INTRODUCTION

Caterpillar is introducing Caterpillar BF-2 technical performance requirements for biodegradable hydraulic fluids. Cat® BF-2 was developed in response to changing environmental regulations and to ensure high performance oils for Cat applications and trouble-free operation for Cat customers.

This document contains all of the performance requirements that a finished lubricant must meet before it legitimately can be marketed as meeting the Cat BF-2 requirements.

APPLICATION

Oils meeting Cat BF-2 performance requirements are applicable for use in hydraulic systems of Cat equipment wherever biodegradable hydraulic fluids are recommended. Cat BF-2 performance requirements replace the Cat BF-1 specification. Cat BF-1 is obsolete. Fluids meeting Cat BF-2 performance requirements can be used where Caterpillar previously specified fluids meeting BF-1 specification were previously required.

OBJECTIVE:

These requirements are intended to communicate the minimum performance requirements for a lubricant that is intended for use in Cat equipment, wherever BF-2 fluids are recommended. The primary use of these fluids will be hydraulic systems.

GENERAL DESCRIPTION:

The Cat BF-2 requirements are divided into seven principal areas: Chemical and Physical Properties, Elastomer Compatibility, Oxidation Stability, Viscometric Properties, Wear Properties, Environmental Compliance and Friction Properties.

Caterpillar Inc. will not monitor or verify the accuracy of claims or advertising suggesting compliance with Cat BF-2 specification made by other manufacturers or suppliers of fluids. Each supplier is responsible for the performance of their own product and the associated liabilities.

Caterpillar reserves the right to change this document without notice. The implementation date of this specification is July 15, 2012.

SUMMARY AND TABLE OF CONTENTS:

Biodegradable Hydraulic Fluid Requirements BF-2

The following information is a summary of the performance requirements that define a fluid that meets the Cat BF-2 fluid requirements. Information regarding the appropriate test methods and the applicable limits for each can be found in the referenced section.

FLUID CLEANLINESS

1.0 Scope :
This test method will be used to evaluate the level of particle contamination within the oil.

2.0 Test Method:
ISO 4406

3.0 Test Procedure:
The ISO 4406 standard test method should be followed as given.

4.0 Acceptance Limits:
A maximum measured value of 18/16/13 is allowed for the hydraulic system.

HOMOGENIETY

1.0 Scope:
This test method will be used to evaluate the compatibility of additives with the biodegradable oil base stock.

2.0 Test Method:
The test fluid is held at -32°C for 24 hours, then warmed to room temperature 20 +/- 5°C), and centrifuged. The absence of sedimentation or separation of insoluble material indicates that the oil and the additives are homogeneous.

3.0 Test Equipment:
100 mL centrifuge tubes
High speed centrifuge capable of producing 6000g

4.0 Test Procedure:
A 100 mL sample of the test fluid is put into a 100 mL centrifuge tube. The sample is stoppered and held at -32°C for 24 hours. Allow the sample to reach room temperature and then centrifuge for 30 minutes at 6000 g. The tube containing the test sample shall be examined for sedimentation or separation of insoluble material.

5.0 Acceptance Limits:
A maximum of 0.01 volume percent sedimentation or precipitation is allowed.

FLUID COMPATIBILITY

1.0 Scope:
This test method will be used to evaluate the compatibility of different hydraulic fluids with one another.

2.0 Test Method:
The test oil is mixed separately with each of the following reference oils:

1. Cat HYDO Advanced 10
2. Cat DEO 15W-40
3. Cat TDTO 10W
4. Cat MTO
5. Cat BIO HYDO Advanced (HEES)
6. Cat DEO Cold Weather 0W-40

The mixture then is heated, cooled, and centrifuged to determine if any residue is present.

3.0 Test Equipment:
50 mL centrifuge tubes
High-speed centrifuge capable of producing 6000 g

4.0 Test Procedure:
Pour a 50 mL sample of the hydraulic oil test fluid and 50 mL of one of the five reference fluids into a 4 oz glass jar. Shake well and heat to 204°C. Cool to room temperature. Pour the mixture into three 50 mL high-speed centrifuge tubes. Centrifuge for 30 minutes at 6000 g. The tubes containing the mixtures of the test samples and the selected oil shall be examined after centrifuging for precipitation of insoluble residue and separated components. Repeat the procedure for the remaining six reference fluids.

5.0 Acceptance Limits:
No sedimentation or precipitation is allowed in any of the three centrifuge tubes for each reference fluid.

FOAMING CHARACTERISTICS

1.0 Scope:
This test method will be used to determine the foaming characteristics of hydraulic fluids at specified temperatures. The method of qualitatively rating the foaming tendency and the stability of the foam is described.

2.0 Test Method:
ASTM D892 modified as described in the test procedure outlined below.

3.0 Test Procedure:
ASTM D892 standard test method will be with the following modifications. The test will be divided into two parts.
Part I: Standard ASTM D892 test method without water added.
Part II: Water is mixed with the test fluid and the foaming characteristics are measured following the ASTM D892 standard test method.

Procedure: Mix 500 mL of the fluid to be tested with 0.5 mL of distilled water in a blender for 5 minutes at low speed (1000 RPM) and then for 1 minute at high speed (1300 RPM). Allow any foam to dissipate before determining the foam by all three sequences of the ASTM D892 test method. Additional tests have to be performed with the candidate oil mixed with 5%, 50%, and 75% of the following reference oils:

1. Cat HYDO Advanced 10
2. Cat TDTO 10W
3. Cat DEO 15W-40

4.0 Acceptance Limits:
Part I:

	Without Added Water	With 0.1% Water
Sequence I	25/0	25/0
Sequence II	50/0	50/0
Sequence III	25/0	25/0

HUMIDITY CORROSION

1.0 Scope:
This test method will be used to determine the corrosion protection offered by Cat BF-2 fluids to a finished ferrous surface under dynamic humidity conditions.

2.0 Test Method:
CEMS BT-9, International Truck and Engine Corporation Humidity Corrosion Test. Cleaned ferrous rods are exposed to dynamic humidity conditions and the rod is monitored for the appearance of corrosion spots over time.

3.0 Test Equipment:
CEMS BT-9, International Truck and Engine Corporation Humidity Corrosion Test should be used.

4.0 Test Materials:
CEMS BT-9, International Truck and Engine Corporation Humidity Corrosion Test materials should be used.

5.0 Test Procedure:
CEMS BT-9, International Truck and Engine Corporation Humidity Corrosion Test should be followed as given to evaluate humidity corrosion characteristics of hydraulic fluids.

6.0 Acceptance Limits:
Minimum time to failure is 20 hours. The specimen shall be examined for appearance of corrosion spots after 20 hours. Failure is defined as six or more spots per any linear inch (as viewed without magnification). The first 9.5 mm (3/8 inch) below the contact line between the stopper and the rod shall be disregarded. Two specimen failures in less than 20 hours shall be considered a failure of this requirement.

COPPER STRIP CORROSION

1.0 Scope:
This test method will be used to evaluate the corrosiveness of hydraulic fluids to copper.

2.0 Test Method:
ASTM D130

3.0 Test Procedure:
The ASTM D130 standard test method will be used to evaluate the copper strip corrosion characteristics of hydraulic fluids under the following conditions:
Oil Temperature: 150°C
Time of Immersion: 3 hours

4.0 Acceptance Limits:
1a slight tarnish is allowed
1b or worse is considered to be a failure

RUST PREVENTIVE CHARACTERISTICS

The oil must pass the ASTM D665, Procedure B, test temperature is 60°C (140°F) and the test duration is 24 hours.

1.0 Scope:
This test method will be used to evaluate the ability of the candidate oil to prevent the rusting of ferrous parts in presence of synthetic seawater.

2.0 Test Method:
ASTM D665, Procedure B

3.0 Test Procedure:
The ASTM D665, Procedure B standard test method will be used:
Oil Temperature: 60°C
Time of Immersion: 24 hours

4.0 Acceptance Limits:
The candidate oil has to pass the test according to criteria specified in ASTM D665, Procedure B.

LOW TEMPERATURE STORAGE

1.0 Scope:
This test method will be used to evaluate the low temperature storage stability of biodegradable hydraulic fluids.

2.0 Test Method:
Following preliminary heating, the fluid sample is placed in a freezer preset to -25ºC. The sample is checked every 24 hours for the formation of precipitates, particles, and for fluidity.

3.0 Test Equipment:
Test jar made of clear cylindrical glass with a flat bottom, 30 to 33.5 mm inside diameter and 115 to 125 mm in height. To indicate the height of the sample, the jar should be marked with a line 54 +/- 3 mm above the inside bottom.
Cork to fit the mouth of the test jar
Tray to hold the sample jars in an upright position while in the freezer
Freezer capable of maintaining the test temperature

4.0 Test Procedure:
Pour the fluid sample into the test jar to the level marked on the outside.
Heat the fluid sample to 50°C for 30 minutes.
Remove the sample from the oven and stopper the test jar with the cork. Allow the sample to cool to room temperature (20 +/- 5°C).
Place the sample in a freezer preset at -25°C.
Check the sample following each 24 hour period for fluidity and for the appearance of any type of precipitate and particles.
End the test at the first appearance of precipitates forming anywhere in the sample of when the sample shows no movement within 5 seconds when the sample jar is tilted to the horizontal.
Report this time as the test duration and cite the reason for failure.
If failure has not occurred within 168 hours, end the test.

