## INTRODUCTION

In 2007 Caterpillar Inc. (Cat) is introducing on-highway automatic transmissions. The new Cat "Automatic Transmission – 1" (AT-1) specification defines the requirements for fluids that are acceptable for use with extended fluid drain interval programs for Cat on-highway automatic transmissions.

### APPLICATION

Oils meeting Cat AT-1 specification are applicable to use in all Cat on-highway automatic transmissions. The Cat AT-1 specification is not the replacement or the equivalent of Cat TO-4 specification. Oils meeting Cat AT-1 specification can not be used in the applications where TO-4 fluids are recommended, and oils meeting Cat TO-4 specification can not be used in applications where Cat AT-1 fluids are recommended.

### OBJECTIVE

The requirements described herein communicate the minimum performance requirements for a lubricant that is intended for use in Cat on-highway automatic transmissions that are on the extended drain interval programs, and for wherever Cat AT-1 fluids are recommended.

### GENERAL DESCRIPTION

The Cat AT-1 requirements are divided into seven principal areas: 1) general requirements, 2) physical properties, 3) elastomer compatibility, 4) oxidation stability, 5) viscometrics, 6) wear properties, 7) friction material performance.

### NOTICE

1. This document contains all of the performance requirements that a finished lubricant must meet before the lubricant can legitimately be marketed as meeting the Cat AT-1 specification. Caterpillar Inc. will not monitor or verify the accuracy of claims or advertising suggesting compliance with Cat AT-1 specification made by other manufacturers or suppliers of fluids. Each supplier is responsible for the performance of their own product and the associated liabilities.

2. Refer to your specific operation manual for detailed application guidance

Caterpillar reserves the right to change this document without notice. The implementation date of this specification is February 1, 2007.

**SUMMARY AND TABLE OF CONTENTS**:

The following information is a summary of the performance requirements that define a fluid that meets the Caterpillar AT-1 transmission and drive train fluid requirements. Information regarding the appropriate test methods and the applicable limits for each can be found in the referenced section.

## GENERAL REQUIREMENTS

In order to be marketed as meeting the Cat AT-1 specification, the automatic transmission fluid must meet the criteria listed in sections 2 through 7 of the Cat AT-1 specification and in addition hold a license of one of the following industry specifications:

1) Ford MERCON®
2) GM DEXRON® III revision H
3) Transmission Engineering Specification TES-389 by Allison Transmission

## HOMOGENEITY

### 1. Scope:

This method will be used to evaluate the compatibility of additives with the oil base stock of the Cat AT-1 candidate fluid.

### 2. Test Procedure:

Place a 35 ml sample of the test fluid into a 50 mL centrifuge tube. Stopper the sample and hold the sample at –32°C for a minimum of 24 hours. Allow the sample to reach room temperature and then centrifuge for 30 minutes at 6000 g. Examine the tube containing the test sample for sedimentation or separation of insoluble material.

### 3. Acceptance Limits:

No sedimentation, precipitation or separation of insoluble material is allowed.

# FLASH AND FIRE POINTS

## 1. Scope:

This test method will be used to evaluate the flash and fire points of Cat AT-1 candidate fluid.

## 2. Test Procedure:

Fire point ASTM D92, Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester.

Flash point - ASTM D93, Standard Test Method for Flash Point by Pensky-Martens Closed Cup Tester.

## 3. Acceptance Limits:

ASTM D92: 230$^{o}$C min

ASTM D93: 250$^{o}$C min

## WATER CONTENT

### 1. Scope:

This test method will be used to determine the amount of water in the Cat AT-1 candidate fluid.

### 2. Test Procedure:

The ASTM D6304 Standard Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fisher Titration.

### 3. Acceptance Limits:

The water content as measured by ASTM D6304 must not exceed 0.1 volume percent.

# ELASTOMER COMPATIBILITY

## 1.0 Scope

To measure the compatibility of the candidate fluid with elastomeric materials typically used Caterpillar Inc. on-highway automatic transmissions.

## 2.0 Test Methods

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 table below. Table shall include numeric values and Pass / Fail summary for each characteristic. Report shall also include rubber material batch and/or lot #.

