remaining oil is used for make-up oil following break-in if needed.

10. PREPARATION OF APPARATUS

10.1 *Test Stand Preparation*

10.1.1 *Cleaning of Reusable Hardware* - Clean as necessary all reusable parts including: axle shafts, thermocoupled axle housing cover, and all associated drain pans and funnels used for the addition of and collection of test oil.

10.1.2 *Cleaning and Pretest Measuring of Test Unit*

10.1.2.1 Coated test units are to have both ring and pinion coated. To verify that the pinion is coated, remove the cover plate and visually inspect the end of the pinion (with the aid of a mirror). If the pinion end is black or copper colored, it has been coated. If it is bright, it has not been coated.

NOTE 6 - An optional inspection method is a follows:

- Remove the cover plate. Record backlash at four equally spaced locations. Record the axle tuning torque. Before removing the carrier, record the torque of the carrier hold down bolts.

- After inspecting the pinion, reassemble the carrier using the same shims in the same location. Retighten the carrier hold down bolts to the original weak torque. Recheck and record the backlash and tuning torque.

- Report the initial and final values of backlash and tuning torque in the test report.

10.1.2.2 Wash the axle housing, axle shafts, and test unit, using Stoddard solvent or equivalent, paying particular attention to the pinion bearings to remove all preservative oil. Dry by blowing with clean, dry compressed air.

NOTE 7 - The preservative oil can be removed from the bearings by directing a spray into the oil passage cast in the housing of the unit.

10.1.2.3 Lubricate the carrier bearings, pinion bearings, differential gears, and the ring and pinion gears, using the test lubricant.

10.1.2.4 Determine and record the torques required to break and to turn the pinion shaft of the completely assembled test unit.

10.1.2.5 Determine and record the backlash in the gear set.

10.2 *Installation of Test Unit*

10.2.1 Connect the dynamometers to the axle.

10.2.2 Fill the axle housing with 6 pt (2.8L) of the test lubricant.

10.2.3 Set the revolutions counters to zero (or record the readings).

11. CALIBRATION

11.1 *Test Stand Calibration*

11.1.1 Test stands are calibrated using reference oils. Two reference oils are currently used: One giving mild results or minimal gear distress; the second giving severe results or substantial gear distress. Reference testing requires the oils be tested sequentially and for each test stand

- when a test stand is moved or commissioned;

- every 50 tests or every six months, which ever comes first; or

- when a test stand is out of service for a period of six months or more.

NOTE 8 - Alternate testing of L-37 and L-42 tests does not necessitate referencing as long as above requirements are met.

11.1.2 Reference oils used for this test are designated RGO 103 and RGO 108. These oils may be obtained from:

ASTM Test Monitoring Center
4400 Fifth Avenue
Pittsburgh, PA 15213
Attn: Mr. Paul Eisaman

11.1.3 All tests are consecutively numbered on a stand basis using the following format: L37 - XX - YY - ZZZ, where XX: Test Stand Number, YY: Number of tests run since last reference in stand XX, ZZZ: Total L-37 tests run in lab.

11.2 *Instrumentation Calibration*

11.2.1 *Drive Speed* - Calibration of drive speed should be done on a periodic basis according to good engineering judgement.

11.2.2 *Torque* - Calibration of the load absorbing dynamometers and associated readouts should be done on a periodic basis according to good engineering judgement.

11.2.3 *Temperature* - Calibration of the temperature controller/recorder should be done on a periodic basis according to good engineering judgement.

12. TEST PROCEDURE

12.1 *Sequence 1*: High-Speed, Low-Torque Operation - Operate the test unit under high-speed, low-torque conditions for 100 min as follows:

12.1.1 Set the temperature control to maintain a lubricant temperature of 297±3°F (147.2±1.7°C). In the case of lower viscosity lubricants (i.e., SAE 75W types), set the control for a temperature of 220±3°F (104.4±1.7°C).

12.1.2 Determine the dynamometer field voltage required for a wheel torque of 4730±150 lb.in (535±.02 N.m).

12.1.3 With the engine warmed up, and with no load applied to the dynamometers, start the test unit in first gear. When the engine speed reaches 2000 to 2200 rpm, shift to the next higher gear. Continue to shift into successively higher gears when the engine speed is 2000 to 2200 rpm until the unit is operated in direct drive (fourth gear).

12.1.4 After shifting into high gear, apply the predetermined field voltage, accelerate to 440±5 wheel rpm and record the time. Hold the variation in speed between the dynamometers to a minimum.

NOTE 9 - The time required to accelerate to the test condition of 440 rpm (axle speed) is about two min.

12.1.5 After reaching speed and load conditions, run the test for 100 min.

12.1.6 At the end of 100 min, close the throttle, and stop the equipment.

12.1.7 Record the revolutions, total time, and temperature of the lubricant and then calculate average rpm.

12.1.8 At this time an optional inspection of the gear set condition is permitted. If chosen, remove the inspection plug located at the top of the axle cover and note the condition of the ring gear.

NOTE 10 - The test oil is not to be removed from the axle at this time.

NOTE 11 - In describing the condition of the gear tooth surface, the definitions in Table I are to be used.

12.1.9 After inspecting, reinstall the inspection plug and proceed to paragraph 12.2.

12.2 *Sequence 2*: Low-Speed, High-Torque Operation - Operate the test units under low-speed, high-torque conditions for 24 h as follows:

12.2.1 Set the temperature control to maintain a lubricant temperature of 275±3°F (135±1.7°C). In the case of lower viscosity lubricants (i.e., SAE 75W types), set the control for a temperature of 200±3°F (93.3±1.7°C).

12.2.2 Determine the dynamometer field voltage required for a wheel torque of 20900±200 lb.in (2.35±.02 kN.m).

12.2.3 With the engine warmed up and with no load applied to the dynamometers start and run test unit in first gear.

12.2.4 After shifting into low gear, apply the predetermined field voltage and adjust the engine speed for an axle speed of 80±1 rpm. Record the time when all test conditions, including temperature, have been met.

NOTE 12 - Preheating of the oil in the axle housing through external heat sources is acceptable after prolonged shutdowns.

12.2.5 Run the test continuously for 24 h

NOTE 13 - No more than a total of three stops is permitted during the test period. This includes the stop required in paragraph 12.1.6.

12.2.6 At the end of the 24 h, stop the engine and record the revolutions, average speed in rpm, total time of test run, and the temperature of the lubricant.

12.2.7 While the unit is hot, disconnect the drive shaft and axle shafts from the dynamometers. Determine and record the torque required to break and to turn the pinion shaft of the completely assembled test unit.

12.3 *Test Unit Post Test Measurements*

12.3.1 Allow the unit to cool and record the torques required to break and to turn the pinion shaft.

12.3.2 Disconnect the axle shafts and record the pinion shaft torques. Also determine and record the backlash in the gear set.

CAUTION - In handling the test unit, avoid staining the cleaned and polished surfaces with perspiration or with moisture from other sources.

12.3.3 Remove the ring gear and differential assembly from the carrier.

12.3.4 Determine and record the torques required to break and to turn the pinion shaft.

12.3.5 Completely disassemble the differential and the pinion shaft assemblies for inspection.

13. **DETERMINATION OF TEST RESULTS**

Rating should be conducted under the lighting conditions described in paragraph 5.1.2.

13.1 Examine the axle shafts, axle housing, carrier housing, ring gear, pinion, differential, and differential pin for discoloration, rust, condensation, or other deposits.

13.2 Examine the tooth surfaces on the drive side of the pinion and ring for burnishing, scratches, wear, surface fatigue, scoring, discoloration, and corrosion.

NOTE 14 - Gear-tooth surface conditions, such as burnishing, are defined in Table I.

13.2.1 Deposits and varying degree of surface distress will be assigned a numerical value as follows:

None = 0.00
Trace = 0.01
Light = 0.50
Medium = 5.00
Heavy =10.00

13.2.2 By filling in values on the rating sheet (Annex A1), then applying the appropriate weighting values shown, two final demerit values will be obtained, one for surface distress, another for deposits (Annex A2).

NOTE 15 - The above numerical ratings are for information

only.

14. FINAL TEST REPORT

The final test report will include the Test Report (Annex B), Rating Sheets (Annex A1), and one black and white 8 by 10 in. (20 by 25 cm) photograph of the drive side of test ring and pinion showing the test number.

15. PRECISION AND BIAS

Precision and bias of this test have not yet been formally established.

TABLE I -- L-37 Terminology -- Gear Distress

BURNISH:	An alteration of the original manufactured surface to a dull or brightly polished condition.
WEAR:	The removal of metal, without evidence of surface fatigue or scoring, resulting in partial or complete elimination of tool or grinding marks or development of a discernible shoulder ridge at the bottom of the contact area near the root or at the toe or heel end of pinion tooth contact area.
SCRATCHING:	An alteration of the tooth surface in the form of irregular scratches, of random length, across the tooth surface in the direction of sliding of the surfaces.
RIPPLING:	An alteration of the tooth surface to give an appearance of a more or less regular pattern resembling ripples on water, or fish scales.
RIDGING:	An alteration of the tooth surface to give a series of parallel raised and polished ridges running diagonally in the direction of sliding motion, either partially or completely across the tooth surfaces of hypoid gears.
PITTING:	Small irregular cavities in the tooth surface, resulting from the breaking out of small areas of surface metal.
DEPOSITS:	Material of pasty, gummy, or brittle nature adhering to or collecting around any of the working parts.
CORROSION:	A general alteration of the finished surfaces of bearings or gears by discoloration, accompanied by roughening not attributable to mechanical action.
SCORING:	The rapid removal of metal from the tooth surfaces caused by the tearing out of small contacting particles that have welded together as a result of metal-to-metal contact. The scored surface is characterized by a matte or dull finish.
SPALLING:	The breaking out of flakes of irregular area of the tooth surface, a condition more extensive than pitting.
DISCOLORATION:	Any alteration in the normal color of finished steel surfaces.

Annex A1

Gear Distress Rating Sheet
(For Information Only)
L-37 TEST

Laboratory: _____ Date Completed: _____

Test Run Number: _____ Test Oil Sample Number: _____

Section I

	Numerical Rating		
Description	Ring	Pinion	
Ridging	_____	_____	
Rippling	_____	_____	Subtotal I
Spalling	_____	_____	_____

Section II

	Numerical Rating		
Description	Ring	Pinion	
Wear	_____	_____	
Pitting	_____	_____	Subtotal II
Scoring	_____	_____	_____

Test Total (10 I+II) = _____

None = 0.00

Trace = 0.01

Light = 0.50

Medium = 5.00

Heavy = 10.00

Annex A2

Deposits Rating Sheet (For Information Only) L-37 TEST

Section I

Description	Ring	Pinion
Burnish	_____	_____
Discoloration	_____	_____
Corrosion	_____	_____

Section II - Deposits

Description	Amount	Nature
Axle Shafts	_____	_____
Axle Housing	_____	_____
Differential Cross Shaft	_____	_____
Pinion Assembly	_____	_____
Ring Assembly	_____	_____
Bearings	_____	_____

None = 0.00

Trace = 0.01

Light = 0.50

Medium = 5.00

Heavy =10.00

Annex B

L-37 Test Report

A. GEAR LUBRICANT IDENTIFICATION

1. Company _____

2. Brand Name _____

3. Formula No. _____ Viscosity Grade _____

B. GEAR TEST IDENTIFICATION

1. Test Run at _____

2. Under their Code Number _____

3. Date of Start _____ Date of Completion _____

4. Gear Batch (Pinion - Ring) _____ Gear Set No. _____

C. EVALUATION OF RESULTS

1. Sequence 1 - Ring-Gear Drive Side Inspection after Completion of High-Speed, Low-Torque 100-Minute Run.

   a. Gear-tooth surface condition _____

   _____

2. Sequence 2 - Pinion-Drive Side and Ring-Gear Drive Side Inspection after Complete Test.

   a. Gear-tooth surface condition

	Pinion	Ring Gear
(1) Burnish	_____	_____
(2) Wear	_____	_____
(3) Surface fatigue		
(a) Rippling	_____	_____
(b) Ridging	_____	_____
(c) Pitting	_____	_____
(d) Spalling	_____	_____
(4) Scoring	_____	_____

	Pinion	Ring Gear
(5) Discoloration	_____	_____
(6) Corrosion	_____	_____
(7) Deposits	_____	_____
b. Backlash, in. (cm)		
(1) Initial _____	_____	_____
(2) After Test ___	_____	_____
(3) Average Increase	_____	_____

3. For Stability and Corrosion*

a. Axle Shafts _____

b. Axle Housing _____

c. Carrier Housing _____

d. Pinion Assembly _____

e. Ring-Gear Assembly _____

f. Bearings _____

_____

g. Differential Assembly _____

_____

h. Differential Pins _____

_____

4. For Stability

(1) Before test - Full axle assembly: to break _____ lb.in (N.m), to turn _____ lb.in (N.m)
(2) After test - Full axle assembly (hot): to break _____ lb.in (N.m), to turn _____ lb.in (N.m)
Full axle assembly (cool): to break _____ lb.in (N.m), to turn _____ lb.in (N.m)
Axle shafts removed: to break _____ lb.in (N.m) to turn _____ lb.in (N.m) Pinion assembly: to break _____ lb.in (N.m) to turn _____ lb.in (N.m)

*Indicate exent and nature of deposits, discoloration, corrosion, or rusting.