5.0 Acceptance Limits:
Samples that show no precipitates and remain fluid for 168 consecutive hours are considered passing.

DEMULSIBILITY

1.0 Scope:
This test method will be used to evaluate the ability of biodegradable hydraulic fluids to separate from water.

2.0 Test Method:
ASTM D1401

3.0 Test Procedure:
The ASTM D1401 standard test method should be followed as given.

4.0 Acceptance Limits:
The test sample must have separated sufficiently that a water layer having a volume of at least 37 mL is observed before 20 min has elapsed.

IODINE NUMBER

1.0 Scope:
This test method will be used to evaluate the degree of unsaturation of the fatty acids in the biodegradable hydraulic fluid.

2.0 Test Method:
AOCS Da 15-48 (WIJS Method)

3.0 Test Procedure:
The AOCS Da 15-48 standard test method should be followed as given.

4.0 Acceptance Limits:
Report the values obtained.

FLASH AND FIRE POINTS

1.0 Scope:
This test method will be used to evaluate the flash point of biodegradable hydraulic fluids by the Cleveland Open Cup method.

2.0 Test Method:
ASTM D92

3.0 Test Procedure:
The ASTM D92 standard test method should be followed as given.

4.0 Acceptance Limit:

ISO 46 and ISO 68

Flash Point	220°C or legal limit, whichever is greater
Fire Point	220°C or legal limit, whichever is greater

ISO 32

Flash Point	200°C or legal limit, whichever is greater
Fire Point	200°C or legal limit, whichever is greater

POUR POINT

1.0 Scope:
This test method will be used to determine the minimum temperature for which biodegradable hydraulic fluids remain fluid.

2.0 Test Method:
ASTM D97

3.0 Test Procedure:
The ASTM D97 standard test method should be followed as given.

4.0 Acceptance Limit:

Viscosity Grade	Pour Point (°C)
ISO 32 and 46	Below or equal to -35
ISO 68	Below or equal to -25

WATER CONTENT

1.0 Scope:
The Karl Fischer test method will be used to determine the amount of water in a candidate biodegradable hydraulic fluid.

2.0 Test Method:
ASTM D6304

3.0 Test Procedure:
The ASTM D6304 standard test method should be followed as given.

4.0 Acceptance Limit:
The maximum water content as measured by ASTM D6304 should not exceed 0.05 volume percent.

FILTERABILITY

1.0 Scope:
This test method will be used to evaluate the filterability of hydraulic oils in the presence of water.

2.0 Test Method:
ISO 13357 stage 1 and stage 2 dry and wet.

3.0 Test Equipment:
As outlined in test procedure ISO 13357T

4.0 Test Procedure Summary:
The ISO 13357 test procedure should be followed as given.

5.0 Acceptance Limits:
Stage I - dry greater than 80%
Stage II - dry greater than 60%

Stage I - wet greater than 70%
Stage II - wet greater than 50%

AIR ENTRAINMENT

1.0 Scope:
This test method will be used to evaluate the ability of hydraulic fluids to quickly separate entrained air. Candidate oil of ISO 46 viscosity grade must be used to test for air entrainment.

2.0 Test Method:
ASTM D3427

3.0 Test Equipment:
As outlined in the ASTM D3427 procedure

4.0 Test Procedure Summary:
Compressed air is blow through test oil at 50°C. The time required for the air entrained within the oil to reduce to 0.2%, by recovered density, after the blowing is stopped, is the air release time.

5.0 Acceptance Limits:
The air release time shall be less than 4 minutes for the oils satisfying viscosity requirements of ISO viscosity grade 46 or SAE J300 viscosity grade of 10W-20 and 5W-20.

ELASTOMER COMPATIBILITY

1.0 Scope:
To measure the compatibility of the candidate fluid with Elastomer materials typically used in Caterpillar, Inc. hydraulic systems.

2.0 Test Method:
Test according to ASTM D2000 unless otherwise specified. The test materials will be in accordance with ASTM D3182. Data shall be reported in a format similar to the table below. Table shall include numeric values and Pass / Fail summary for each characteristic. Report shall also include rubber material batch and/or lot number.

3.0 Test Materials:
To request materials and testing guidance, contact:
FNFHelp@cat.com

4.0 Acceptance Limits:

Duration (Hrs)	Material	Candidate Fluid Temperature (°C)	Volume Change (%)	Hardness Change (pts)	Tensile Strength Change (%)	Elongation Change (%)	Residual Elongation (%)
1000	1E2719A	100	-3 / +20	-10 / +10	-50	-50	80%
1000	1E0741	100	-3 / +20	-10 / +10	-50	-50	80%
1000	1E0804	100	-3 / +20	-10 / +10	-50	-50	80%
1000	1E0724	100	-3 / +20	-10 / +10	-50	-50	80%
1000	1E4323	100	REPORT				

5.0 Test Laboratory Requirements:
The testing laboratory shall have an ISO/IEC 17025 Accreditation, issued by an ILAC MRA Signatory, and accredited Scope including the testing listed above.

OXIDATION STABILITY

1.0 Scope:
This test method will be used to evaluate the thermal oxidation stability of biodegradable hydraulic fluids.

2.0 Test Method:
ASTM D943 modified as described below

3.0 Test Procedure:
Follow the procedure outlined in ASTM D943 except for the addition of water. Do not initially add water to the hydraulic fluid or replenish water during the testing.

4.0 Acceptance Limit:
A lifetime of 4,000 hr or longer is considered passing.

VISCOSITY

1.0 Scope:
This test method will be used to evaluate the ability of biodegradable fluids to provide acceptable viscometric properties in cold and hot ambient conditions when used in hydraulic systems.

2.0 Test Methods:
SAE J300 or ISO viscosity system can be utilized to describe the viscosity. Oils meeting SAE 10W requirements of SAE J300 or the oils characterized by ISO viscosity system must meet additional requirements summarized in this section. In addition, shear stability of the oil has to be confirmed by KRL Shear Stability Test, CEC L-45 40 hrs at 100°C.

3.0 Test Procedure:
Kinematic viscosity according to ASTM D445
Brookfield viscosity according to ASTM D2983
Shear stability according to CEC L-45 (40 hrs at 100°C)

4.0 Acceptance Limits:
For all oils meeting BF-2 specification, the loss of kinematic viscosity at 100°C after the KRL shear stability test must be 5% or less. Additional Kinematic and Brookfield viscosity requirements are summarized below.

Viscosity Grade	Temperature	Kinematic or Brookfield Viscosity
SAE 10W	-20°C	3500 cP
	100°C	6.5 cSt
ISO 32	-30°C	3500 cP (max)
	100°C	6.5 cSt (min)
ISO 46	-25°C	3500 cP (max)
	100°C	8.0 cSt (min)
ISO 68	-15°C	3500 cP (max)
	100°C	10.0 cSt (min)

WEAR PROPERTIES

VANE PUMP

1.0 Scope:
This test method will be used to evaluate the ability of a hydraulic fluid to provide acceptable vane pump antiwear characteristics.

2.0 Test Method:
Eaton® "Pump Test Procedure for Evaluation of Antiwear Fluids for Mobile Systems", Eaton Engineering Standard ATS-373 Revision C (March 11, 2004) and revised re-issue (March 19, 2004) - ASTM D6973.

3.0 Test Procedure Summary:
Eaton® "Pump Test Procedure for Evaluation of Antiwear Fluids for Mobile Systems", Eaton Engineering Standard ATS-373 Revision C (March 11, 2004) and revised re-issue (March 19, 2004) - ASTM D6973.

4.0 Acceptance Limits:
50 mg loss for the ring and 10 for the vane is considered passing result.

FZG RATING

1.0 Scope:
This test method will be used to evaluate the scuffing load capacity of hydraulic fluids.

2.0 Test Method:
ASTM D5182

3.0 Test Procedure Summary:
ASTM D5182 standard test method will be used to evaluate the scuffing load capacity of hydraulic fluids when used in hydraulic applications in Cat products.

4.0 Acceptance Limits:
The test must achieve a Pass Load Stage through a minimum of 11 load stages or Fail Load Stage of 12.

FOUR-BALL WEAR TEST

1.0 Scope:
This test method will be used to evaluate the relative wear preventative properties of hydraulic fluids in sliding contact.

2.0 Test Method:
ASTM D4172

3.0 Test Procedure:
ASTM D4172 standard test method will be used to evaluate the wear preventative properties of fluids when used in hydraulic applications in Cat products. The required test conditions are as follows: 40 kg load, 93°C, 600 RPM, and 30 minutes test duration.

4.0 Acceptance Limits:
The measured wear scar diameter must not exceed 0.40 mm.

ENVIRONMENTAL COMPLIANCE

1.0 Scope:
Environmental compliance will ensure the candidate fluid is suitable for use in Caterpillar machines in the areas where local or government regulations restrict biodegradability or toxicity properties of hydraulic oils. Maximum mineral oil content is often enforced and special care has to be taken during hydraulic system conversion to biodegradable lubricant to achieve the maximum allowable mineral oil content.