## 3.0 Acceptance Limits

| Duration (hours) | Material | Caterpillar Material Specification | Candidate Fluid Temperature (°C) | Hardness Change (pts) | | Tensile Strength Change (%) | Elongation Change (%) | Volume Change (%) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | MAX | MAX | MAX | MIN | MAX |
| 70 | **NBR** | 1E0741 | 120 | -10 | 0 | -10 | -10 | 0 | 5 |
| 70 | **FKM** | 1E0944 | 150 | -5 | 5 | -10 | -30 | 0 | 5 |
| 70 | **FKM** | 1E1039B | 150 | -5 | 0 | -15 | -25 | 0 | 5 |
| 70 | **AEM** | 1E1798A | 150 | -15 | 0 | -5 | -10 | 0 | 20 |
| 70 | **HNBR** | 1E2719A | 120 | -5 | 5 | -5 | -5 | 0 | 5 |
| 70 | **FKM** | 1E2865A | 150 | -5 | 5 | -20 | -20 | 0 | 5 |

| Duration (hours) | Material | Caterpillar Material Specification | Candidate Fluid Temperature (°C) | Hardness Change (pts) | | Tensile Strength Change (%) | Elongation Change (%) | Volume Change (%) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | MAX | MAX | MAX | MIN | MAX |
| 168 | **NBR** | 1E0741 | 120 | -10 | 0 | -10 | -15 | 0 | 5 |
| 168 | **FKM** | 1E0944 | 150 | -5 | 5 | -10 | -40 | 0 | 5 |
| 168 | **FKM** | 1E1039B | 150 | -5 | 0 | -30 | -30 | 0 | 5 |
| 168 | **AEM** | 1E1798A | 150 | -15 | 0 | -5 | -20 | 0 | 20 |
| 168 | **HNBR** | 1E2719A | 120 | -5 | 5 | -10 | -10 | 0 | 5 |
| 168 | **FKM** | 1E2865A | 150 | -5 | 5 | -30 | -30 | 0 | 5 |

## 4.0 Test Laboratory Requirements

The test lab must have the following minimum certifications:

American Association for Laboratory Accreditation (A2LA) accredited for Mechanical and Chemical Testing.

# OXIDATION STABILITY

## 1. Scope:

This test method will be used to evaluate the thermal oxidation stability of the Cat AT-1 candidate fluid.

## 2. Test Procedure:

ABOT (Same as MERCON®)
Cycling Test (Same as Appendix F, 4L60 in DEXRON® III, Revision H)

## 3. Acceptance Limits:

| | |
|---|---|
| ABOT: | 1) Delta IR less than 5.0<br>2) Delta TAN: less than 1.0 |
| Cycling Test: | 1) TAN Increase less than 0.5<br>2) Carbonyl Absorbance increase less than 0.1 |

# VISCOMETRIC PROPERTIES

## 1. Scope:

This test method will be used to evaluate the ability of Cat AT-1 fluids to provide acceptable viscometric properties in cold and hot ambient conditions when used in Cat on-highway automatic transmissions.

## 2. Test Procedures:

2.1 ASTM D445-06 Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity).

2.2 ASTM D2983-04a Standard Test Method for Low-Temperature Viscosity of Lubricants Measured by Brookfield Viscometer.

2.3 ASTM D4683-04 Standard Test Method for Measuring Viscosity at High Shear Rate and High Temperature by Tapered Bearing Simulator.

## 3. Acceptance Limits:

| Test Method | Test Temperature | Description | Acceptance Limits |
|---|---|---|---|
| D445 | 100$^{o}$C | Kinematic Viscosity | 7.0 cSt Minimum |
| D2983 | -40 $^{o}$C | Brookfield Viscosity, | 8,700 cP maximum |
| D4683 | 150 $^{o}$C | HTHS | 2.4 $10^{6}$ $s^{-1}$ minimum |
| CEC L-45 | 100 $^{o}$C | KRL Shear stability, 40h at 100$^{o}$C | Viscosity loss not more than 5% (Kinematic viscosity measured at 100$^{o}$C with ASTM D445) |

# WEAR PROPERTIES

## 1.0 Scope:

This test method will be used to evaluate the scuffing load capacity of Cat AT-1 fluids.

## 2.0 Test Procedure:

ASTM D5182, Standard Test Method for Evaluating the Scuffing Load Capacity of Oils (FZG Visual Method),1450RPM, 8.3 m/s, 90C temp.

## 4.0 Acceptance Limits:

Fail Stage 11

## Friction Properties

### Introduction

In addition to being licensed as a Ford MERCON®, GM DEXRON®-III(H) or an Allison TES-389 fluid, the test fluid must perform satisfactorily in the friction test described in this section.