D. GENERAL OPERATING CONDITIONS

1. Sequence 1. High-Speed, Low-Torque

a. Revolution counter at start _____ at finish _____
Total _____ Average rpm _____

b. Time at start _____ at finish _____
Total time _____ minutes _____

c. Oil Temperature at start _____°F(°C)
at finish _____°F(°C)

2. Sequence 2. Low-Speed, High-Torque

a. Revolution counter at start _____ at finish _____
Total _____ Average rpm _____

b. Time at start _____at finish _____

NOTE - If test is interrupted during Sequence 1 or Sequence 2, record time of interruptions and minimum gear oil temperature reached. A valid test should have no more than three interruptions.

_____

_____

_____

c. Room temperature, max. ___°F(°C) min. ___°F(°C)
average _____°F(°C)

d. Cooling-water temperature, average _____°F(°C)

e. Gear-lubricant temperature, average max. ____°F(°C)
average min. _____°F(°C)

f. The complete temperature-time chart shall be attached to and become a part of this report.

3. Remarks _____

_____

_____

DATE _____ SIGNED _____

COMPANY _____

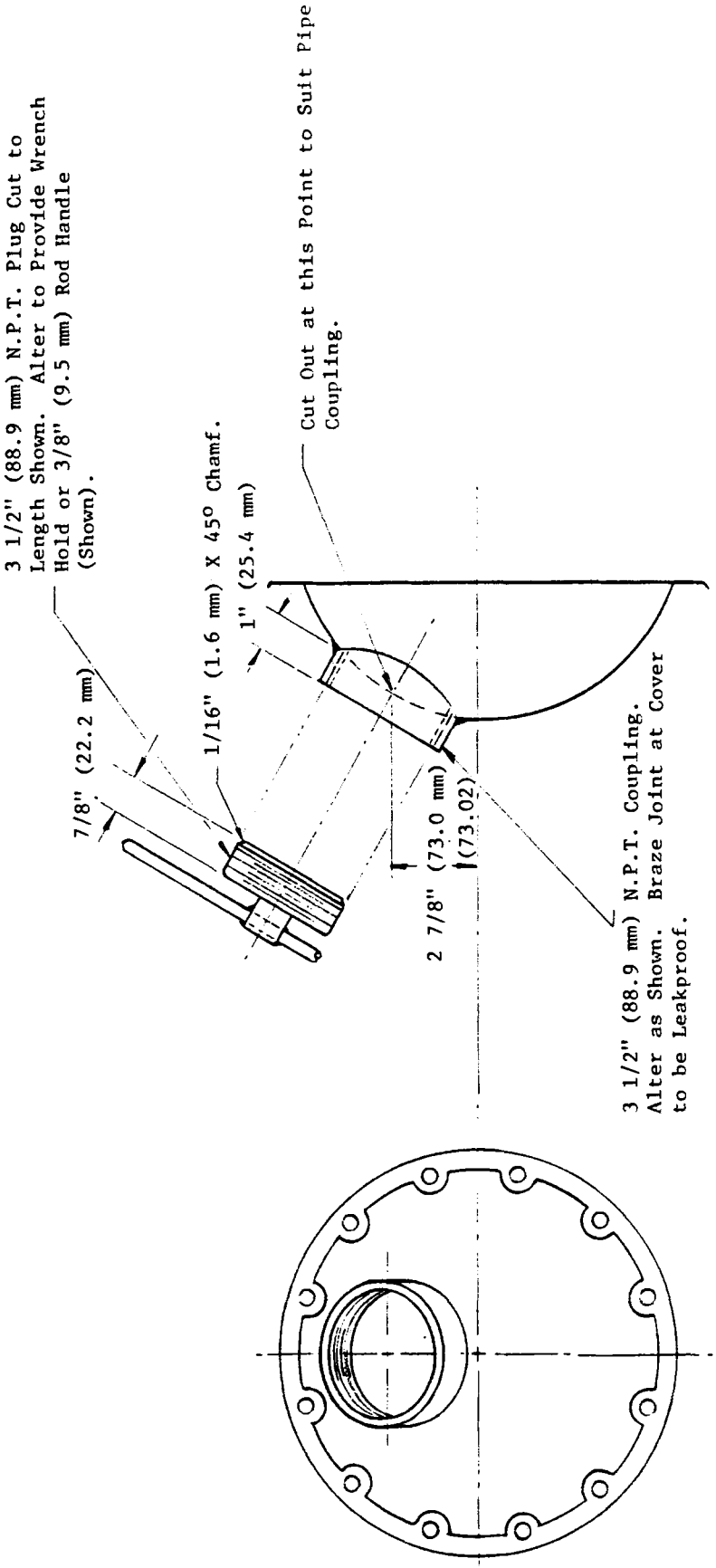


FIG. 1 - Axle Cover (All dimensions in inches with millimeteres in parenthesis)

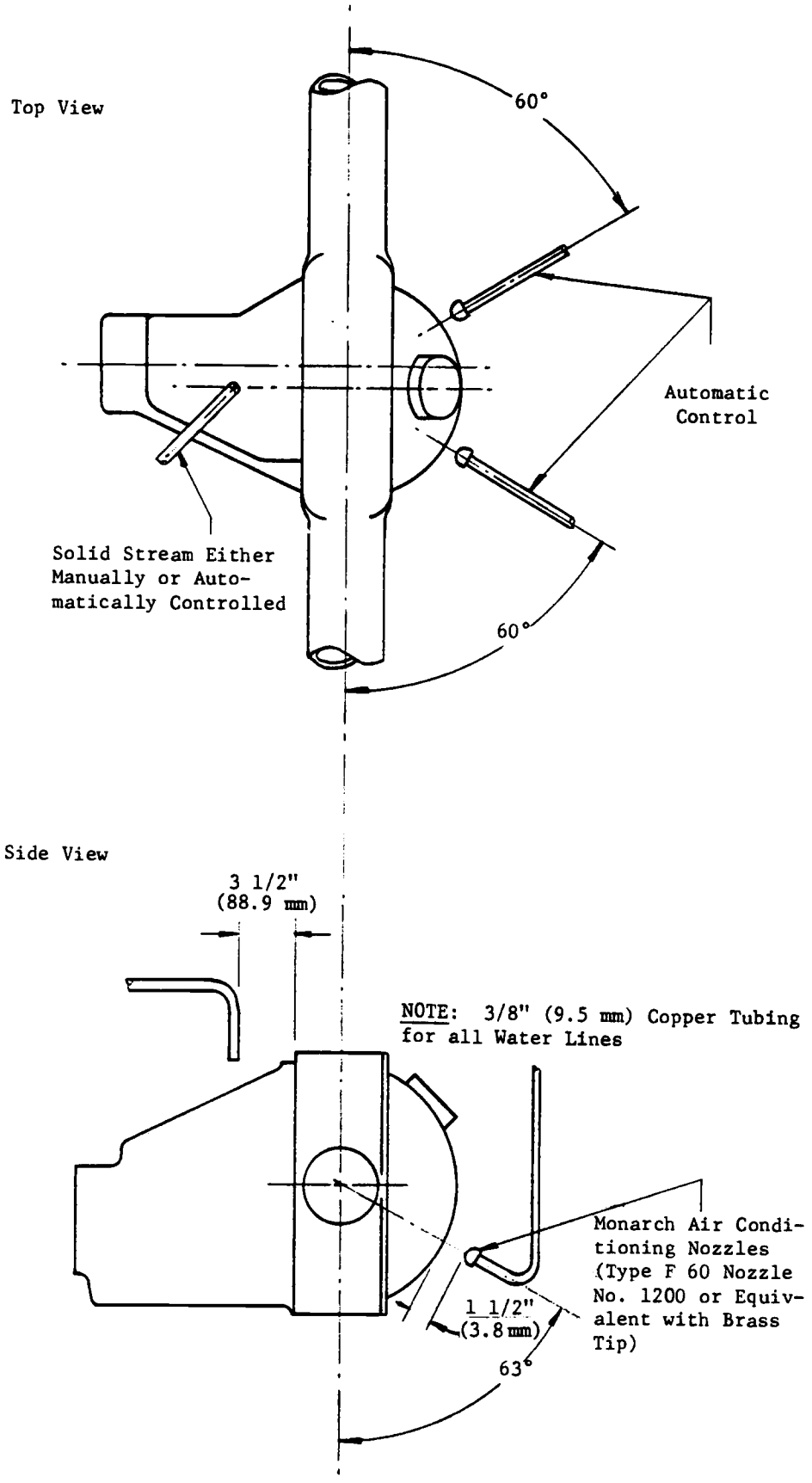


FIG. 2 - Cooling System (All dimensions in inches with millimeters in parenthesis)

SECTION 3 (L-42 TEST)
Performance Test for Evaluating the Load Carrying Capacity of Automotive Gear Lubricants Under Conditions of High Speed Shock Loading

The test method described herein has no official status as an ASTM Standard.

L-42 TEST PROCEDURES

(formerly CRC L-42 Test and FTMS 791B Method 6507.1)

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1. **SCOPE**

1.1 This test method is used for determining the antiscoring properties of gear lubricants under high-speed and shock conditions.

CAUTION - This test method may involve hazardous materials, operations, and equipment. This test method does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this test method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. **SAMPLE**

2.1 Approximately 2 gal (7.5L) of gear lubricant to be tested.

3. **APPARATUS**

3.1 *Test Unit* - The test unit shall consist of a Spicer Model 44-1 rear axle, 45 to 11 ratio, uncoated gears (Model No. 044AA-100-1, Dana Corp., Mobile Off-Highway Division, P.O. Box 2424, Fort Wayne, IN 46801). No change in factory adjustments shall be made.

NOTE 2 - When ordering, specify a "Spicer rear axle for L-42 testing; ring pinion ratio, 45:11; no surface treatment".

3.1.1 *Rear Cover Plate* - The standard cover plate of the test unit shall be modified to provide a thermocouple mounting as shown in Fig. 1.

3.1.2 *Axle Shafts* - Ford axle shafts (Dana Part No. 26762- 14X) shall be used with this test method.

3.2 The test unit shall be mounted and secured in place with the fixtures supplied with the standardized axle supports manufactured by Southwest Research Institute and shown in Fig. 2.

3.3 *Temperature Control* - The test axle housing shall include a means of maintaining the lubricant at a specified temperature. This shall include a thermocouple, a temperature recording instrument, and a

cooling method.

3.3.1 *Thermocouple* - The thermocouple shall be installed in the rear cover plate such that the tip is approximately 3/8 in. (9.5 mm) from the crest of the teeth and approximately on the centerline of the ring gear.

3.3.2 *Temperature recording instrument* - The temperature recording instrument shall continuously record the temperature of the lubricant throughout the test.

3.3.3 *Cooling* - A suitable tube shall be used to distribute water over the rear cover plate and/or housing. The water control valve shall start and stop the flow of water and shall be actuated through the temperature recording instrument (see Fig. 1).

3.4 *Torque Measuring* - The test equipment shall include a means for measuring the load applied to the test unit. It shall consist of the following:

3.4.1 *Load Cells* - Two BLH type 43G1 load cells or equivalent shall be used to measure torque and mounted to restrain the test axle as shown in Figures 2 and 4.