2.0 Test Methods:
According to European Eco Label

3.0 Test Procedures:
Follow the procedure outlined in the 2005/360/EC (European Ecolabel)

4.0 Acceptance Limits:
The candidate fluid must qualify for all criteria of the 2005/360/EC (European Ecolabel) for hydraulic fluids and be listed at www.eco-label.com.

FRICTION PROPERTIES

Introduction:
This test method will be used to evaluate the ability of a biodegradable lubricant to provide acceptable friction performance characteristics when used in conjunction with various oil-cooled friction mechanisms in Cat brakes or wherever BF-2 is specified for service fill.

Any questions pertinent to the test method shall be directed to:
BF-2 Oil / Friction Test
Caterpillar Inc., Component Development Division
Technical Center

(for First Class Mail)
P.O. Box 1875
Peoria, IL 61656-1875
Phone: 1-877-228-2420

Standard Test Method for Lubrication and Friction:

Characteristics of Biodegradable Oils in Caterpillar Hydraulic Compartments

1. Scope
   - 1.1. Test Method for Evaluation of Lubricant and Frictional Characteristics
   - 1.2. Acceptance Criteria for Oil Evaluation
   - 1.3. Safety Practices
   - 1.4. Revisions
2. Terminology
   - 2.1. Dynamic Coefficient
   - 2.2. Static Coefficient
   - 2.3. Initial Speed
   - 2.4. Energy Limit
   - 2.5. Phase
   - 2.6. Sequence
   - 2.7. Run
   - 2.8. Test
3. Summary of Test Method
   - 3.1. Uses Link M1158 Oil / Friction Test Machine
   - 3.2. Characteristics Measured
   - 3.3. Parts Used
4. Significance of Use
   - 4.1. Measures Frictional Characteristics
   - 4.2. Test Results are Compared with Reference Test
5. Interferences
   - 5.1. Machine Configuration Must Not Be Changed
   - 5.2. No Air Leaks Allowed
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   - 5.4. Constants Must Be True
6. Apparatus
   - 6.1. Link M1158 Oil / Friction Test Machine
   - 6.2. Discs and Plats in 137-1271 Kit
   - 6.3. Surface Roughness Measured by Supplier
   - 6.4. Special Micrometer for Thickness Measurements
7. Preparation of Apparatus
   - 7.1. Drain and Refill
   - 7.2. Filtration
   - 7.3. Disc and Plate Installation
   - 7.4. Selection and Definition of Sequences
   - 7.5. General Instructions
   - 7.6. Cooling Flow and Temperature
8. Procedure
   - 8.1. Signal Conditioner Calibration Check
   - 8.2. Force Output Calibration
   - 8.3. Test Directory, Edit and Select
   - 8.4. Run Subdirectory, Select and Edit
   - 8.5. Select Sequence, Disc and Plate Software Options

1.0 Scope:

1.1 This procedure defines the test method for evaluation of the lubrication and frictional performance characteristics of biodegradable hydraulic oil used in Cat hydraulic friction mechanisms.

1.2 This procedure defines the acceptance criteria related to the lubrication and frictional requirements which must be met by an oil for it to be given a BF-2 rating.

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

1.4 These requirements are subject to revision at any time by Caterpillar, Inc.

2.0 Terminology:

2.1 Average Dynamic Coefficient of Friction, μ_d – The coefficient value calculated from initial speed, stop time and unit load. This calculation is made as though the coefficient were constant throughout the engagement.

2.2 Static Coefficient of Friction, μ_d –The coefficient value calculated from unit load and the torque measured at the instant that sliding velocity reaches zero.

2.3 Initial Speed – The surface speed of the friction disc at the mean radius at the start of an engagement.

2.4 Energy Limit – The highest speed at which the friction material / oil / reaction plate will operate in the specified sequences and produce uniform results consistent with the results produced at lower speeds. In most instances the limit can be determined visually from the torque trace, but for oil certification with this specification, the limit will always be determined by the computer.

2.4.1 Visual Determination: The shape of the torque curve is indicative of the conditions at the lubricated interface of the friction disc and reaction plate. In normal operation, the torque makes a smooth, repeatable transition from the initial engagement through lockup. When the energy limit is reached there will usually be a hump or irregular shape in the torque curve revealing that there are unstable or destructive changes occurring at the friction interface. This condition is indicated by a significant change in the coefficient of friction. Figures 1 and 2 show typical torque curves both in normal operation and above the energy limit.

2.4.2 Computerized Determination: The computer will check for changes in μ_d (average dynamic coefficient of friction) during the phases after phase 20. The μ_d of each cycle will be compared with the mean μ_d of the previous phase. A change of 12% or more will be taken as an indication that the energy limit has been reached. The dynamic coefficient was chosen because minor inaccuracies in the speed or pressure settings will not influence its value, and by using a baseline from the previous phase, the check can be applied to all cycles.

2.5 Phase – A specified number of engagements at a given unit pressure and initial speed.

2.6 Sequence – A specific series of phases

2.7 Run – The operation of the M1158 machine through a sequence

2.7.1 Each run will be identified using the following numbering system; first character – letter assigned to the specific M1158 machines; next four digits – month and

year of last machine qualification; last three digits – number of runs since last qualification

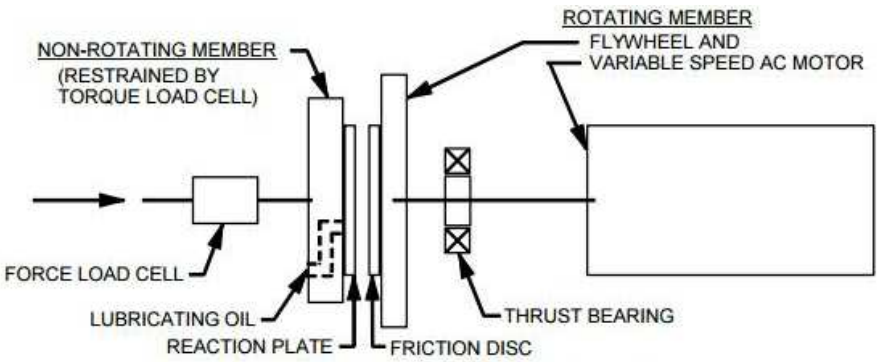
Example: B0589023

- 23rd Run since Qualification
- Machine last qualified in May '89
- Machine B

2.8 Test – The two runs required for oil certification

3.0 Summary of Test Method:

3.1 This procedure utilizes the Link Model 1158 Oil / Friction Test Machine, which is an inertia dynamometer in which the kinetic energy of a freely rotating mass is absorbed by the reaction of a rating friction disc and an opposing stationary steel plate. A flywheel is accelerated to predetermined speeds and brought to a stop by bringing the disc and plate together at various engagement pressures.



SCHEMATIC OF THE LINK M1158 OIL/FRICTION

3.2 This apparatus will be used to measure the characteristics itemized below on one friction material, as these characteristics are influenced by the lubricating oil.

Average Dynamic Coefficient of Friction
Static Coefficient of Friction
Energy Capability
Wear Resistance
Friction Retention

3.3 A complete oil test consists of two runs, which are made using the friction discs and reaction plates from a single 137-1271 clutch group (oil test kit).

3.3.1 Because of the restrictions on the material in each kit, all performance comparisons for evaluating a test oil will be made using discs from the same

manufacturing lot and reaction plates with the same range of surface finish variation.

4.0 Significance and Use:

4.1 This test method is used to determine comparative values for static coefficients of friction, energy capability and wear properties of a friction disc and opposing plate when tested under prescribed conditions. The lubricating oil used can influence the results. The procedure and values established are for evaluating the suitability of these oils.

4.2 The results of a test on the M1158 machine, if they are within the allowable ranges of variation from the reference test made from the same 137-1271 kit, may be used to designate the test oil as BF-2 oil.

5.0 Interferences:

5.1 Each M1158 machine is made with identical components to eliminate functional differences between the machines.

5.1.1 Replacement of the air valves or air lines with components of different size will change the response of the machine

5.1.2 Changes in bearing drag or windage losses will change the effective inertia of the machine.

5.2 An air leak from the tank, lines, valves or rotochamber will change the response and loading of the machine

5.3 An oil leak of more than one liter in any run will significantly reduce the volume of oil being tested.

5.4 Items which are stated as constants must be true, viz.:
Cooling oil temp and flow
Filtration – 4T-6788 Filter
Oil Capacity – total system volume
Friction disc size – mean radius
Reaction plate surface finish
Calibration of instrumentation – torque, load, flow, temperature, time, speed
Cycle time
Retraction clearance

6.0 Apparatus:

6.1 This procedure utilizes the Model 1158 Oil / Friction Test machine available from Link Engineering Company, Detroit, Michigan. This specific model and manufacturer must be used for reproducibility. The factors which are critical are: effective inertia, coast-down time, rate of pressure rise at the beginning of engagement, cooling flow distribution, response of the transducers and signal conditioners, the mass elastic system of the machine and its components and the method of heating the lube oil.

6.2 The friction discs and the reaction plates are supplied by Caterpillar, Inc. as a 137-1271 Clutch Group (Oil Test Kit). The kits are available by contacting Caterpillar, Inc..

6.2.1 Each 137-1271 Kit contains enough material for a reference test and nineteen oil tests (if no runs have to be repeated). These friction materials are identified by manufacturing lot. The reaction plates are closely controlled for surface finish, and the clutch groups are certified for performance by Caterpillar Inc.