The test described herein requires running the test fluid and a reference fluid with each of two friction materials on a qualified LINK M1158 Oil / Friction Test Machine. The results from the reference and test runs are to be reported and plotted in standard LINK M1158 report format, with the exception that friction coefficient limits for AT-1 fluid are defined for both friction materials only at 25 m/s and 1050 kPa.

The test will be used to evaluate the ability of an automatic transmission fluid to provide acceptable friction performance characteristics when used in various oil-cooled friction mechanisms in Caterpillar transmissions or wherever AT-1 fluid is specified for service fill.

Any question pertinent to the test method shall be directed to:

Cat AT-1 Oil/Friction Test
Caterpillar Inc., Component and Systems Development Division
Technical Center

(For First Class Mail:)
P. O. Box 1875
Peoria, IL 61656-1875
Phone (309) 578-8309 or 578-9229

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   - 3.3 Characteristics Measured
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4. Significance and Use
   - 4.1 Measures Frictional Characteristics
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   - 6.4 Special Micrometer for Thickness Measurements
7. Preparation of Apparatus
   - 7.1 Drain and Refill
   - 7.2 Filtration

## 1.0 Scope:

**1.1** This procedure defines the test method for partial evaluation of the lubrication and frictional performance characteristics of automatic transmission fluid used in Caterpillar transmissions calling for Caterpillar AT-1 automatic transmission fluid.

**1.2** This procedure defines frictional measurements and related acceptance criteria required for designation as an AT-1 fluid.

**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, $\mu_d$ -- 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, $\mu_s$ -- 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 $\mu_d$ (average dynamic coefficient of friction) during the phases after phase 20. The $\mu_d$ of each cycle will be compared with the mean $\mu_d$ 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 machine; next four digits - month and year of last machine qualification; last three digits - number of runs since last qualification

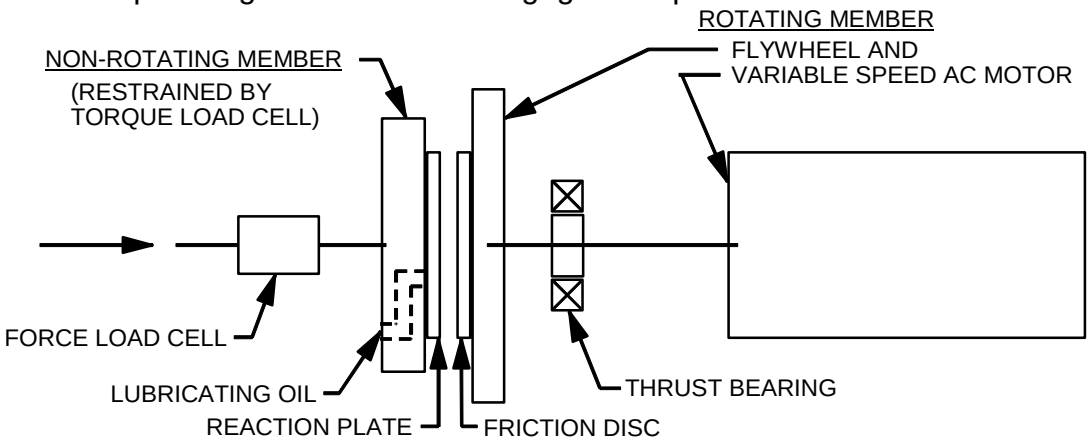
EXAMPLE: B0589023

- 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 rotating 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
- Wring-in coefficient ratio
- Energy Capability
- Wear Resistance

**3.3** The friction test described in this section must be performed on a qualified LINK M1158 Oil / Friction Test Machine. Southwest Research Institute and The Lubrizol Corporation both maintain qualified test stands.

**3.4** Materials Used

**3.4.1** A complete test consumes the following materials

- 2 X Friction Disc 101-8535
- 2 X Friction Disc 190-3534
- 4 X Plate 1Y0726
- 4 X filter element 8J1600
- 30 gallons Caterpillar ATF Reference Fluid CT5797
- 30 gallons Test fluid

**3.4.2** Because of the restrictions on the material in each kit, all performance comparisons for evaluating a test fluid 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, wring-in friction coefficient ratios, 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 fluids.