3.4.2 *Amplifier* - (Brush Model BL-520, or equivalent.)

3.4.3 *Oscillograph* - (Brush Model BL-201, or equivalent.)

3.4.4 *Dynamometers* - Two axle dynamometers (Midwest Dynamatic, Model 3232, or equivalent) with suitable control equipment shall be used. The suggested minimum average inertia loads are as follows: Coast Side Load, 950 lb.ft (1287.3 N.m); Drive Side Load, 1100 lb.ft (1490.5 N.M). The minimum average peak torque loads suggested are Coast Side Load, 1600 lb.ft (2168 N.m); Drive Side Load 2300 lb.ft (3116.5 N.m). Test torques may require modification for different gear batch approvals.

NOTE 3 - The Midwest dynamometer has a 0.050 in. (1.27 mm) air gap. Its moment of inertia is 1731 in.lb sec^2, or 4640 lb/ft^2 (7428.6 kg/m^2).

3.5 *Power Source* - (All parts are available through local General Motors dealers). The power source shall include:

3.5.1 Chevrolet LS-9, 350 $in.^3$ (573 m^3) truck engine

(Part No. 467377) - The engine shall be mounted on suitable stands, supported at three points by flexible mounts, at front, using normal motor castings, and at the rear of the transmission case. The engine ignition timing shall be adjusted in accordance with manufacturer's specifications. The carburetor idlespeed adjustment shall be set so that the engine will stall when the hand throttle is closed and the transmission is in neutral.

3.5.2 Four Barrel Carburetor - Rochester Quadrajet. Part No. 17057213.

3.5.3 Intake Manifold - Part No. 346250 GM.

3.5.4 Camshaft - Part No. 346250 GM.

3.5.5 Heads - Part No. 14034808 GM (Group 269).

3.5.6 Valve Springs - Intake - 6263796 GM, Exhaust - 3911068 GM.

3.5.7 Clutch Disk - Part No. 3836011 GM.

3.5.8 Pressure Plate - Part No. 3837155 GM.

3.5.9 Bell Housing - Part No. 460486 GM.

3.6 *Four Speed Truck Transmission (M-20 GM)*

3.7 *Drive Shaft* - Shelby welded steel tubing, 3.5 in. (88.9 mm) OD, 0.093 in. (2.36 mm) wall thickness, 58.5 in. (1486 mm) long from end of spline to eye of U-joint, dynamically balanced up to 5000 rpm.

3.7.1 U-Joint Flange - Part No. 591700 (U-Joint - Spicer 5-200X).

3.7.2 U-Joint Yoke - Part No. 605056 (U-Joint - Spicer 5-178X).

3.8 *Throttle Actuator* - An air actuated device assembled as shown in the schematic drawing, Fig. 3, may be used for regulated actuation of the throttle. This should include:

3.8.1 Honeywell NP-909A-1041 Single Acting Air Cylinder with Spring Return.

3.8.2 Two Skinner Solenoid Actuated Air Valves No. A5DB2127 or A5LB2127.

3.8.3 Orifices for Skinner valves graduated 0.029 in. (0.736 mm) diameter to 0.073 in. (18.5 mm)

diameter.

4. MATERIALS

4.1 *Sealing Compound* - Sealing compound, where necessary, is to be Permatex No. 2 or equivalent.

4.2 *Cleaning Solvent* - Stoddard solvent, or equivalent.

CAUTION - Cleaning solvent is both toxic and flammable. Do not breathe its fumes or allow it to come in contact with the skin. Keep flames away from the cleaning solvent.

5. PROCEDURE

5.1 *Test Preparation*

5.1.1 Note the nature and extent of the contact area. Record the torques to break and turn the pinion shaft of the assembled unit.

5.1.2 Spray clean the gears and interior of the case with Stoddard Solvent and air dry. Do not disassemble.

5.1.3 Prelubricate the ring and pinion and bearings with a small amount of test lubricant.

5.1.4 Measure and record the backlash at four positions and check ring gear runout.

NOTE 4 - The backlash should be between 0.004 in. (0.102 mm) and 0.009 in. (0.229 mm); the runout should not exceed 0.003 in. (0.076 mm). If the measurements are not within these limits, do not use the unit for test purposes. Do not change original factory adjustments.

5.1.5 Install the test unit on the test stand supports and connect to dynamometers and driveshaft.

5.1.6 Fill the axle housing with 3.5 pt (1655 cc) of test lubricant or until the level reaches the bottom of the fill hole in the cover plate.

5.2 *Break-In* - Break-in the test unit as follows:

5.2.1 Set temperature control equipment to maintain a lubricant temperature of 225°±5°F (107.2°±2.8°C).

5.2.2 With the engine warmed up and with no load applied to the dynamometers, start in first gear (low-low). When the axle speed reaches approximately 80 rpm, shift into second gear, operating the clutch and throttle so that

shifting is smooth and without bucking. Continue shifting smoothly into third and fourth gears at 150 to 240 rpm, respectively.

5.2.3 After shifting into high gear, accelerate to an axle speed of 575 rpm with a manifold pressure of 12 to 14 in. of mercury, apply 120 lb.ft (162.6 N.m) load to each dynamometer and run for 30 min.

5.2.4 After 30 min, slowly (5 s) close the throttle to decelerate the axle speed to 400 rpm then slowly (5 s) open throttle to accelerate to 575 rpm. Do not remove the 120 lb.ft (162.6 N.m) load during this operation.

5.2.5 Repeat step 5.2.4 three additional times.

5.2.6 Increase axle speed to 815 rpm, apply 156 lb.ft (211 N.m) load to each dynamometer and run the unit for 1 h under these conditions.

5.2.7 After 1 h, slowly (5 s) decelerate and accelerate through four cycles between 815 and 670 rpm axle speed.

5.2.8 Disengage the clutch, allow axles to stop. Shut off the cooling water and drain and discard test oil.

5.2.9 Inspect gears for distress through the 2 in. (50.8 mm) plug in cover and check the load-cell recorder, balance and reset to "0."

NOTE 5 - The original 30 min CRC breakin procedure is shown as Annex A1. This method has been replaced with the above 90 min procedure for some gear batches to obtain accurate break-in prior to testing.

5.3 *High Speed Operation* - Operate the unit under high speed conditions with inertia loading only. Record the torque values and obtain zero load trace at the beginning and end of the operation.

5.3.1 When temperature of the lubricant has reached 200°F (93.3°C) and with no load applied, start the unit in first gear and shift smoothly into second, third, and high gear when the axle speeds reach 80, 150, 250 rpm, respectively.

NOTE 6 - If the temperature of the lubricant did not reach 200°F (93.3°C) during the breakin operation, start the shock sequence as soon as possible to avoid unnecessary cooling.

5.3.2 After shifting into high gear, accelerate to 530 rpm with a manifold pressure of 12 to 14 inches of mercury.

5.3.3 Next, open throttle rapidly to accelerate to an axle speed of 1050 rpm. Then close throttle rapidly to decelerate to 530 rpm.

5.3.4 Repeat step 5.3.3 four additional times.

5.3.5 With the throttle closed, de-clutch, shift to neutral and allow axles to coast to a stop.

5.3.6 Allow the temperature to drop to 280°F (137.8°C) under static conditions, then continue the shock operation portion of the test.

NOTE 7 - If the temperature of the lubricant did not reach 280°F (137.8°C) during the high speed operation, start the shock sequence as soon as possible to avoid unnecessary cooling.

5.4 *Shock Operation* - Operate the test axle under shock (peak torque) condition (described below), record the torque values, and obtain zero load trace at the beginning and end of the operation.

5.4.1 With no load applied, start in first gear and shift smoothly into second and third gears when the axle speeds reach 80 and 150 rpm respectively.

5.4.2 Accelerate in third gear to 530 rpm.

5.4.3 Apply a 131 lb.ft load to each dynamometer and open the throttle rapidly to accelerate to 630 rpm. Then close the throttle rapidly to decelerate to 530 rpm.

5.4.4 Repeat step 5.4.3 nine additional times.

5.4.5 With the throttle closed, de-clutch, shift to neutral and allow axles to coast to a stop.

5.5 *Calibrate* - Calibrate axle torque as follows:

5.5.1 Install a special capstan on engine crankshaft to apply calibrating torque.

5.5.2 Lock both dynamometer rotors to their stators.

5.5.3 Shift transmission into first gear and turn the crankshaft until approximately 500 lb.ft (677.5 N.m) is applied to each dynamometer. Record the deflection and the exact dynamometer readings.

5.5.4 Turn the crankshaft until approximately 1000 lb. ft (1355 N.m) is applied to each dynamometer. Record the deflection and the exact dynamometer readings.

5.5.5 Release load and disengage transmission. Check the recorder zero.

5.5.6 Shift the transmission into reverse and record the deflection and the exact dynamometer readings when the crankshaft is turned to apply loads of approximately 500 lb.ft (677.5 N.m) and 1000 lb ft (1355 N.m) to the dynamometers.

5.5.7 From the values obtained, plot the deflections against the torque readings from coast and drive side loadings.

NOTE 8 - If the clutch is released slowly, the torque recorder may indicate a zero shift. This zero shift may be avoided by releasing the clutch rapidly.

5.6 *Disconnect the Dynamometers and Drive Shaft* - Record backlash and break and turn torques of test unit.

5.7 *Disassemble Test Unit* - Rate (numerically) the surface distress.

5.7.1 *Rating* - At completion of the test the pinion and ring gear are removed from the unit and rated on both drive and coast sides for percent of the contact area exhibiting scoring. The percent scoring for the candidate oil is compared to the percent scoring for the two reference oils.

NOTE 9 - For assistance in defining "Scoring" see CRC Manual No. 6 "Album of Reference Photographs, Gear Tooth Condition", dated August 1958.

6. STAND CALIBRATION

To meet the Military specification MIL-L-2105C, the stand must successfully complete tests on RGO-108 and RGO-110 after every 10 candidate tests (yearly if less than 10 candidate tests are conducted per year).

7. TEST REPORT

The final test report will include a completed Report Form (Annex A2) and one 8 x 10 black and white photo of the ring and pinion coast sides labeled or identified by oil and run number.

8. PRECISION AND BIAS

8.1 The precision and bias of this test have not yet been formally established.

Annex A1

Original 30 Minute Breakin Procedure
4.09 Ratio L-42 Test

RECORD — Date, oil code, time, three initial backlash measurements, break and turn pinion torque and starting axle oil temperature on brush recorder tape.

SEQUENCE I

1. Adjust water to come on at 225°F (107.2°C) so temperature will cycle at 225±5°F (107.2±2.8°C).
2. Up shift speeds in all sequences are 77, 145, and 230 rpm.
3. Run 10 min at 575 wheel rpm, 4th gear, 15 lb (6.8 kg) load.
4. Do four cycles slowly between 575 and 385 rpm.
5. Run 20 min. at 815 rpm, 4th gear, 20 lb (9.1 kg) load.
6. Do four cycles slowly between 815 and 670 rpm.
7. Record maximum temperature during sequence on tape and shut down.

Allow oil temperature to drop to 200°F (93.3°C) before resuming test. Record zero trace on recorder.

SEQUENCE II — This part run with cooling water off and inertia load only.

1. Adjust to 530 rpm, 4th gear, and synchronize dynamometers.
2. Do five cycles with instantaneous wide open and full closed throttle from 530 to 1050 rpm.
3. At the end, record zero trace and maximum temperature on tape.

SEQUENCE III — Gear inspection is optional.

SEQUENCE IV — Alloy temperature to drop to 280°F (137.8°C) before starting, cooling water off. Record starting temperatures.

Annex A1 (continued)

SEQUENCE IV (continued)

1. Adjust to 530 rpm, 3rd gear, 50 lb (22.6 kg) on scales and synchronize dynamometers.

2. Do 10 cycles with instantaneous wide open and full closed throttle from 530 to 630 rpm.

3. At end, record zero trace and maximum temperature.

Calibrate scales and record final backlash to tape.