6.2.2 The following combinations of friction disc and reaction plate, which are to be used only in these pairings, make up a 137-1271 kit:
137-1274 Clutch Group: 118-7181 Disc (Brake Paper) and 1Y-0726 Plate

6.3 The surface roughness (roughness average; refer to 1E2122) of each plate will be measured circumferentially in four places. The average roughness will be within the roughness range specified on the drawing. The side of the plate which is to be in contact with the friction disc will be marked with the average of the roughness measurements (microns) from that surface; the other side of the plate will be marked with the part number and the words: “Do Not Use This Side.” The markings on the plates will be of smear-resistant ink.

7.0 Preparation of Apparatus:

7.1 The system is drained and refilled with new oil for each test. If the oil is different than that used in the previous test, the drain and refill is done a second time after the new oil has been circulated through the system at a temperature of at least 60°C for at least 5 minutes. The machine is to be operating, disengaged, at about 15 m/s while the oil is circulating.

7.2 Filtration - A new filter element (Caterpillar 4T-6788) is to be installed whenever oil is added for a new test. If the oil is different than that used in the previous test, install a new filter only with the second refill.

7.3 Disc and Plate Installation

7.3.1 Friction Disc - Friction material bonded to both sides of a steel core, to be mounted on the flywheel with the test surface toward the steel plate.

7.3.2 Plate - Steel plate, to be mounted on the stationary member with the test surface toward the friction disc.

7.3.3 Clearance between disc and plate: 0.76±0.05 mm when retracted.

7.4 Selection and Definition of Sequences

7.4.1 Sequence no. SEQ1274 (To be used with 137-1274 group)

Twenty second cycle time: engaged 4.0 seconds, disengaged 16.0 seconds.

Phase No.	Phase Repetitions	Speed, m/s	Initial Unit Pressure, kPa	Plot Coefficient Averages and Save Torque Curves at These Cycles:
Initial Measurement for Wear Determination				
1	5	15	350	
2	5	15	1050	
3	100	15	1750	
Second Measurement for Wear Determination				
4	10	15	350	
5	10	15	700	
6	500	15	1050	Each 50th Cycle
Final Measurement for Wear Determination				
7	10	15	350	
8	10	15	700	
9	50	15	1050	
10	15	5	350	15
11	15	5	700	15
12	15	5	1050	15
13	15	5	1400	15
14	15	5	1750	15
15	15	15	350	15
16	15	15	700	15
17	15	15	1050	15
18	15	15	1400	15
19	15	15	1750	15
20	15	15	1050	15
21	15	17.5	1050	15
22	15	20	1050	15
23	15	21	1050	15
24	15	22	1050	15
25	15	23	1050	15
26	15	24	1050	15
27	15	25	1050	15
28	15	26	1050	15
29	15	27	1050	15
30	15	28	1050	15
31	15	29	1050	15
32	15	30	1050	15
33	15	31	1050	15
34	15	32	1050	15
35	15	33	1050	15
36	15	34	1050	15
37	15	35	1050	15
38	15	36	1050	15
39	15	37	1050	15

40	15	38	1050	15
41	15	39	1050	15
42	15	40	1050	15

Energy limit detection is based on a percentage change in μ_d compared to the average μ_d of the previous phase. In SEQ1274, a 12% change denotes failure.

If the energy limit is exceeded before the schedule is completed, the data from the final cycle will be saved and the run will be ended.

7.5 General Instructions

7.5.1 Each sequence is to proceed without delay between cycles except to measure disc thickness. That pause is part of the program. If any of the test or safety conditions are not met (such as: test oil flow too low, bearing temperature too high, desired speed or pressure not reached, etc.), the sequence will be stopped automatically. Except for the following two conditions, the sequence can be continued after the fault is corrected: any interruption of the cycle after the start of Phase 21 in SEQ 1274 will invalidate the run; any interruption of the cycle for more than ten minutes, or more than ten interruptions during a run, will invalidate the run.

7.5.2 Thickness measurements are to be made at six equally spaced locations at both ID and OD of the friction material. Mark position 1 on two teeth, count clockwise around the disc 10 teeth to position 2, then another 11 teeth to each of the remaining positions. The starting position can be at any location. The measurements to determine wear must be taken at the same locations on the disc. The disc is to be installed in the machine with position 1 at the marked drive pin.

7.6 Cooling Oil - Fill Requirement: 18.9±0.5 L
Flow rate: 3.78±0.06 L/min. (As indicated on the M1158 machine instrumentation)

7.6.1 Operating Temperature Range - Set point +3/ -10°C

7.6.1.1 The temperature setting will be 82°C for SEQ 1274.

8.0 Procedure

8.1 Perform the signal conditioner calibration check.

8.2 Perform the force output calibration.

8.3 Edit and select the test directory. Define new one if needed.

8.4 Select and edit the run subdirectory. Define new one if needed.

8.5 Select the sequence to be used.

8.6 Select the disc and plate to be used (specified when the sequence is selected).

8.7 Initiate the test sequence. The machine will control the initial speed, unit pressure and the number of repetitions of each phase.

8.8 Remove the disc and plate for inspection and measurement as required. Check the parts for warpage, measure the disc and reinstall it in the same location and with the same orientation.

8.9 Resume the test sequence. The machine will shut down at the end of the sequence, or earlier if the energy limit is exceeded.

8.10 Produce the printed reports and curves.

8.11 Transfer the test directory to floppy discs when all the runs in it have been completed.

9.0 Calculation and Interpretation of Results:

9.1 Equations and Constants

9.1.1 The average dynamic coefficient of friction is calculated by the M1158 machine from stop time, load and initial speed.

$$\mu_d = 2.44037S/Lt \qquad (1)$$

Where: μ_d = Average dynamic coefficient of friction
S = Surface speed at mean radius - m/s
L = Unit axial load on friction material - kPa
t = Stop time - s

9.1.2 The static coefficient of friction is calculated by the M1158 machine from torque measured at the instant that sliding velocity reaches zero.

$$\mu_s = 0.3121T/L \qquad (2)$$

Where: μ_s = Static coefficient of friction
L = Unit load on friction material - kPa
T = Lockup torque - N·m

9.1.3 In equations 1 and 2 the constants are based on:
Inertia = 1.003 $N \cdot m \cdot s^2$
Friction material area = 0.02499 m^2
Mean radius of friction material = 0.1283 m

9.1.4 Average thickness and wear values are calculated by the M1158 machine from disc measurements entered by the operator. The average thickness is the numerical average of the 12 thickness measurements; the wear is the change in average thickness.

9.2 Oil Requirements - Oils will be evaluated by comparing their performance under controlled conditions with the performance of a reference oil under nearly identical conditions. The controlled conditions include the test machine, test procedure, friction disc and reaction plate.

9.2.1 The friction discs and reaction plates will be supplied in 137-1271 oil test kits. Each kit will contain matched parts so that the performance of the candidate oil on a given machine can be compared directly with the performance of the reference oil (Caterpillar Multipurpose Tractor Oil, part no. 105-3334 in 55-gal. drums) on the same machine. The test sponsor will provide (at nominal cost) the reference fluid which will produce minimum acceptable performance. When the clutch groups in a given test kit have been depleted and a new kit is obtained, a new performance baseline with the new kit and the reference oil must be established.

9.2.2 A Link 1158 Oil/Friction Test Machine which has been qualified can be used for a reference test to establish a performance baseline for oil certification work with a set of friction discs and reaction plates from an oil test kit. The results of the reference test will

determine the performance limits for oil certification within that test kit. The M1158 software will read data from the reference test, calculate the values for the limit lines and save them as the limit files to be used with that specific oil test kit.

9.2.2.1 If any one of the baseline runs with the reference oil reaches its energy limit at a speed equal to or lower than that given in 9.2.4, that reference run is invalid and must be repeated.

9.2.2.2 Instructions for generating the limit files to be used with a specific kit are:

Before a 137-1271 Kit is used for certification testing of candidate oils, a reference test must be done using parts from the kit and a reference oil supplied by Caterpillar Inc. A SEQ1274 run will be made. At the completion of the run, the limit files are to be generated or updated as follows:

Go to the print report menu.

Select the reference test.

Select the limit file for the friction material.

Select the report format for that friction material.

Press F7 and "Enter". The limit file will be automatically updated using the factors defined in Figure 3. (These factors are stored as part of the software in limit generation reference files.) The update of the limit file will also put the run number of the reference run into the description of the limit file.

9.2.2.3 A lab can repeat any of the reference runs on another disc and plate from the kit if they desire, realizing that fewer complete sets will remain for testing of candidate oils. The final reference runs made will be used to establish the baseline.

9.2.3 An oil to be certified as a BF-2 oil must have performance characteristics relative to those of the reference oil, as defined in 9.3.5.

Run Sequence SEQ1274 with 137-1274 Clutch Group (118-7181 Disc and 1Y0726 Plate).

9.2.4 The energy limit must not occur at (during an engagement from) a speed lower than 28 m/s.

9.2.5 Total wear of the friction disc must not exceed 0.07 mm.

9.2.6 Successful completion means that for each sequence the coefficients stay above the specified minimum, the energy limit is at a speed at or above the minimum, and the total wear is less than or equal to the maximum allowable. If the first attempt in any run is unsuccessful, two succeeding successful completions of that run will meet the requirement.