**4.2** The results of a test on the M1158 machine, if they are within the allowed ranges of variation from the reference fluid test made from the same part number friction disc and reaction plate, are necessary designate a test fluid as an AT-1 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 - 8J1600 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 LINK 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 are supplied by Wellman Friction Products, and the reaction plates by Raybestos Products Company. The parts are available through the Caterpillar parts distribution system.

**6.2.1** The friction material is identified by manufacturing lot. The reaction plates are closely controlled for surface finish and both parts are certified for performance by Caterpillar Inc.

**6.2.2** Only the following combinations of friction disc and reaction plate are to be used: 101-726 Friction Disc (high-energy paper) with 1Y0726 Plate, and 190-3534 Friction Disc (extended-life friction material) with 1Y0726 Plate.

**6.3** The surface roughness (roughness average; refer to 1E2122) of each plate will be measured circumferentially by the supplier 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.

**6.4** Thickness measurements of the disc and plate are to be taken with a micrometer which has a spindle and anvil with contact faces approximately 19.0 mm diameter.

## 7.0 Preparation of Apparatus:

**7.1** The system is drained and refilled with new oil for each test. If the oil is different from 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 8J1600) 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. SEQ1275 (to be used for both reference and test fluid).

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 $\mu_d$ compared to the average $\mu_d$ of the previous phase. In SEQ1275, 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.

**7.4.2** Sequence no. SEQ1276 (to be used for both reference and test fluid).

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 $\mu_d$ compared to the average $\mu_d$ of the previous phase. In SEQ1276, 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 fluid 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 either SEQ1275 or SEQ1276 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 SEQ1275 and SEQ1276.

## 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.

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

Where: $\mu_d$ = 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.

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

Where: $\mu_s$ = 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 - Fluids will be evaluated by comparing their performance under controlled conditions with the performance of a reference fluid 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 sets of matched parts so that the performance of the test fluid on a given machine can be compared directly with the performance of the reference fluid (CT5797) on the same machine. The test sponsor will provide (at nominal cost) the reference fluid. When the discs and plates in a given set have been depleted and a new set is obtained, a new performance baseline with the new set and the reference fluid must be established.

**9.2.2** A qualified LINK 1158 Oil/Friction Test Machine can be used for a reference test to establish a performance baseline for fluid certification work with a set of friction discs and reaction plates from an oil test set. The results of the reference test will determine the static friction coefficient limits for oil certification within that test kit. The M1158 software will read data from the reference test, calculate the values for the limits 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 fluid 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 reference runs to be used are:

Before a set of discs and plates is used for certification testing of candidate fluids, reference tests must be done using the set parts and a reference fluid specified or supplied by Caterpillar Inc. A SEQ1275 and a SEQ1276 run will be made. At the completion of the reference runs, the reference files are to be generated or updated as follows:

Go to the print report menu.

Select the reference test

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.

**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 fluids. The final reference runs made will be used to establish the baseline.

**9.2.3** An oil to be certified as an AT-1 oil must have performance characteristics defined in 9.3.5.

**9.2.4** The energy limit must not occur at (during an engagement from) a speed lower than 30 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 (two-run averaging), any one of the following conditions constitutes failure of a candidate oil:

-The "Wring-in Ratio" (defined as the ratio of the static coefficient of friction to the dynamic coefficient of friction, or $\mu_s/\mu_d$) exceeds 1.50 for SEQ1275 or 1.25 for SEQ1276 at a speed of 25 m/s and 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 either run.

-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** Two-run averaging is allowed as follows for the values of friction coefficient:

**9.3.1** If the static friction coefficient at 25 m/s and 1050 kPa for either run is slightly below the low limit based on the reference fluid, or if the wring-in ratio at 25 m/s and 1050 kPa is greater than allowed, a second run with that material may be made and the average coefficient values of the two runs reported. The friction level of the oil with that material is considered passing if the averaged values lie within the given limits. Neither the static friction coefficient limit nor the wring-in coefficient ratio limit will be adjusted from the single-run value.

**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 report format files identified in the following table are to be used in printing the respective test reports. LINK M1158 limit files will not be used, but a 1-Run report in the format below is to be generated for each reference-oil run and each test-oil run.

| | Limit Files | | Report Formats |
|---|---|---|---|
| Sequence | 1-Run | 2-Run | 1-Run |
| SEQ1275 | LIM1275 | LIM1275 | REP1275 |
| SEQ1276 | LIM1276 | LIM1276 | REP1276 |

**9.3.5** For both SEQ1275 and SEQ1276, the minimum acceptable static friction coefficients for the test fluid at 25 m/s and 1050 kPa are, for either a single run or a two-run average, 85% of the corresponding coefficients measured for the reference fluid.