Annex A2

High Speed Short Load Test L-42 Test

Report Form

Laboratory Test Results

(A) GEAR LUBRICANT IDENTIFICATION

1. Company _____
2. Blend No. _____ Viscosity _____

(B) GEAR TEST IDENTIFICATION

1. Test Run No. _____

2. Date of Test _____ Axle Identification _____

(C) EVALUATION OF RESULTS

1. Inspection - Sequence 3

   Ring Gear, Drive Side _____

   Ring Gear, Coast Side _____

2. Inspection - End of Test

   Ring Gear, Drive Side _____

   Ring Gear, Coast Side _____

   Pinion Gear, Drive Side _____

   Pinion Gear, Coast Side _____

COMMENTS

_____
_____
_____
_____
_____

Annex A2 (continued)

(D) GENERAL OPERATING CONDITIONS

1. Gear Loading Data

	SEQUENCE 2		SEQUENCE 4	
	Torque Lb.Ft	Cycle Time Sec Accelerate	Torque Lb.Ft	Cycle Time Sec Accelerate
Drive Side Loads				
Maximum	____	____	____	____
Minimum	____	____	____	____
Average	____	____	____	____
		Decelerate		Decelerate
Coast Side Loads				
Maximum	____	____	____	____
Minimum	____	____	____	____
Average	____	____	____	____

2. Lubricant Temperature Data

Maximum Temperature °F			Starting Temperature °F	
Run In	Sequence 2	Sequence 4	Run In	Sequence 4
____	____	____	____	____

3. Test Axle Data

a. Backlash (in.)	Maximum	Minimum	Average
Initial	____	____	____
Final	____	____	____
Increase			____

b. Initial Pinion Torque

Break ____ in.lb Turn ____ in.lb

Date ____ Signature ____

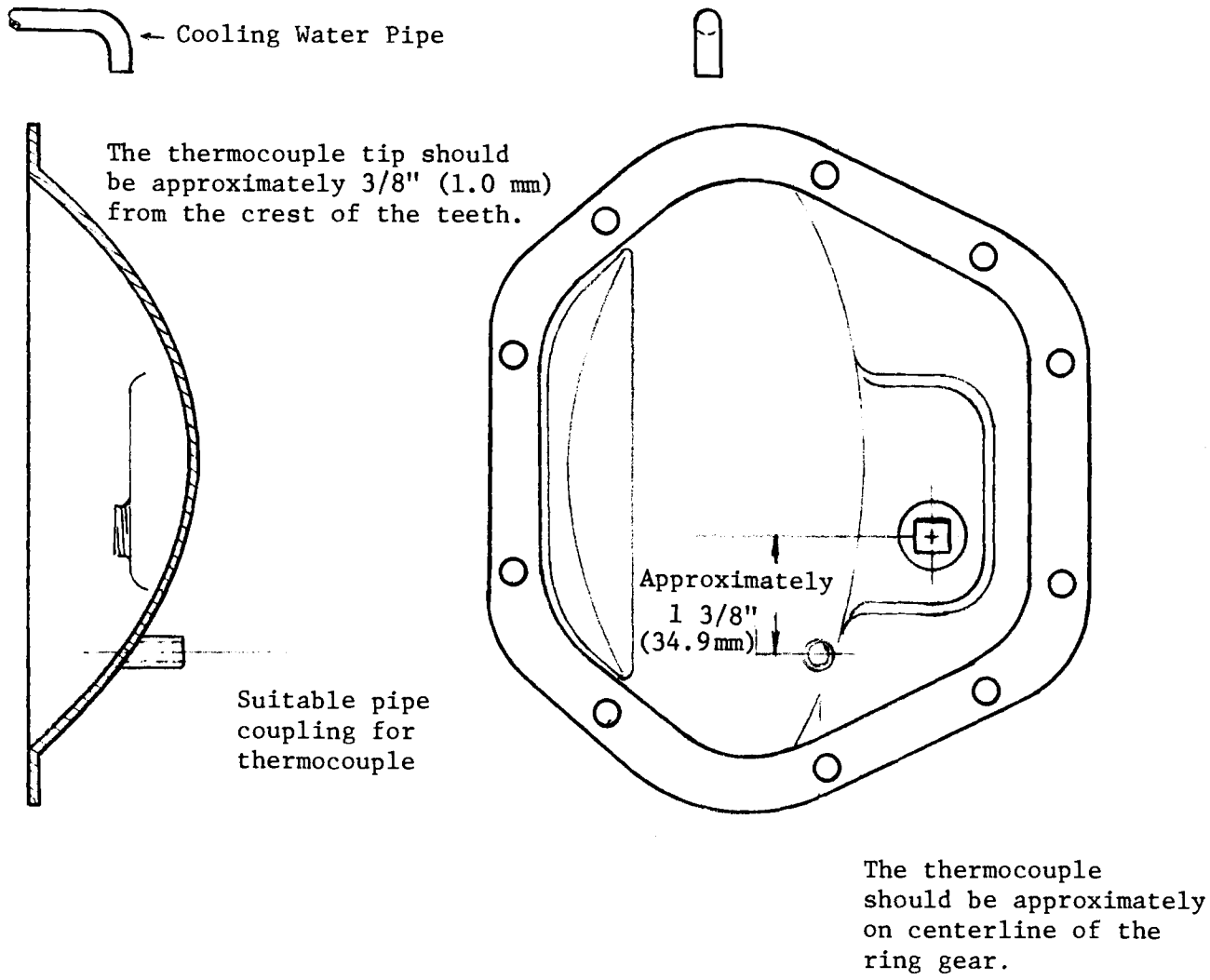


FIG. 1 - Rear Cover Plate (All dimensions in inches with millimeters in parenthesis)

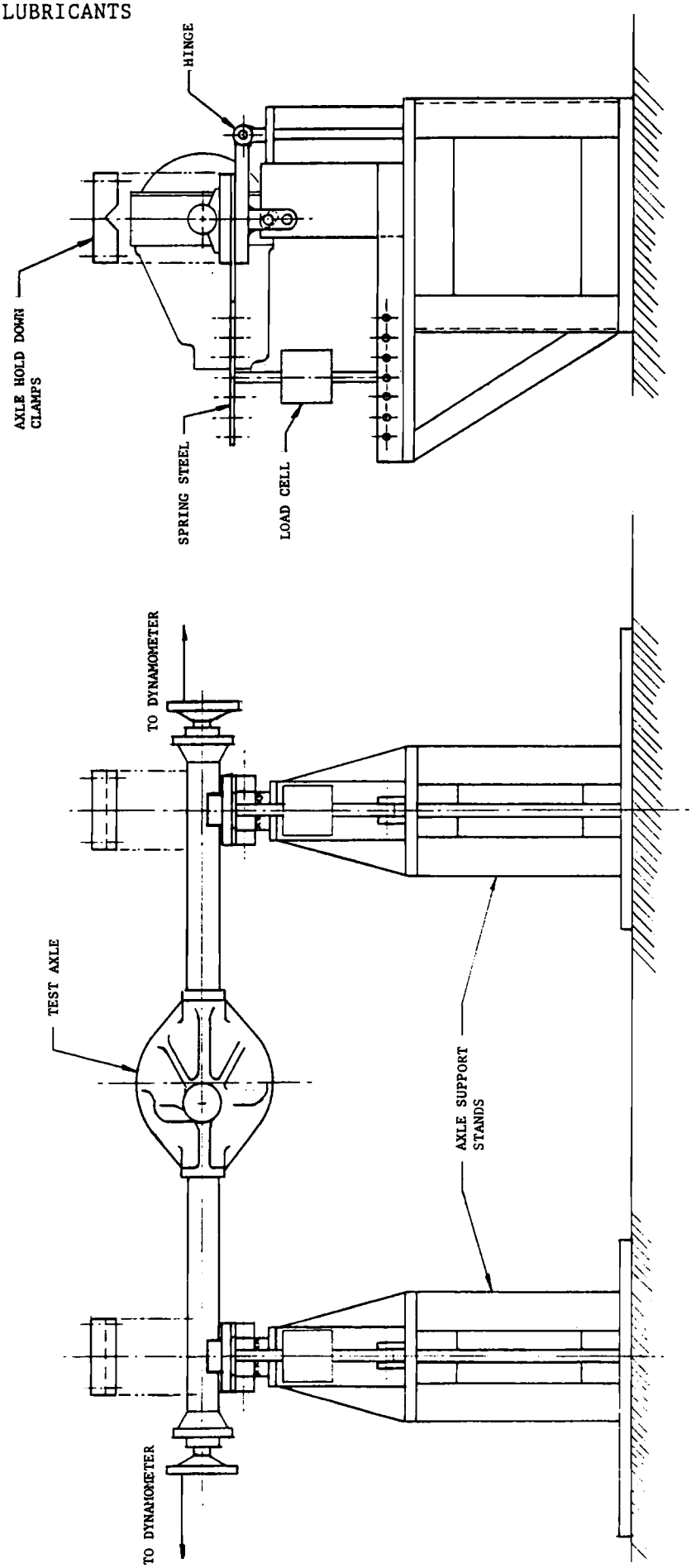
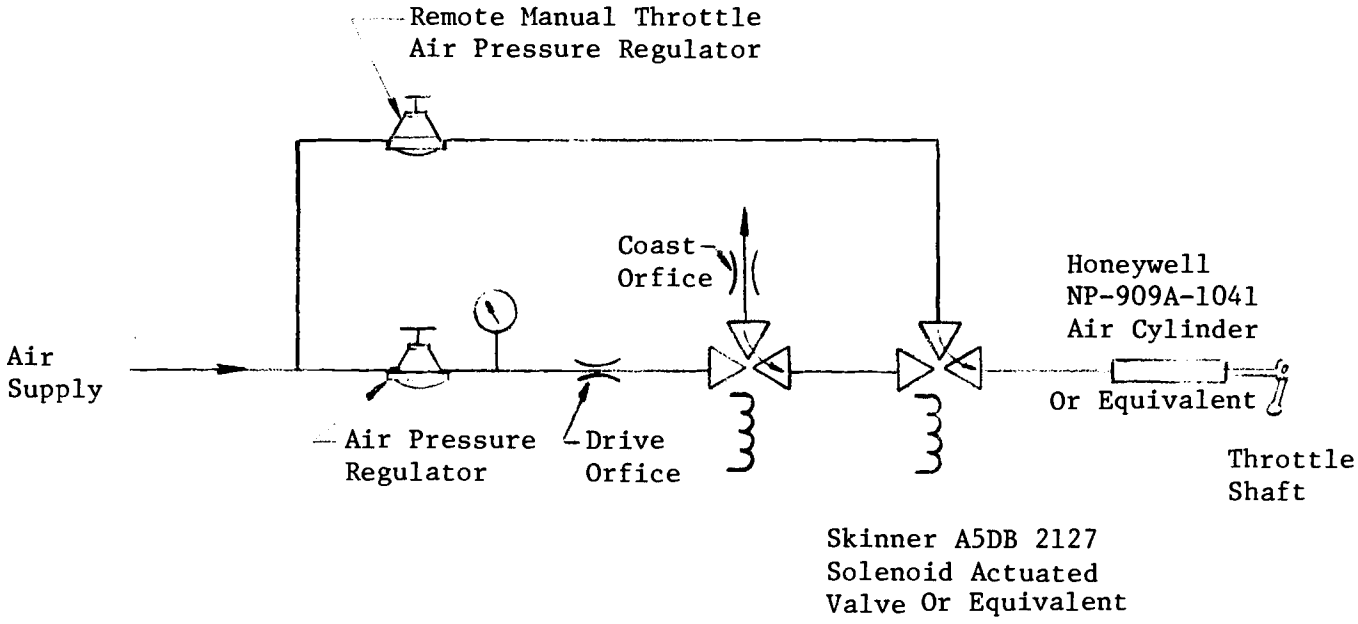