9.2.7 Except as described in 9.3 (multiple run averaging), any one of the following conditions constitutes failure of a candidate oil:

-Any of the plotted points of static coefficient of friction fall below the low-limit lines on the coefficient plots.

-The "Wring-in Ratio" (defined as the ratio of the static coefficient of friction to the dynamic coefficient of friction, or μ_s/μ_d) exceeds 1.50 at a unit axial load of 1050 kPa.

-The energy limit, as determined by the limit detection option of the software, is reached and the sequence is stopped at a speed lower than that indicated by the vertical limit line on the coefficient vs speed plot.

-The disc wear is greater than the allowable maximum for any of the seven runs.

-The disc or plate becomes dished or warped at a speed less than the minimum acceptable energy limit even if the energy limit is not detected.

-The friction material is structurally damaged by erosion or chemical or mechanical forces during the test.

9.3 Multiple run averaging is allowed as follows for the values of friction coefficient:

9.3.1 If the static friction coefficient for any of the runs with a candidate oil are slightly below the low limit, or if the wring-in ratio is greater than 1.50, a second run with that material may be made and the average coefficient values of the two runs (calculated by the M1158 machine) may be plotted against the two-run limit -- which represents the same performance level as does the single run limit with a single run. The friction level of the oil with that material is considered passing if the plotted points are above the low limit and the wring-in ratio is 1.50 or lower.

9.3.2 If the averaged friction data of two runs of a given material with a candidate oil are slightly below the two-run limit, a third run with that material may be made and the average coefficient values of the three runs (calculated by the M1158 machine) may be plotted against the three-run limit -- which represents the same performance level as does the single run limit with a single run. The friction level of the oil with that material is considered passing if the plotted points are above the low limit and the wring-in ratio is 1.50 or lower.

9.3.3 Neither the values of energy limit, nor the speed at which warpage might occur, nor total wear are subject to multiple-run averaging.

9.3.4 The limit files and report format files identified in the following table are to be used in printing the respective test reports. The limit files are generated on command by the M1158 machine based on the performance of the reference runs.

		Limit Files			Report Formats	
Clutch Group	Sequence	1-Run	2-Run	3-Run	1-Run	Multiple
137-1274	SEQ1274	LIM1274	2LIM1274	3LIM1274	REP1274	MULT1274

9.3.5 The acceptability requirements (low limits) for the static coefficient of friction relative to the friction coefficients measured in the reference test are:

Single Run – 93.0% Two-Run Average – 91.0% Three-Run Average – 90.9%

9.4 Test Discontinuation

Any one of the following conditions, if the results are otherwise satisfactory and neither the friction disc nor the reaction plate show damage or warping, would constitute sufficient reason to abort a run without classifying it as a failure of the oil:

The machine is shut down because of low oil level. (The M1158 calls this a spurious fault, stops the run and turns off the circulating pump.)

The energy limit of the friction material is exceeded because a feedback or instrumentation problem causes the input force or input speed to be far greater than the desired amount.

The air supply fails, making it impossible to achieve the required pressures.

The drive motor does not achieve the required speeds.

10.0 Report:

10.1 All reference reports shall be submitted to the address given in the introduction.

10.2 Data presentation

10.2.1 Verification of calibration and setup will be included with each report (Plot type: 6, example in Figure 3).

10.2.2 Coefficient of friction will be plotted against no. of cycles, unit pressure and speed (Plot types 3, 1 and 2, examples in Figures 4, 5 and 6, respectively).

10.2.3 Torque vs time from each of the last 6 recorded cycles of the run will be plotted to show the changes which occurred at the energy limit. (Plot type 5, example in Figure 7).

10.2.4 Disc thickness measurements and average wear will be reported in tabular form (Example in Figure 4).

10.2.5 A print-out of the M1158·VAL file will be included with all reference reports. This can be done with the following command entered at the "c:" prompt:

Type "M1158.VAL>PRN".

10.2.6 The summary data file and the cycles recorded in full in all test sequences are to be retained on diskette by the testing lab for at least seven years for future reference.

11.0 Precision and Bias:

11.1 No statement is made about either the precision or bias of this method for measuring the frictional characteristics of a hydraulic oil, since the result merely states whether there is conformance to the criteria for success specified in the procedure.