**9.3.6** The maximum acceptable wring-in ratios at 25 m/s and 1050 kPa are, for either a single run or a two-run average, 1.50 for SEQ1275 and 1.25 for SEQ1276.

**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.

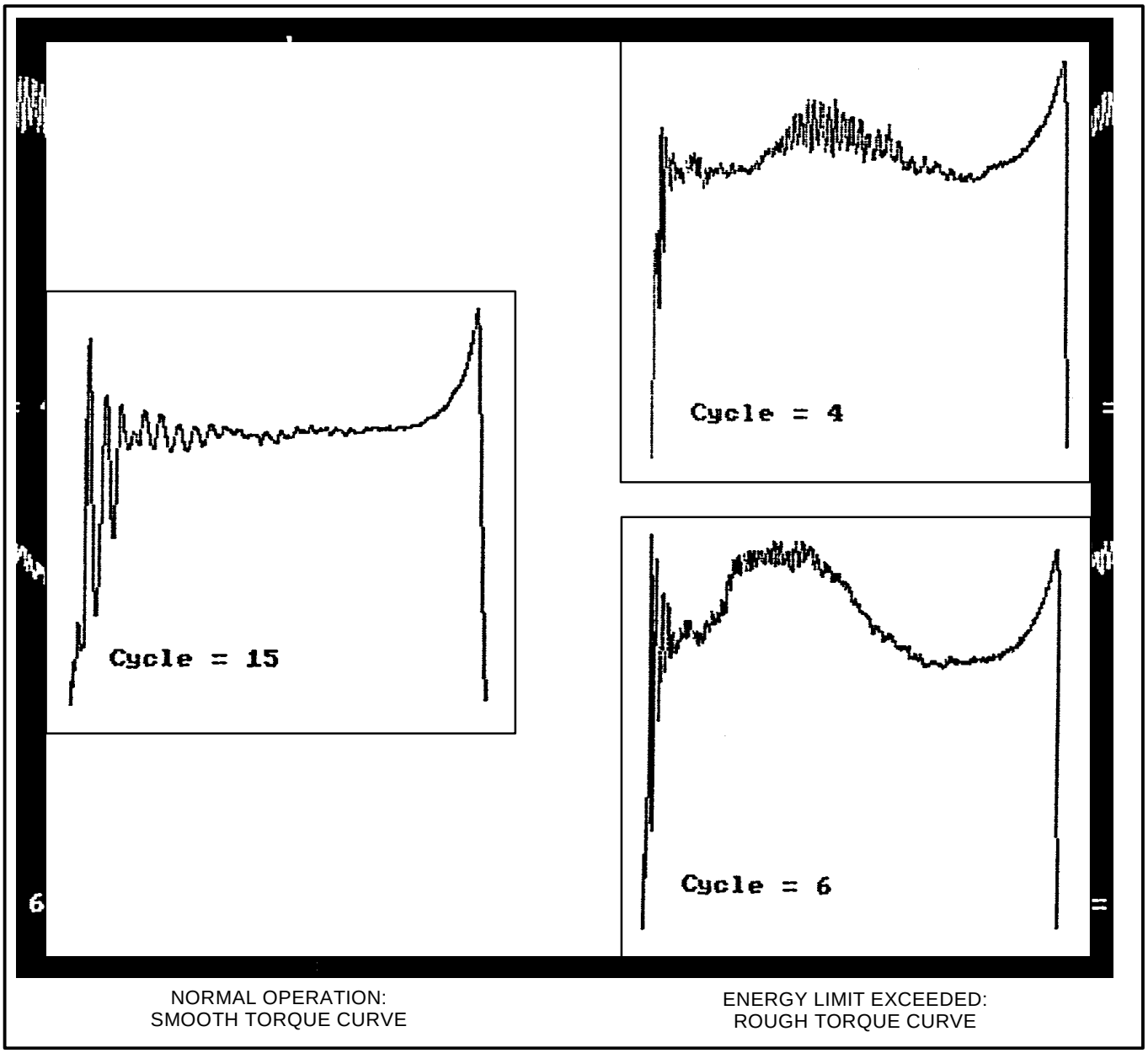



Figure 1 – Typical Torque Traces From the Link 1158 Oil/Friction Test Machine

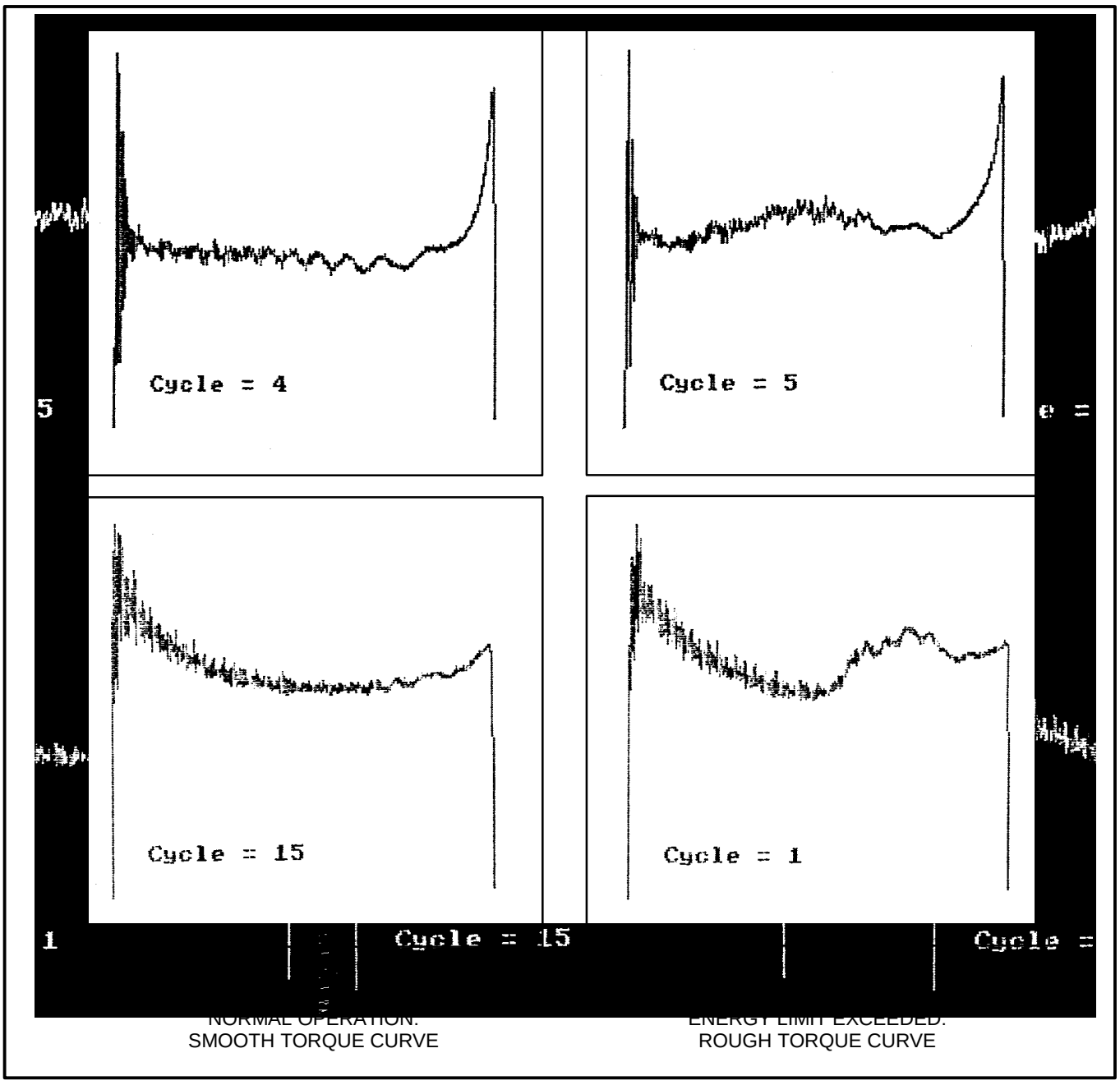



Figure 2 – Typical Torque Traces from the Link 1158 Oil/Friction Test Machine

XYZ Laboratories
AT-1 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: | ATF |
| Miscellaneous: | ---- |
| Software Version: | 1.2 |
| | |
| Run Name & Desc: | N0690032 |
| Run Date: | 08/27/03 |
| Oil Temperature: | 82° C |
| Oil Flow Rate: | 3.78 liter/minute |
| Operator: | SJones |
| Remarks: | ---- |
| Sequence Name: | SEQ1275 |
| Remarks: | Use 101-8535 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: | High-energy Paper |
| Material: | Wellman Friction Products 401-3.5 |
| 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: | LIM1275 - Reference Run: N0690018 |
| Limit File Generated: | 08/06/03 |
| Report Format Name: | REP1275 – High-Energy Paper |