FIG. 2 - Flexible Axle Mount



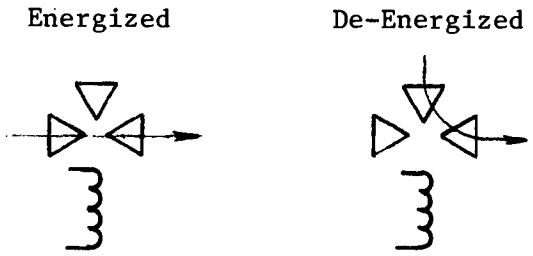


FIG. 3 - Remote Air Throttle

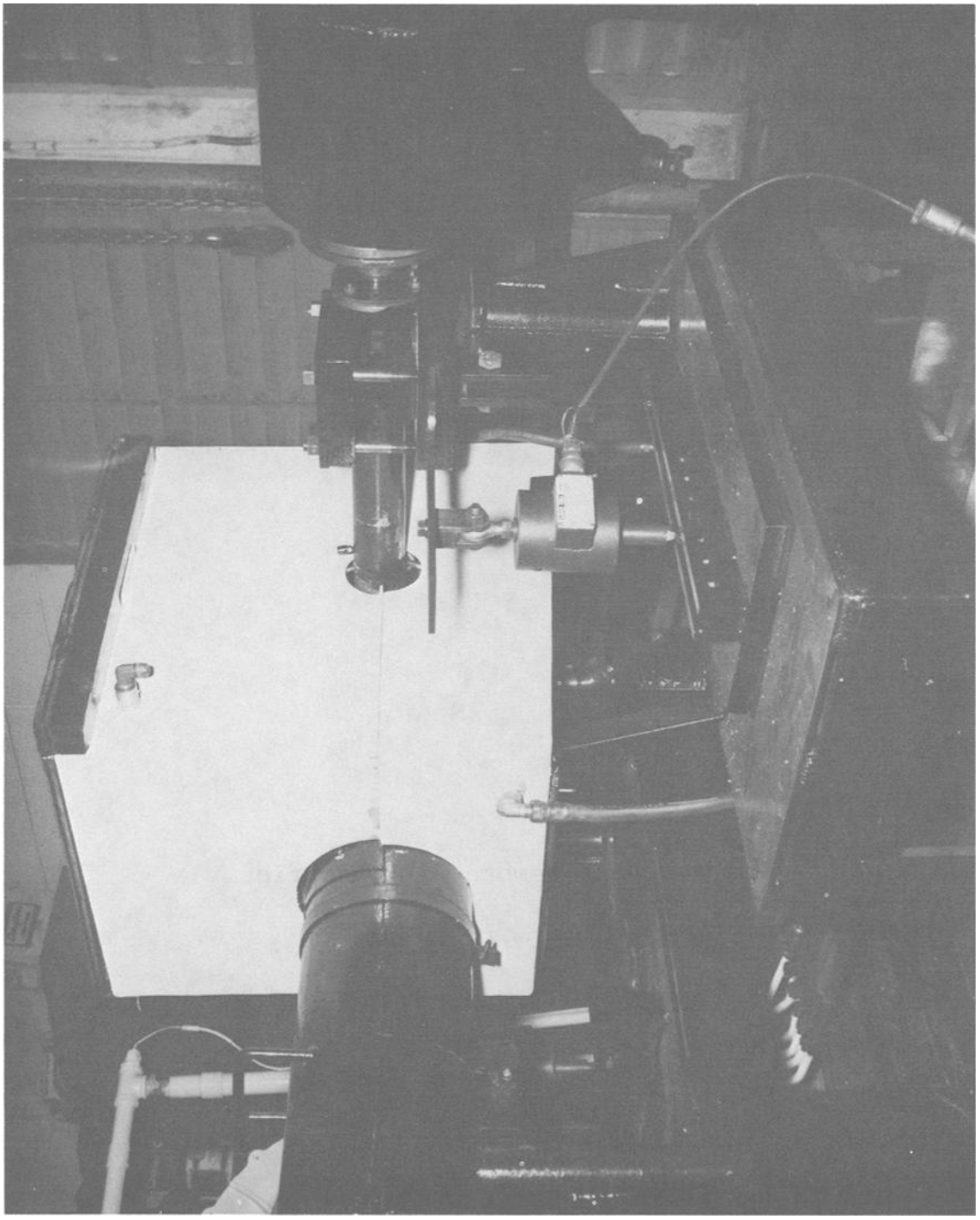


FIG. 4 - L-42 Stand Illustrating Load Cell Location

SECTION 4 (L-60 TEST) -- Performance Test for Evaluating the Thermal Oxidation Stability of Automotive Gear Lubricants

The test method described herein has no official status as an ASTM Standard.

L-60 TEST

(formerly CRC L-60 Test and FTMS 791B Method 2504)

1. SCOPE

1.1 This test method describes a test procedure for determining the deterioration of gear lubricants when subject to severe thermal oxidation conditions.

CAUTION - This test method may involve hazardous materials, operations, and equipment. This test method does not purport to address all the safety problems associated with its use. It is the responsibility of the user of this test method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. SUMMARY OF METHOD

2.1 A sample of gear lubricant to be tested is placed in a heated gear box in which two spur gears and a test bearing are operating at a predetermined load in the presence of a copper catalyst. The temperature of the test lubricant is maintained at 325°F (163°C) while bubbling 0.3 gal/h (1.1L/h) of oil through oil in the gear box for a test duration of 50 h of continuous operation.

3. APPARATUS

3.1 The test apparatus consists of the following (see Annex 4, Fig. 1 through 6[1]:

3.1.1 *Gear Case Assembly* - Used in conjunction with a new test bearing, a pair of new test gears, and copper catalyst specimens.

3.1.2 *Temperature Control System* - Consisting of an insulated heater case, a circulating blower, a thermistor probe with indicating controller, an air box temperature limiting thermoswitch set to 350°F (177°C) and an ASTM 2F-63 thermometer (for air box temperature measurement).

3.1.3 *Generator* - 12 volt, 45 ampere suitable for applying a load of 128 watts generator output to the test gears. The generator system shall be equipped with the means for regulating the field supply, and provisions for determining output.[2]

---

1 *A suitable apparatus may be purchased from Faville-LeVally, 2055 Comprehensive Drive, Aurora, Illinois 60505*

3.1.4 *Air* - Compressed.

3.1.5 *Regulatory* - With flow-meter capable of controlling the air supply at a flow rate of 0.3 gal/h (1.1 L/h) at 1 psi (7 kPa).

3.1.6 *Copper Catalyst* - Cold rolled electrolytic copper meeting Federal Specification QQ-C-576 Alloy 110. The two strips shall be sheared to approximately 9/16 in. by 1-13/16 in. from 1/16 in. thick stock (14 mm by 46 mm from 1.5 mm).

3.1.7 *Test Gears* - One Boston Gear Works GA-34, 34 teeth, 3/8 in. wide (9.5 mm), wide machine tool change gear. One Boston Gear Works GA-50, 50 teeth, 3/8 in. wide (9.5 mm), wide machine tool change gear.

3.1.8 *Test Bearing* -New Departure R-14 ball bearing.

3.1.9 Oakite 811 (Available from: Oakite Products, Inc., 13177 Huron River Drive, Romulus, Michigan 48174).

CAUTION - Flammable, vapor harmful. See Annex A1.1.

3.1.10 Penetone ECS (Available from: Penton Corp., 131 West Summit, Akron, Ohio 44309).

CAUTION - Combustible. Vapor harmful. See Annex A1.2.

3.1.11 Stoddard Solvent.

CAUTION - Combustible. Vapor harmful. See Annex A1.3, conforming to ASTM Specification D 235 Specification for Mineral Spirits (Petroleum Spirits) (Hydrocarbon Drycleaning Solvents).

3.1.12 Toluene.

WARNING - Flammable, vapor harmful. See Annex A1.4, industrial grade, conforming to Specification D 362.

3.1.13 Silicon Carbon Cloth - 150 grit.

4. PREPARATION FOR TEST

4.1 *Gear Case*

Clean the gear case, case glass and retainer, seal plate, nuts, bolts, flat washers, baffle plate, spacer

---

[2] *Delco Remy Buick 1102101 or equivalent has been found suitable.*

bushing, slinger bushings, slingers, bearing bushing and clamp keys, shaft nuts, catalyst holder, air supply tube, vent tube, with Oakite 811 or Penetone ECS, at 70-110°F (21.1-43.3°C). Nylon bristle brushes and long pipe cleaners may be used to aid cleaning. Following the Solvent cleaning procedure, wash parts thoroughly with Stoddard solvent, and finally with toluene, allowing parts to air dry.

CAUTION - Since the proper operation of the apparatus depends upon the maintenance of numerous accurately machined surfaces, do not use steel brushes or abrasive cloth materials except as noted in paragraph 4.2.

4.2 *Test Gears*

Polish the sides of the test gears with 150 grit silicon carbide cloth, and wash with Stoddard solvent. Carefully examine the gear teeth for nicks and burrs. Gears with major imperfections may be blended with a fine stone. After polishing, wash gears with Stoddard solvent and finally with toluene, and allow to air dry.

4.3 *Test Bearing*

Prior to installation, wash the test bearing first with Stoddard solvent, and finally with toluene, and allow to air dry.

4.4 *Copper Catalyst*

Notch one strip for purpose of identification. Polish both catalyst strips on all six sides with silicon carbon cloth and wipe with absorbent cotton pads moistened with Stoddard solvent; wash with toluene and allow to air dry. Record the weight (to the nearest 0.10 milligram) of the notched strip prior to installation.

CAUTION - Handle catalyst strips with only tweezers or ashless filter paper.

4.5 *Air Box Thermoswitch*

Prior to assembly of the complete apparatus for test, it is desirable to preset the air box temperature limiting thermoswitch. This may be achieved by placing the insulated air box cover in position on the rig, installing the air temperature thermocouple at a penetration depth of 3 in. (75 mm) below the top surface of the cover, and switching on the heaters and circulating fan. Adjust the thermoswitch to actuate when the thermocouple readout indicates 177°C (350°F) air temperature. This procedure is necessary during

initial installation and should be checked periodically between tests to ensure consistent calibration.

4.6 *Temperature Recording and Controlling Instrumentation*

Since this test procedure is extremely sensitive to temperature, it is necessary to maintain a periodic check upon the accuracy of all items related to temperature measurement and control. Therefore, immediately after the installation of a new test rig, (and periodically thereafter) the instrumentation used to measure and record the air and oil temperatures must be calibrated against known standards.

At the same time, it is recommended that the thermistor probe and its indicating controller be calibrated. This may be accomplished by immersing the tip of the probe 3/4 in. (20 mm) (See Note 1) into an auxiliary temperature controlled oil bath equipment with a stirrer. The bath temperature should be set accurately at 163°C (325°F).

5. **ASSEMBLY OF TEST APPARATUS** (Refer to Annex 3, Fig. 1 through 6)

5.2 *Gear Case*

Assemble the gear case components except for the test bearing, test gears, catalyst and gear case window. Use a new 0.005 in. (0.125 mm) thick paper seal plate gasket for each test, and safety wire the plate bolts with stainless steel wire.

5.2 *Test Bearing*

Install the test bearing so that the manufacturer's number faces the front of the case. Tighten the cap screw of the test bearing clamp, and safety wire it, using stainless steel wire.

5.3 *Test Gears*

Install the test gears so that the manufacturer's number faces the front of the case, and safety wire the retaining nuts with stainless steel wire.

NOTE 1 - The 3/4 in. (20 mm) represents the probe/oil operating depth when installed correctly in the apparatus.

5.4 *Copper Catalyst*

Install catalyst holder and safety wire retaining screws using stainless steel wire. Insert catalysts in the grooves provided, with notched strip adjacent to glass.

5.5 *Thermistor Probe*

Locate the thermistor probe so that the sensitive tip is located on the bottom of the case; withdraw it 3/16 in. (5 mm) and lock the retaining collar.

5.6 *Gear Case Window*

Install the gear case window using new 1/16 in. (1.5 mm) thick cork gaskets.

5.7 *Insulated Air-Box Cover*

Install the air-box in 3 in. (75 mm) below the top surface. Install the cover on the rig.

6. **PROCEDURE**

6.1 Pour 4 fl oz (120 mL) of the test lubricant through the vent tube into the gear case, and rotate the driving gear shaft four times by hand to coat the test gears and bearings. Operate the rig for 5 min without added heat to establish hang up oil. Drain the gear case for 5 min after the drain breaks into droplets and discard. Record the weight of 4 fl oz (120 mL) of fresh test lubricant and pour it into gear case through the vent tube.

6.2 Preset air flow rate to 0.3 gal/h (1.1L/h) at 1 psi (7 kPa).

6.3 Record the time, turn on the main drive motor, and adjust the temperature control system to maintain the test lubricant at 325±1°F (162.8±.6°C). Adjust the field supply of the generator for an output of 128 watts (see Note 2).