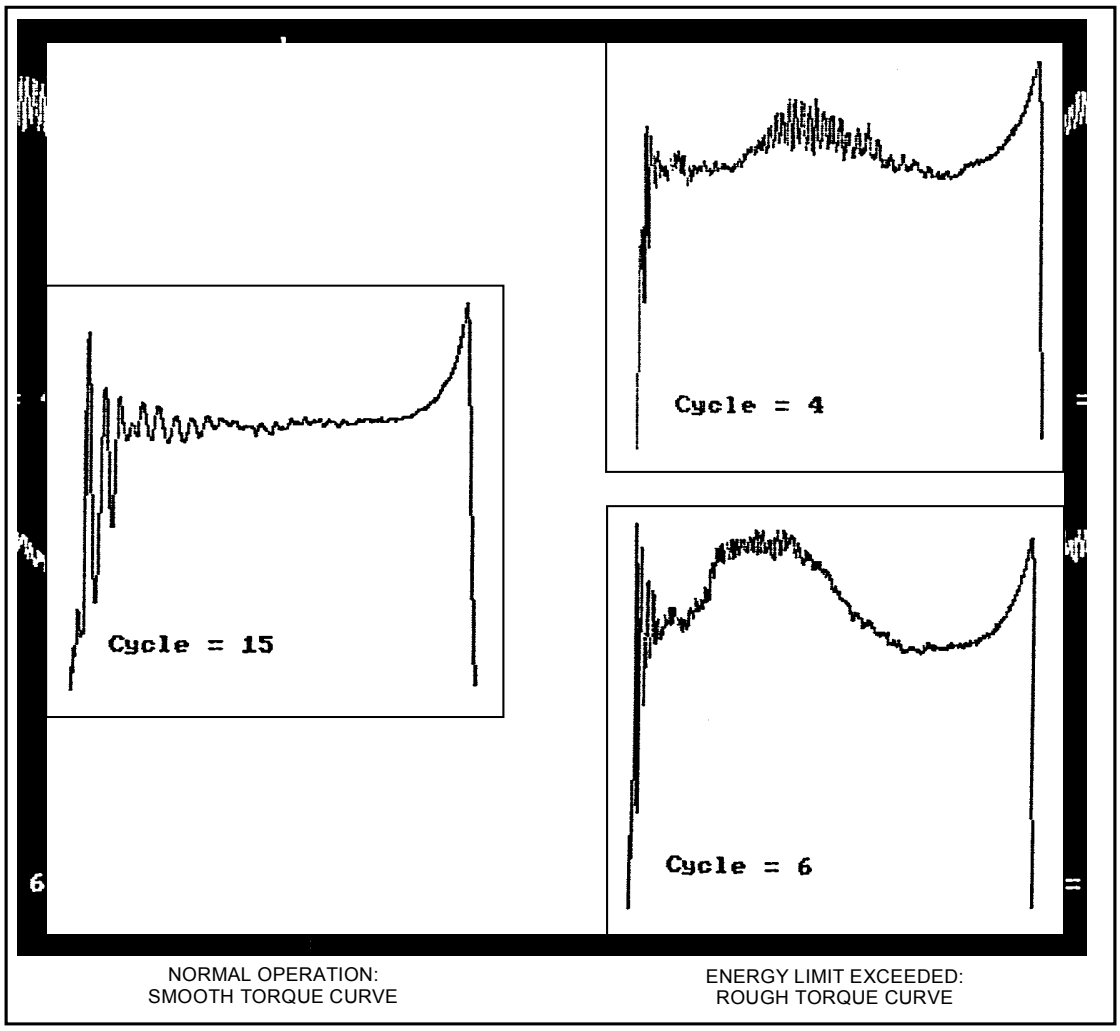


Figure 1 – Typical Torque Traces From the Link 1158 Oil/Friction Test Machine

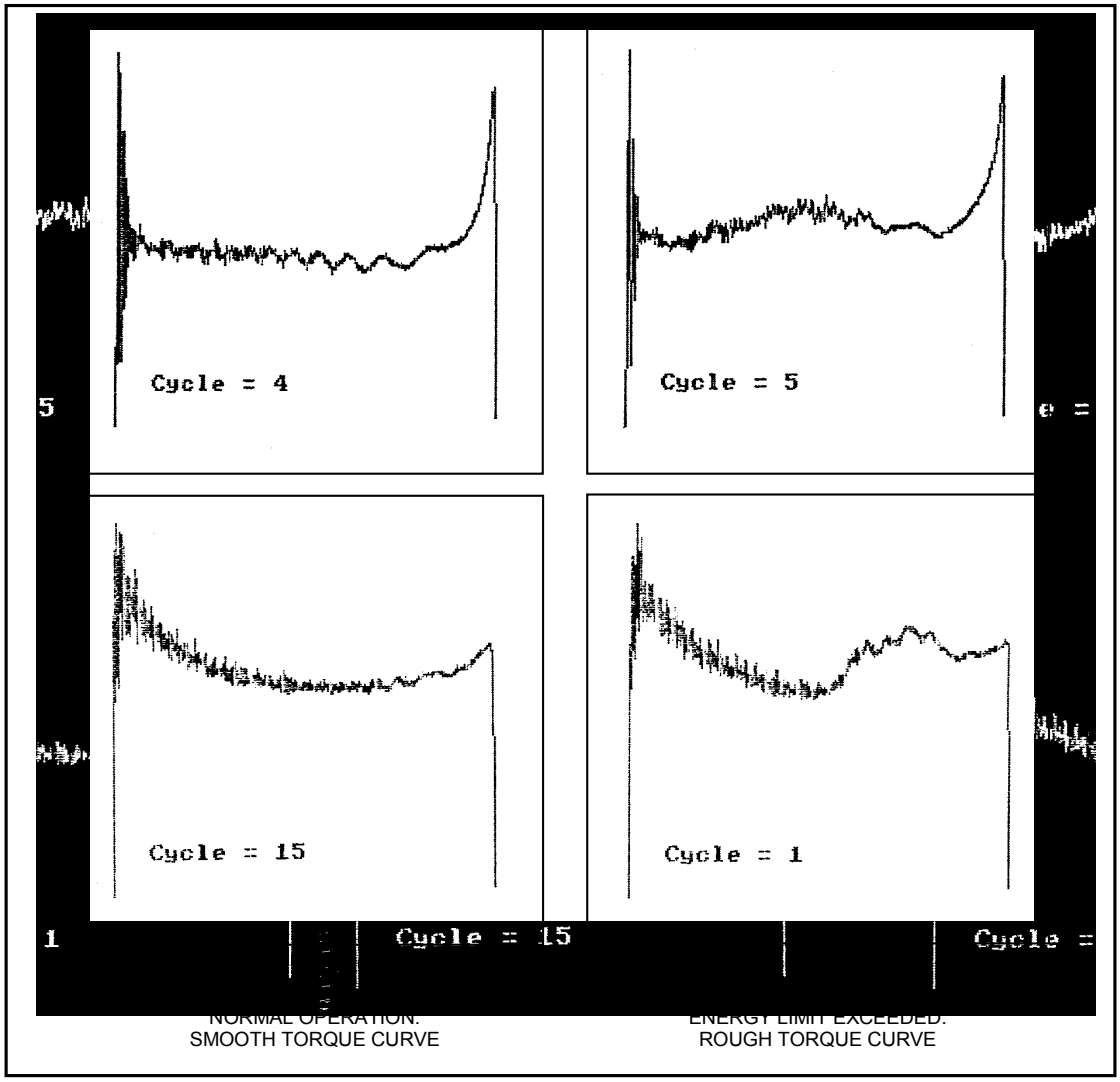
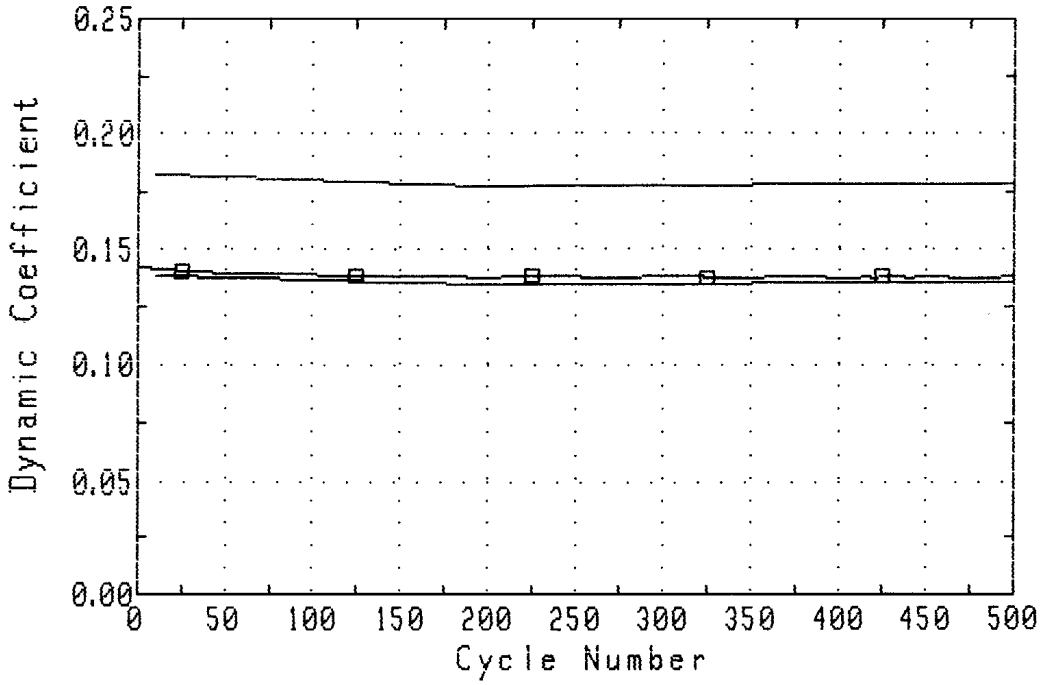


Figure 2 – Typical Torque Traces from the Link 1158 Oil/Friction Test Machine

XYZ Laboratories
BF-2 Certification of Oil Sample # 12345-C

Test Name:	12345C01
Test Date:	08/27/03
Test Description:	First Certification Test of 12345-C
Oil Type:	Hometown Oil Co.
Viscosity:	ISO VG 46
Miscellaneous:	----
Software Version:	1.2
Run Name & Desc:	N0690032 – 137-1274 Clutch Group
Run Date:	08/27/03
Oil Temperature:	82° C
Oil Flow Rate:	3.78 liter/minute
Operator:	SJones
Remarks:	----
Sequence Name:	SEQ1274
Remarks:	Use 118-7181 disc and 1Y0726 plate
Number Of Cycles Run:	1126
Machine:	N
Coast Down Check Run:	08/20/03
Result:	79.88 seconds
Inertia Check Run:	08/20/96
Result:	1.0239 N-m-s^2
Disc Name & Desc:	Brake Paper
Material:	Wellman Friction Products 266-4
Groove Pattern:	2-37 Multiple - Parallel
Miscellaneous:	Use with 1Y0726 steel plate
Outer Diameter (mm):	285.80
Inner Diameter (mm):	223.20
Mean Radius (mm):	128.21
Batch Number:	C592
Remarks:	----
Plate Name & Desc:	1Y0726 - steel plate
Surface:	0.70 To 1.00 micron roughness
Miscellaneous:	----
Batch Number:	----
Remarks:	0.76 micron measured roughness
Report Limit Name: Run: N0690018	LIM1274 - Reference
Limit File Generated:	08/06/03
Report Format Name:	REP1274 – Wheel Brake

Figure 3. Report Title Page - Example



118-7181
Disc Thickness

	Outer Diameter			Inner Diameter		
Location	M1	M2	M3	M1	M2	M3
1	4.90	4.87	4.87	4.90	4.88	4.87
2	4.90	4.87	4.86	4.91	4.87	4.86
3	4.91	4.88	4.87	4.91	4.88	4.87
4	4.90	4.87	4.87	4.90	4.87	4.87
5	4.89	4.87	4.86	4.90	4.87	4.87
6	4.90	4.87	4.87	4.91	4.87	4.87
Avg	4.90	4.87	4.87	4.91	4.87	4.87

Compression Set Average Wear: 0.030
M2-M3 Average Wear: 0.006
Total Wear (All measurements in mm): 0.036