Figure 3. Report Title Page - Example

101-8535
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

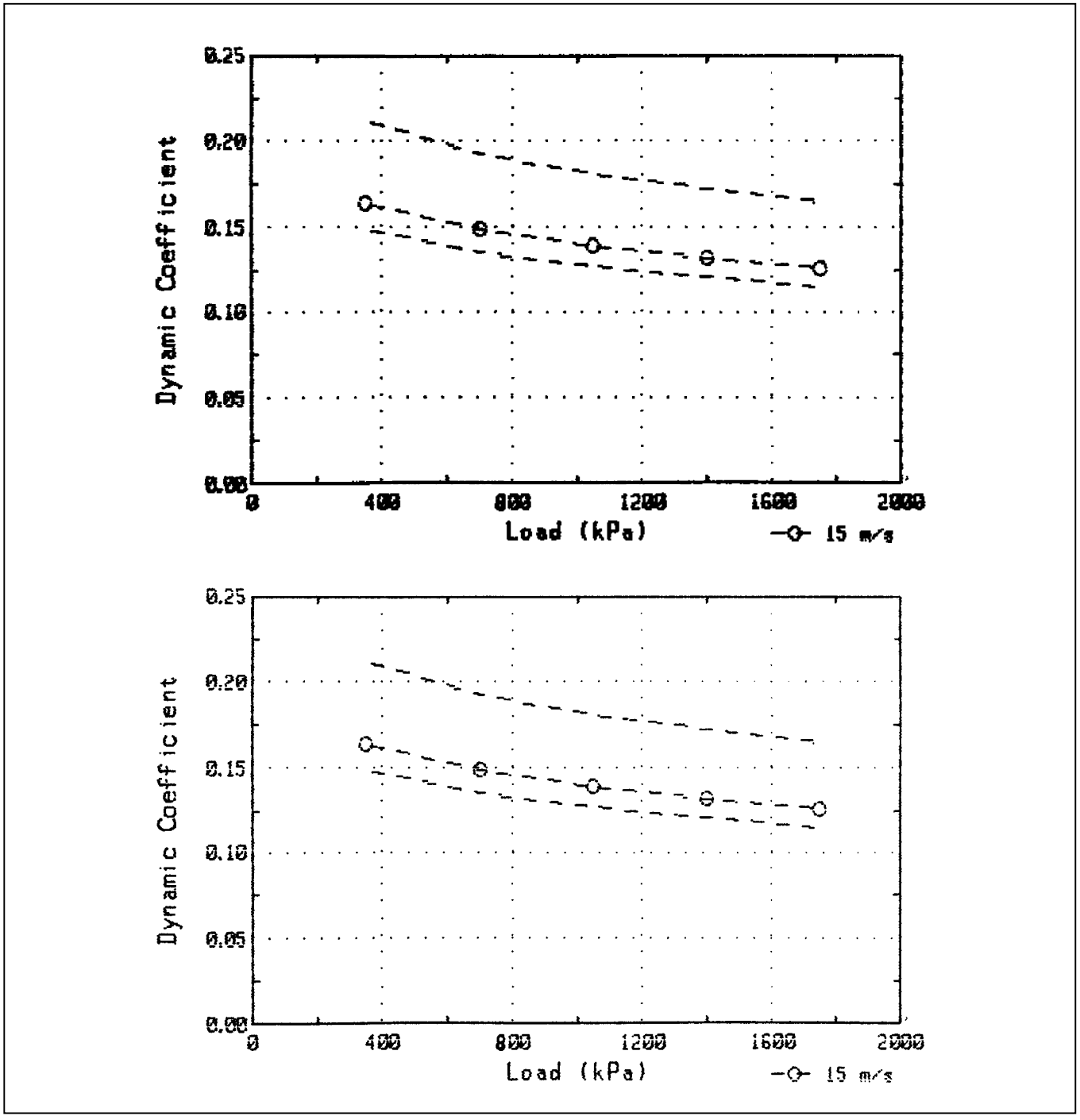