6.4 When the lubricant temperature reaches 325°F (162.8°C), record the time and start the test (see Note 3).

6.5 Run the test continuously for 50 h. Test is to be terminated if it is interrupted for more than 5 min. However, a judgement of the results may be possible when further interruptions are experienced during the last two hours of the 50-hour test.

6.6 At the completion of 50 h of operation, shut down the equipment, and drain the test lubricant (within 5 min) through the air supply tube into a clean sample jar. Record the weight of the final oil drain.

6.7 Remove the gear case window.

NOTE 2 - Approximately 55-60 min will be required to raise the

test lubricant temperature to 325°F (162.8°C).

NOTE 3 - The air box temperature as indicated by the thermocouple should register 340±5°F (171.1±2.8°C).

6.8 Without disturbing the deposits on the various components, remove the catalyst strips, test gears, test bearing, and internal gear case components.

7. TEST DATA AND REPORTING

7.1 The following items shall be recorded (see Note 4).

7.1.1 Duration of warm-up time (minutes).

7.1.2 Test oil and air box temperature.

7.1.3 Report duration of any unscheduled stop.

7.2 Carefully remove all of the deposits from the notched copper catalyst strip as follows:

7.2.1 Soak for 30 min in Oakite 811 or equivalent.

7.2.2 Wash in Stoddard solvent.

7.2.3 Remove deposit residue from surface by rubbing lightly with bare fingers and a clean cloth.

NOTE 4 - Temperature recorder charts shall be included in final reports.

7.2.4 Wash in Stoddard solvent.

7.2.5 Wipe with absorbent cotton pads moistened with toluene.

7.2.6 Wash in toluene and allow to air dry.

7.2.7 Weigh the cleaned catalyst to determine the copper activity of the test lubricant. The weight loss shall be reported as a percent loss based upon the original weight. The remaining catalyst strip shall be retained without further cleaning for inspection purposes.

7.3 Inspect and describe the deposits on the various components, including the gear surfaces and the catalyst. Describe the deposits for:

7.3.1 *Color* - light brown, brown, dark brown, black, etc.

7.3.2 *Hardness* - very soft, soft, medium, hard, or very hard.

7.3.3 *Thickness* - estimated in thousandths of an inch (mm).

7.3.4 *Type* - lacquer, which cannot be wiped off sludge, which is easily removed.

7.4 Determine and report the following test lubricant properties:

	ASTM Method
7.4.1 Initial and final viscosity centistokes at 212°F (100°C). (Be sure to follow special sample handling instruction in ASTM D 445, paragraph 7.3.2.1. Final viscosity determinations shall be run within 48 h of end of test. Do not filter sample except as required by ASTM D 445).	D 445
7.4.2 Percent viscosity increase.	Report
7.4.3 Total acid number (pay particular attention to the instructions in ASTM D 664, paragraphs 9.1, 9.2, and 9.3 for sample preparation).	D 664
7.4.4 n-Pentane and Toluene Insolubles (pay particular attention to the instructions in ASTM. D 893, paragraph 6.1 for sample preparation).	D 893, Method A Uncoagulated
7.4.5 Catalyst weight loss	Report
7.5 Report the lubricant weight loss in grams as the difference between the weights of the initial charge and final drain of test oil.	Report

8. STAND CALIBRATION

8.1 In order to assure that uniform results are being obtained in the L-60 Motorized Gear Oil Oxidation Test, reference tests shall be conducted on the two established reference oils[3] on the following schedule.

8.1.1 *New Test Stand* - For a new test stand, reference tests giving results within the established limits shall be conducted on both reference oils

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[3] *RGO 4668 and RGO 4669 have been established as the reference oils for this test.*

before tests to evaluate lubricant can be considered standardized.

8.1.2 *Previously Referenced Stand* - For a previously referenced test stand, a reference test giving results within the standardized limits for that oil shall be conducted every 20th test. All tests which have completed at least 10h of operation shall receive a sequential test number. If 20 tests are not completed within six months, reference tests shall be started not later than six months after the start of the last satisfactory reference tests. The two established reference oils shall be tested. If the test stand has been moved or relocated or has been out of operation for four months or longer, satisfactory reference tests shall be run before any tests to evaluate lubricants can be considered standardized.

8.1.3 Established reference oils are available from:

ASTM Test Monitoring Center
440 Fifth Avenue
Pittsburgh, PA 15213
ATTN: Paul Eisaman

9. TEST REPORT

9.1 Test results should be reported as indicated on the data sheets for Thermal Oxidation Stability of Gear Lubricants. (Sample form is included as Annex A2). Also include temperature recording charts.

10. PRECISION AND BIAS

10.1 A mean and standard deviation are developed for percent viscosity increase and for pentane and toluene insolubles are each established reference oil. An acceptance band for each reference oil is establihsed based on ±1.8 standard deviations from the mean. Data used for these calculations are generated on all operationally valid tests. Outliers are determined by ASTM procedure E 178-80.

10.2 Statistical data and acceptance bands for the established reference oils follow.

NOTE 5 - Data used to generate this statistical base appear in Annex A3.

RGO-4668

	%VIS INCREASE	PENTANE	TOLUENE
Average, X	7.06	0.26	0.20
Standard Dev, S	1.84	0.16	0.13
ALI±	3.32	0.29	0.24
N =	37		
Acceptable Range			
High	10.38	0.55	0.44
Low	3.74	0.00	0.00

RGO-4669

	%VIS INCREASE	PENTANE	TOLUENE
Average, X	88.40	2.05	0.52
Standard Dev, S	18.84	1.05	0.23
ALI ±	33.92	1.90	0.41
N =	35		
Acceptable Range			
High	122.23	3.95	0.93
Low	54.48	0.16	0.11

NOTE 6 - Statistics are re-calculated peridodically based on the number of reference tests conducted by participating laboratories.

Annex A1

Precautionary STatements

A1.1 *Oakite 811*

CAUTION - Combustible. Vapor harmful.
Keep away from heat, sparks, and open flame.
Keep container closed.
Use with adequate ventilation.
Avoid breathing vapor or spray mist.
Avoid prolonged or repeated contact with skin.
In case of spillage, soak up with clay, diatomaceous earth, or similar materials.
In case of fire, use foam, dry chemical, or CO_2.

A1.2 *Penetone ECS*

CAUTION - Combustible. Vapor harmful.
Keep away from heat, sparks, and open flame.
Keep container closed.
Use with adequate ventilation.
Avoid breathing vapor or spray mist.
Avoid prolonged or repeated contact with skin.
In case of spillage, soak up with clay, diatomaceous earth, or similar materials.
In case of fire, use foam, dry chemical, or CO_2.

A1.3 Stoddard Solvent

CAUTION - Combustible. Vapor harmful.
Keep away from heat, sparks and open flame.
Keep container closed.
Use with adequate ventilation.
Avoid breathing vapor or spray mist.
Avoid prolonged or repeated contact with skin.
In case of spillage, soak up with clay, diatomaceous earth, or similar materials.
In case of fire, use foam, dry chemical, or CO_2.

A1.4 *Toluene*

WARNING - Combustible. Vapor harmful.
Keep away from heat, sparks and open flame.
Keep container closed.
Use with adequate ventilation.
Avoid breathing vapor or spray mist.
Avoid prolonged or repeated contact with skin.

Annex A2

L-60 TEST
THERMAL OXIDATION STABILITY

A.4 DATA SHEET

Test run at _____ Date _____

Test Lubricant Identification _____ SAE Grade _____

Test Number _____

Company _____

TEST CONDITIONS

Hours Run _____ Warm-up Time (Minutes) _____

Air Temperature °F (°C) max. _____ min. _____ average _____

Test Oil Temperature °F (°C) max. ___ min. ___ average _____
(include test oil temperature chart)

Unscheduled Shut-down _____

TEST RESULTS

Catalyst Weight Loss, grms. _____ Percent _____
Oil Data:

Test Oil Viscosity Centistokes at 212oF (100oC) (AST.1 D 445)

Hours Run	Viscosity	Percent Increase
New Oil	_____	
50 Hours	_____	_____

Initial Oil Charge Wt. Grms. _____

Final Oil Drain Wt. Grms. _____

Weight Loss Grms _____

Acid Number (ASTM D 664) _____

Pentane Insolubles (ASTM D 893, Method A) _____

Benzene Insolubles (Uncoagulated) _____

DESCRIPTION OF PARTS AFTER TEST

(a) Catalyst - Front face: (Face adjacent to gear teeth).

_____

Rear Face: _____

_____

(b) Small Gear. Front face (Numbered surface facing out)

_____

_____

Rear Face: _____

_____

Gear Teeth: _____

_____

(c) Large Gear. Front face (Numbered surface facing out)

_____

_____

Rear Face: _____

_____

Gear Teeth: _____

(d) Bearings: Front face (Numbered surface facing out)

_____

Rear Face: _____

Bearings and Carrier _____

_____

_____

_____ _____

DATE SIGNATURE

Annex A3

L-60 Test Results (through July 7, 1986)
RGO-4668

* Outliers

TEST	%VIS	INCREASE	PENTANE	TOLUENE
1		6.29	0.23	0.20
2		6.22	0.30	0.27
3		6.19	0.09	0.07
4		5.14	0.23	0.21
5	*	7.00	0.91	0.36
6		8.09	0.38	0.19
7		5.90	0.21	0.20
8		4.80	0.39	0.30
9		4.45	0.31	0.27
10		7.39	0.23	0.20
11		6.56	0.21	0.14
12		3.09	0.13	0.08
13		4.07	0.50	0.40
14		7.62	0.20	0.15
15	*	9.68	0.73	1.07
16		9.88	0.59	0.43
17		8.43	0.58	0.55
18		7.70	0.62	0.48
19		9.68	0.21	0.18
20		9.16	0.15	0.12
21		9.02	0.18	0.17
22		5.17	0.17	0.09
23	*	8.60	0.85	0.68
24		8.14	0.71	0.56
25		5.10	0.08	0.06
26		4.91	0.11	0.08
27		7.75	0.19	0.20
28		6.38	0.16	0.12
29		5.91	0.45	0.32
30		8.35	0.25	0.17
31		5.74	0.14	0.07
32		9.47	0.10	0.08
33		9.84	0.26	0.20
34		7.02	0.33	0.18
25		10.04	0.19	0.19
36		7.74	0.09	0.04
37		7.60	0.15	0.08
38		6.81	0.12	0.10
39		9.89	0.22	0.20
40		5.82	0.25	0.16

Annex A3 (continued)

L-60 Test Results (through July 7, 1986)
RGO-4669

* Outliers

TEST	%VIS	INCREASE	PENTANE	TOLUENE
1		99.30	2.74	0.52
2		99.30	2.53	0.61
3		72.00	0.85	0.30
4		81.00	1.40	0.26
5		87.40	2.40	2.30
6	*	111.54	2.50	1.70
7		85.20	1.40	0.60
8		78.50	1.40	0.36
9		100.08	2.00	0.57
10		96.57	2.98	0.56
11		93.23	3.00	0.43
12		93.01	2.40	0.57
13		80.35	1.90	0.83
14		123.94	4.20	0.40
15	*	139.00	1.56	1.67
16		64.00	0.30	0.18
17		137.00	4.56	1.03
18		97.70	2.53	0.24
19		96.00	1.46	1.03
20		95.60	1.48	0.95
21		89.00	1.84	0.36
22		84.30	1.97	0.56
23		67.13	1.64	0.43
24		73.80	0.90	0.60
25		75.98	0.76	0.41
26		93.08	0.80	0.48
27		85.23	2.30	0.23
28		88.30	1.88	0.06
29		121.30	3.82	0.36
30		47.76	0.94	0.53
31		68.41	0.91	0.56
32		121.55	4.13	0.76
33		80.48	1.87	0.56
34		73.11	2.00	0.45
35		69.03	1.77	0.38
36		81.08	1.86	0.65
37		111.10	3.61	0.61
38		70.31	1.83	0.78