Figure 4 -- Dynamic Coefficient vs Number of Cycles

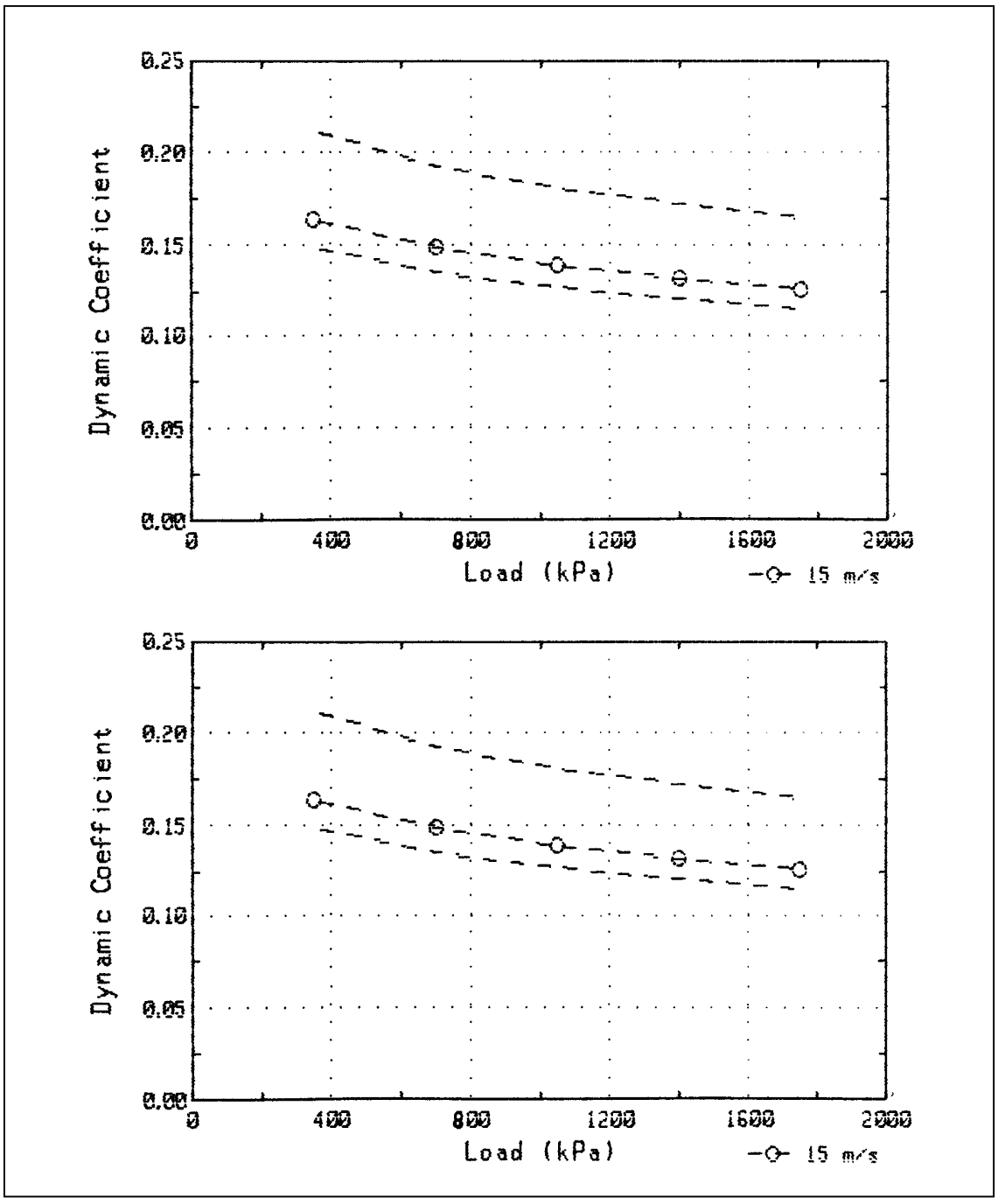


Figure 5 - Dynamic and Static Coefficients vs Unit Pressure

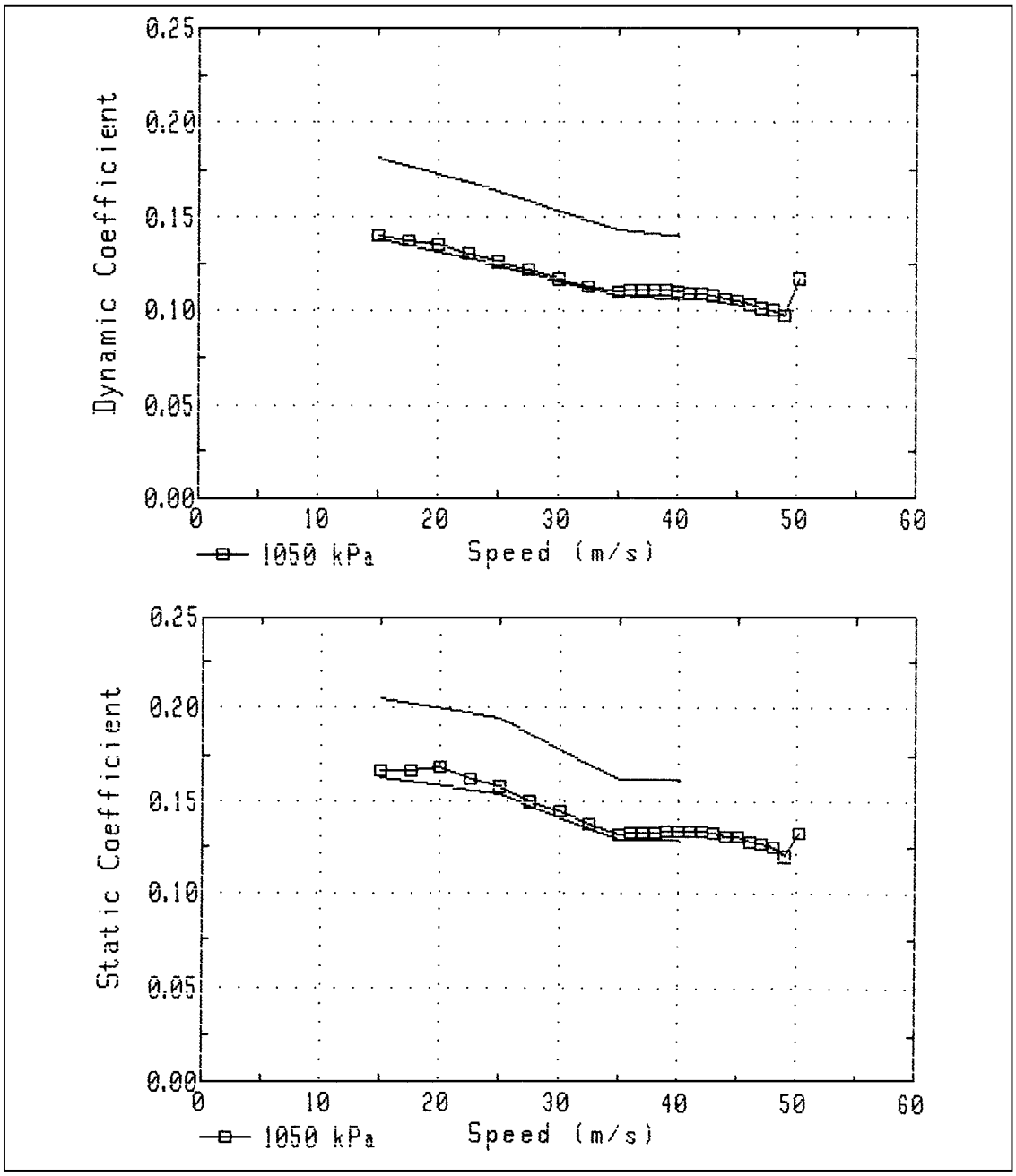


Figure 6 - Dynamic and Static Coefficients vs initial Speed

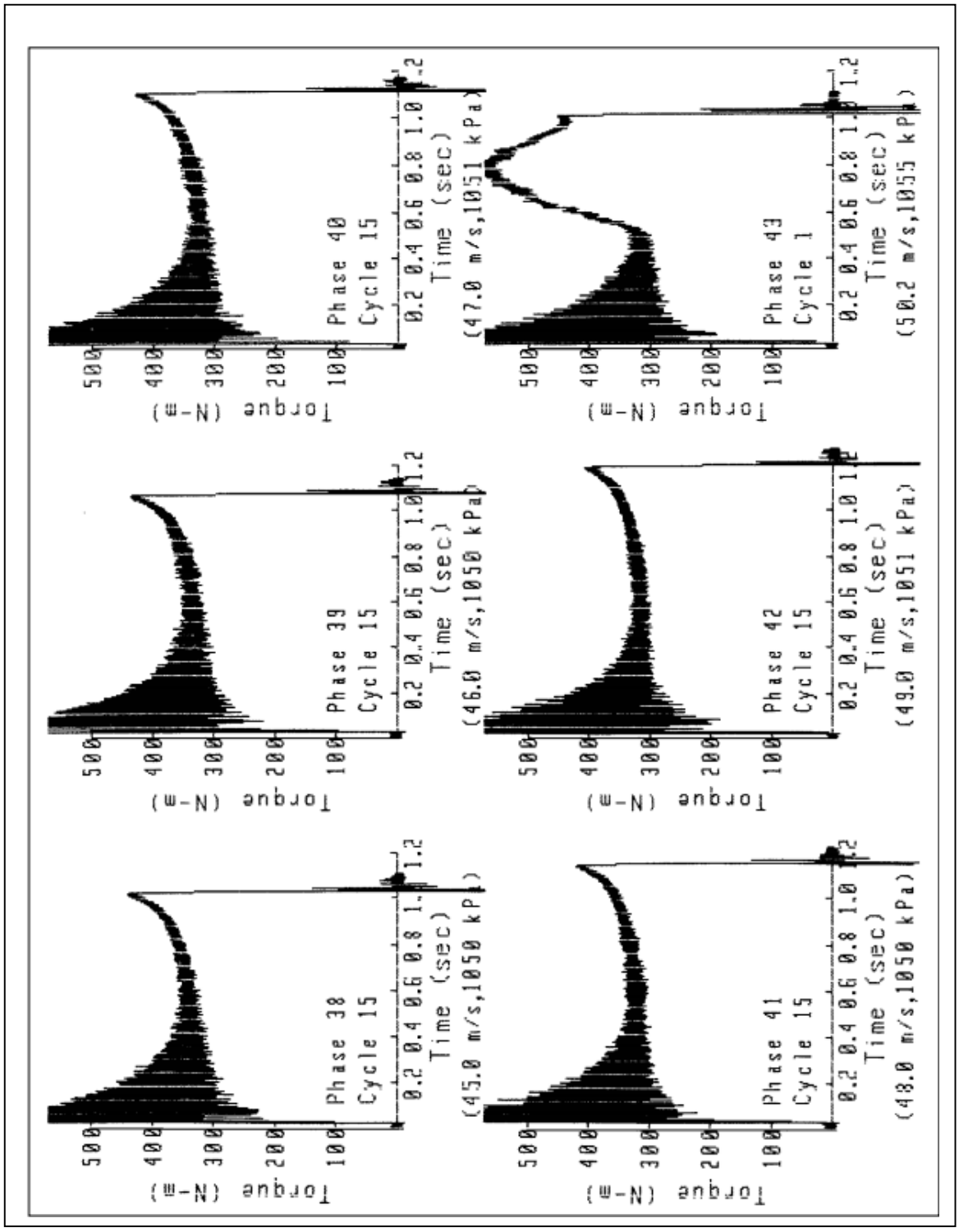


Figure 7 – Torque vs Time

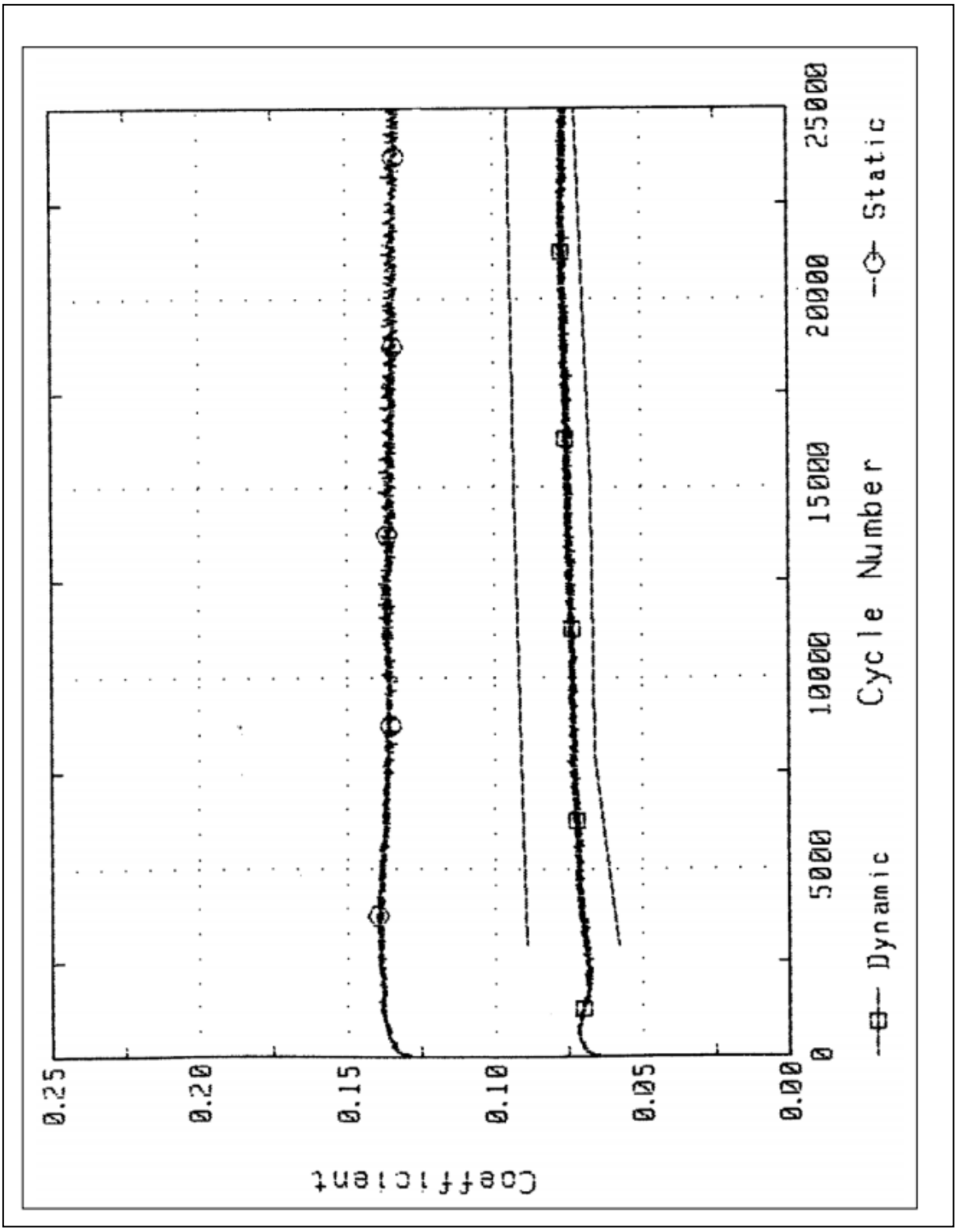


Figure 9 – Dynamic and Static Coefficient vs Number of Cycles

Sequence: SEQ1274 Desc: 137-1274 Group
Remarks: Use 118-7181 Disc and 1Y0726 Plate
Constant Factors:

Acceleration Time	- 8.00 s	Torque Threshold	- 50 N·m
Soak Time	- 4.00 s	Sample Rate	- 5000/s
Cycle Time	- 20.00 s	Cycle Type	- Normal

No.	Phase Name	Apply Speed	Cool. Speed	Load	No. of Cycles	Store Intv.	Det. Type	Pause	Allow. Var.
1	1WU05A15	15.00	4.00	350	5	0	0	N	0
2	1WU05C15	15.00	4.00	1050	5	0	0	N	0
3	1WU1CE15	15.00	4.00	1750	100	0	0	Y	0
4	2WU1XA15	15.00	4.00	350	10	0	0	N	0
5	2WU1XB15	15.00	4.00	700	10	0	0	N	0
6	WER5CC15	15.00	4.00	1050	500	50	0	Y	0
7	3WU1XA15	15.00	4.00	350	10	0	0	N	0
8	3WU1XB15	15.00	4.00	700	10	0	0	N	0
9	3WU5XC15	15.00	4.00	1050	50	0	0	N	0
10	PRT15A05	5.00	4.00	350	15	15	0	N	0
11	PRT15B05	5.00	4.00	700	15	15	3	N	12
12	PRT15C05	5.00	4.00	1050	15	15	3	N	12
13	PRT15D05	5.00	4.00	1400	15	15	3	N	12
14	PRT15E05	5.00	4.00	1750	15	15	3	N	12
15	PRT15A15	15.00	4.00	350	15	15	0	N	0
16	PRT15B15	15.00	4.00	700	15	15	3	N	12
17	PRT15C15	15.00	4.00	1050	15	15	3	N	12
18	PRT15D15	15.00	4.00	1400	15	15	3	N	12
19	PRT15E15	15.00	4.00	1750	15	15	3	N	12
20	ST15C150	15.00	4.00	1050	15	15	0	N	0
21	SS15C175	17.50	4.00	1050	15	15	3	N	12