ANNEX A4 - TEST EQUIPMENT

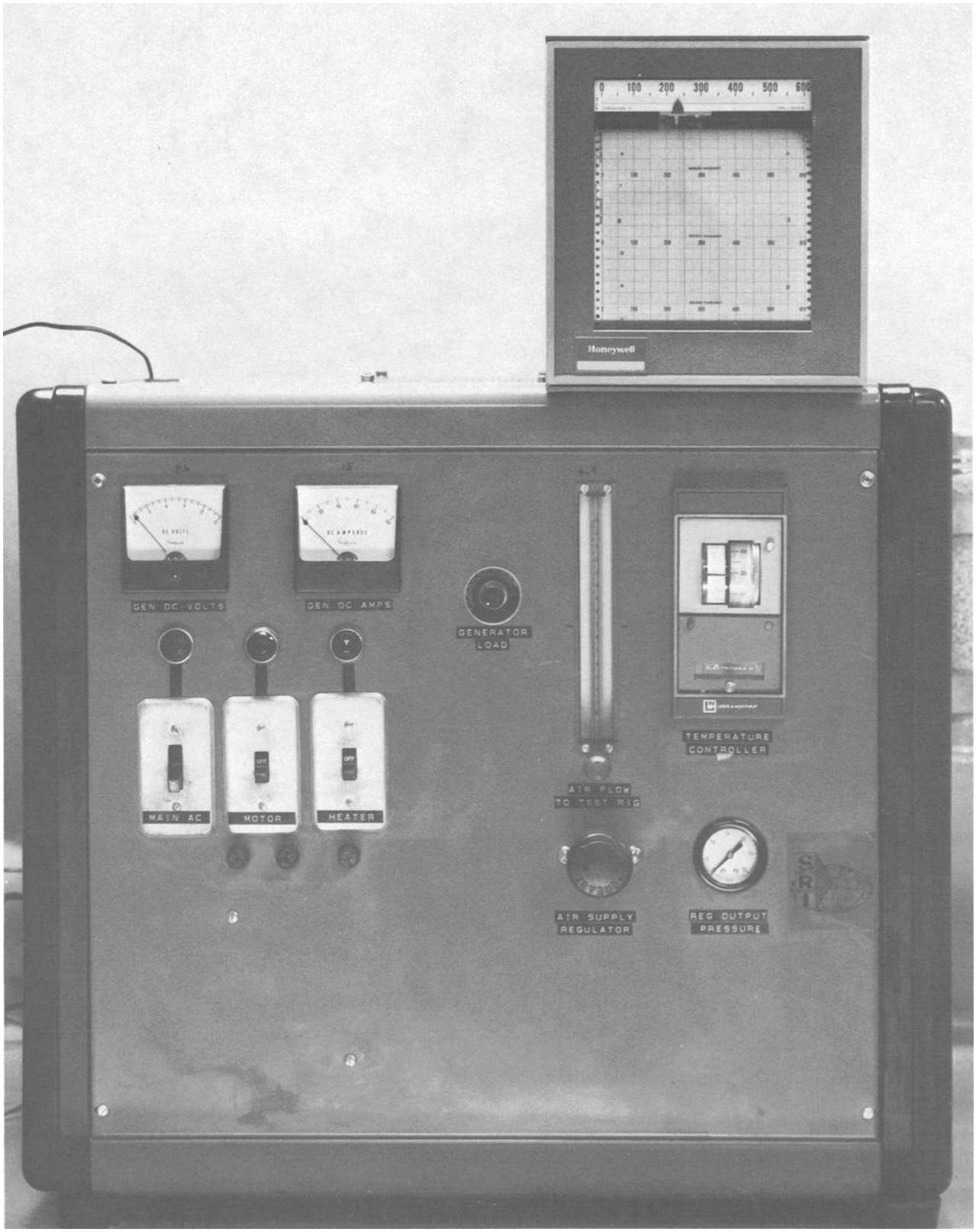


FIG. 1 - Thermal Oxidation Stability Test Apparatus

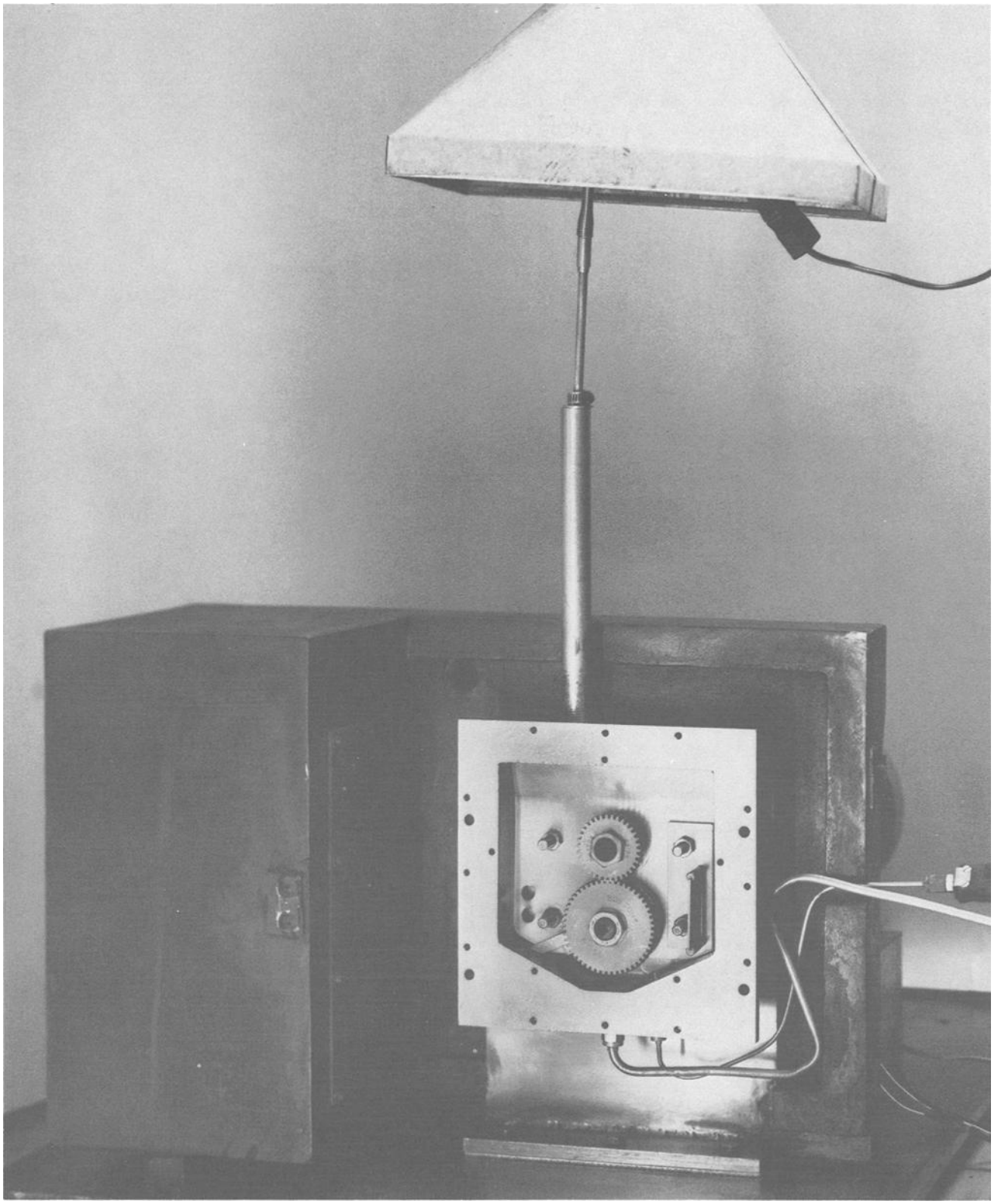


FIG. 2 - Front View of Gear Case

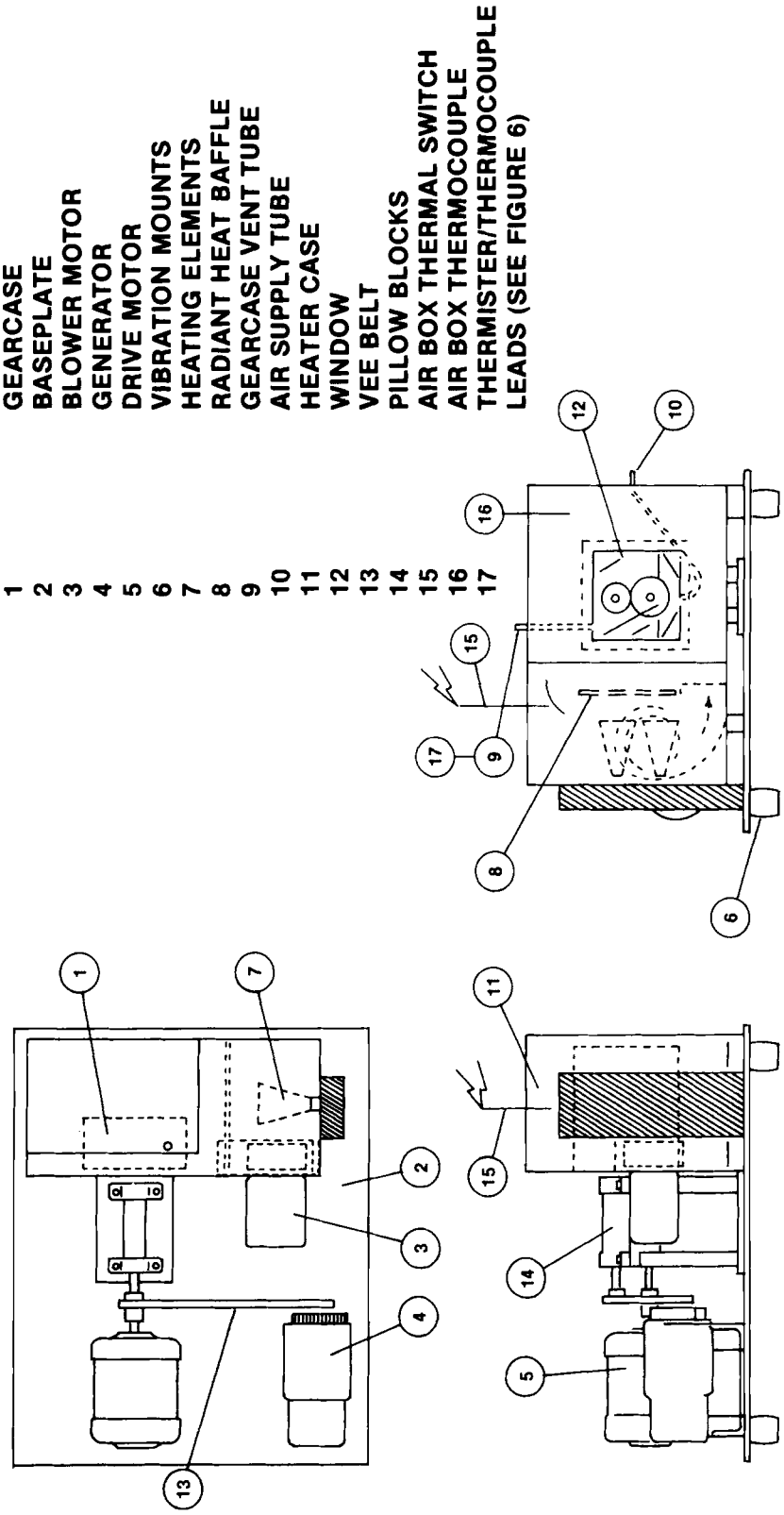


FIG. 3 - Sketch of the Thermal - Oxidation Stability Test Apparatus

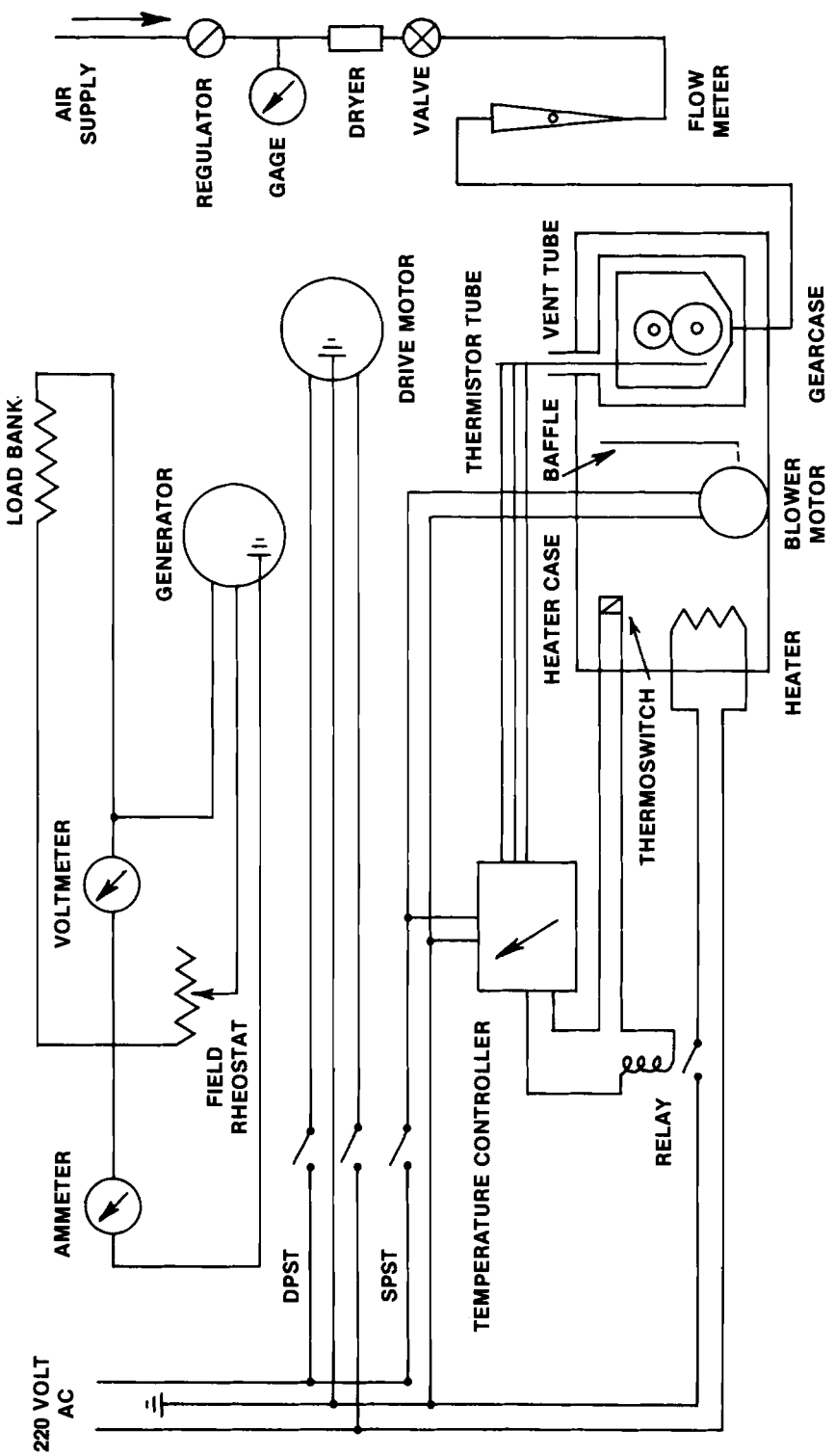
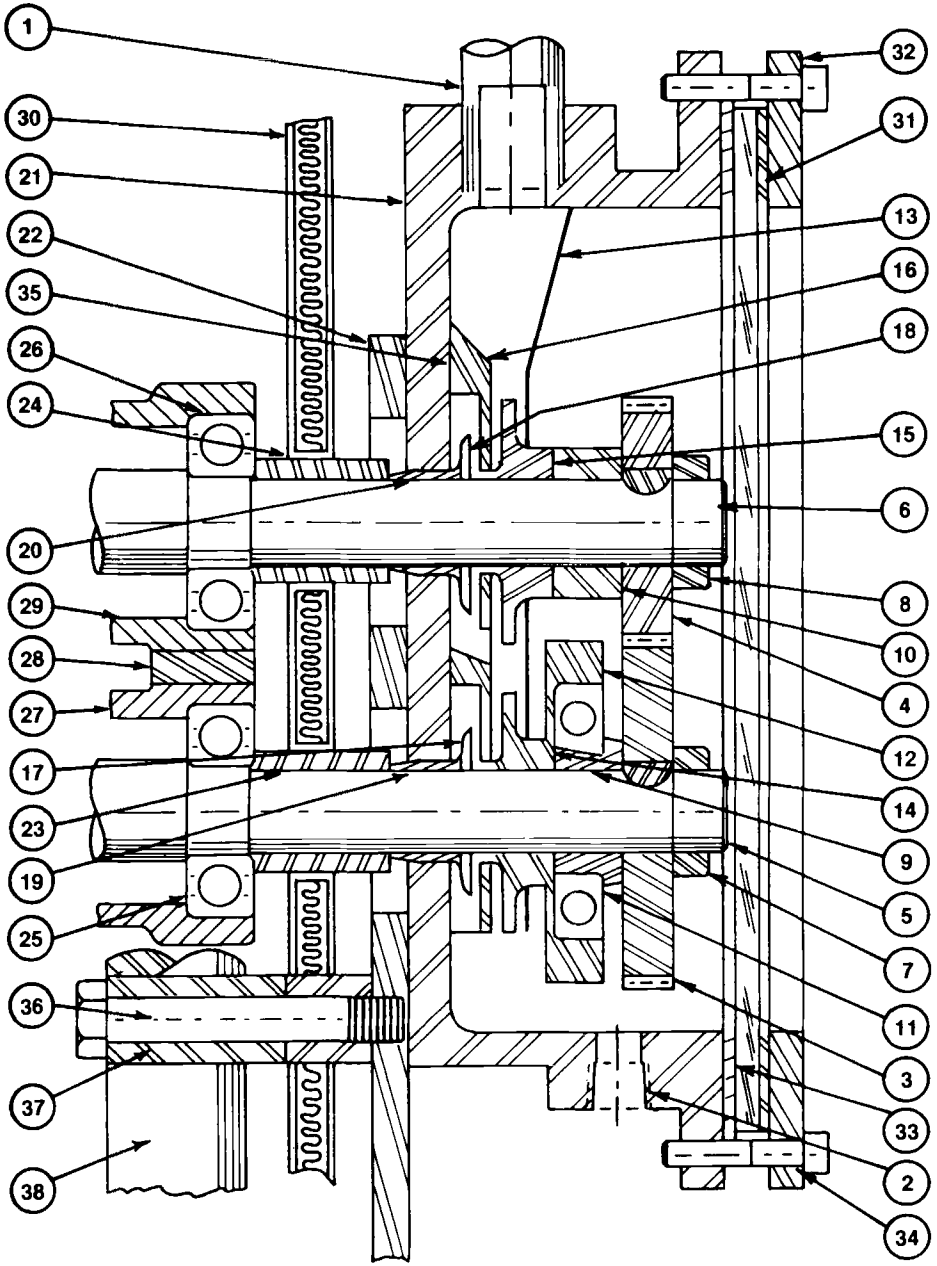


FIG. 4 - Schematic Layout of the Apparatus



LEGEND

NUMBER	PART
1	VENT TUBE
2	CASE AIR INLET
3	TEST GEAR, 50 TEETH
4	TEST GEAR, 34 TEETH
5	GEAR SHAFT, DRIVING
6	GEAR SHAFT, DRIVEN
7	GEAR RETAINING NUT, RH THREAD
8	GEAR RETAINING NUT, LH THREAD
9	TEST BEARING BUSHING
10	SPACER BUSHING
11	TEST BEARING
12	TEST BEARING CLAMP
13	BAFFLE PLATE
14	OUTER SLINGER, LOWER
15	OUTER SLINGER, UPPER
16	SEAL PLATE
17	INNER SLINGER, LOWER
18	INNER SLINGER, UPPER
19	SLINGER BUSHING, LOWER
20	SLINGER BUSHING, UPPER
21	GEARCASE
22	GEARCASE SUPPORT
23	RETAINER BUSHING, LOWER
24	RETAINER BUSHING, UPPER
25	PILLOW BLOCK BEARING, LOWER
26	PILLOW BLOCK BEARING, UPPER
27	PILLOW BLOCK, LOWER
28	SPACER, PILLOW BLOCK
29	PILLOW BLOCK, UPPER
30	HEATER CASE
31	WINDOW, GEARCASE
32	RETAINER, GEARCASE WINDOW
33	GASKETS, GEARCASE WINDOW, 1/16" THICK
34	CAP SCREW, GEARCASE WINDOW RETAINER
35	GASKET, SEAL PLATE
36	BOLT, CASE SUPPORT TO PILLOW BLOCK SUPPORT
37	BOLT TUBE
38	PILLOW BLOCK SUPPORT

FIG. 5 - Gearcase Cross Section

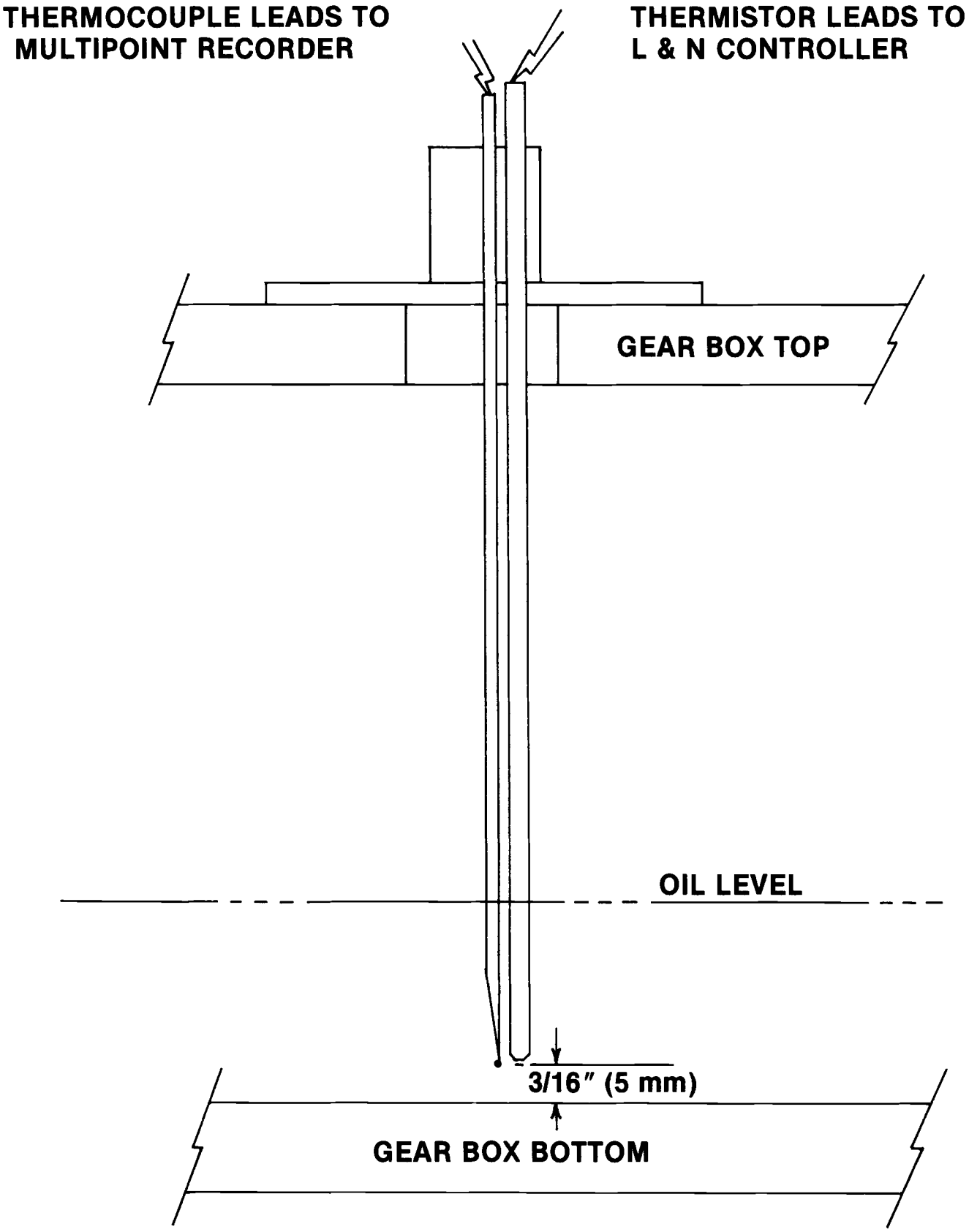


FIG. 6 - Temperature Probe Locations

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