22	SS15C200	20.00	4.00	1050	15	15	4	N	12
23	SS15C210	21.00	4.00	1050	15	15	4	N	12
24	SS15C220	22.00	4.00	1050	15	15	4	N	12
25	SS15C230	23.00	4.00	1050	15	15	4	N	12
26	SS15C240	24.00	4.00	1050	15	15	4	N	12

27	SS15C250	25.00	4.00	1050	15	15	4	N	12
28	SS15C260	26.00	4.00	1050	15	15	4	N	12
29	SS15C270	27.00	4.00	1050	15	15	4	N	12
30	SS15C280	28.00	4.00	1050	15	15	4	N	12
31	SS15C290	29.00	4.00	1050	15	15	4	N	12
32	SS15C300	30.00	4.00	1050	15	15	4	N	12
33	SS15C310	31.00	4.00	1050	15	15	4	N	12
34	SS15C320	32.00	4.00	1050	15	15	4	N	12
35	SS15C330	33.00	4.00	1050	15	15	4	N	12
36	SS15C340	34.00	4.00	1050	15	15	4	N	12
37	SS15C350	35.00	4.00	1050	15	15	4	N	12
38	SS15C360	36.00	4.00	1050	15	15	4	N	12
39	SS15C370	37.00	4.00	1050	15	15	4	N	12
40	SS15C380	38.00	4.00	1050	15	15	4	N	12
41	SS15C390	39.00	4.00	1050	15	15	4	N	12
42	SS15C400	40.00	4.00	1050	15	15	4	N	12

Annex II. Disc Files

Name: 118-7181 Description: Brake Paper
Groove Pattern: 2-37 Multiple Parallel
Miscellaneous: Use with 1Y0726 steel plate
Outer Diam (mm): 285.80
Inner Diam (mm): 223.20
Mean Radius (mm): 128.21

Annex III. Plate Files

Name: 1Y0726 Description
Surface: 0.30 micron maximum roughness
Misc.: Install the side marked with the average roughness toward the friction disc; the side marked “Do Not Use” toward the torque arm.

Annex IV. Report Format Files

Name: REP1274 Description: Brake Paper

Page	Plot Type	Phase Range 1	Phase Range 2
1	6	0 - 0	
2	3	6 - 6	
3	1	0 - 0	15 - 19
4	2		20 - 42
5	5		20 - 42

Annex V. Report Format Files

Name: MULT1274

Page	Plot Type	Phase Range 1	Phase Range 2
1	6	0 - 0	
2	3	6 - 6	
3	1	0 - 0	15 - 19
4	2		20 - 42