Figure 5 - Dynamic and Static Coefficients vs Unit Pressure

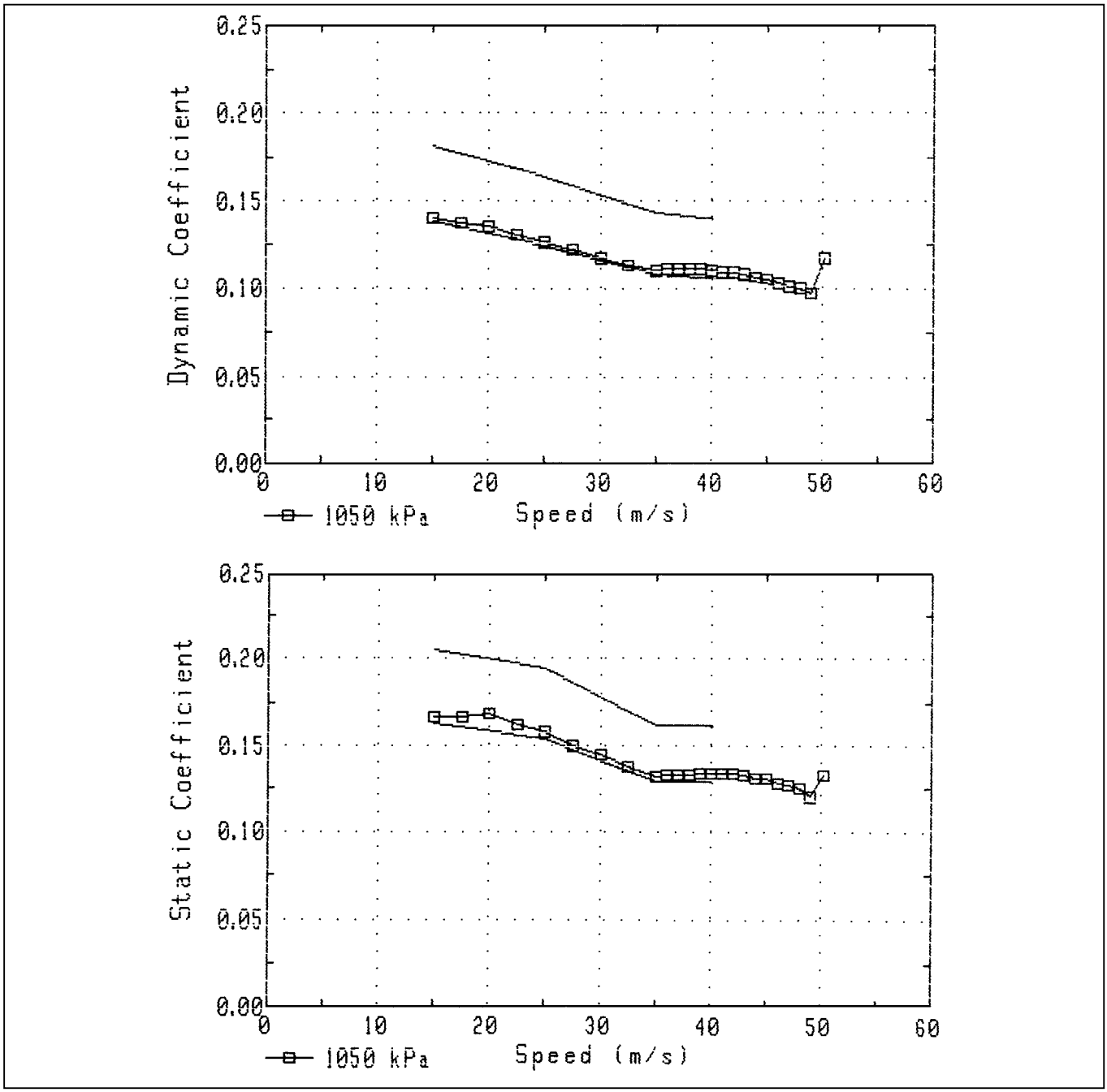



Figure 6 - Dynamic and Static Coefficients vs initial Speed

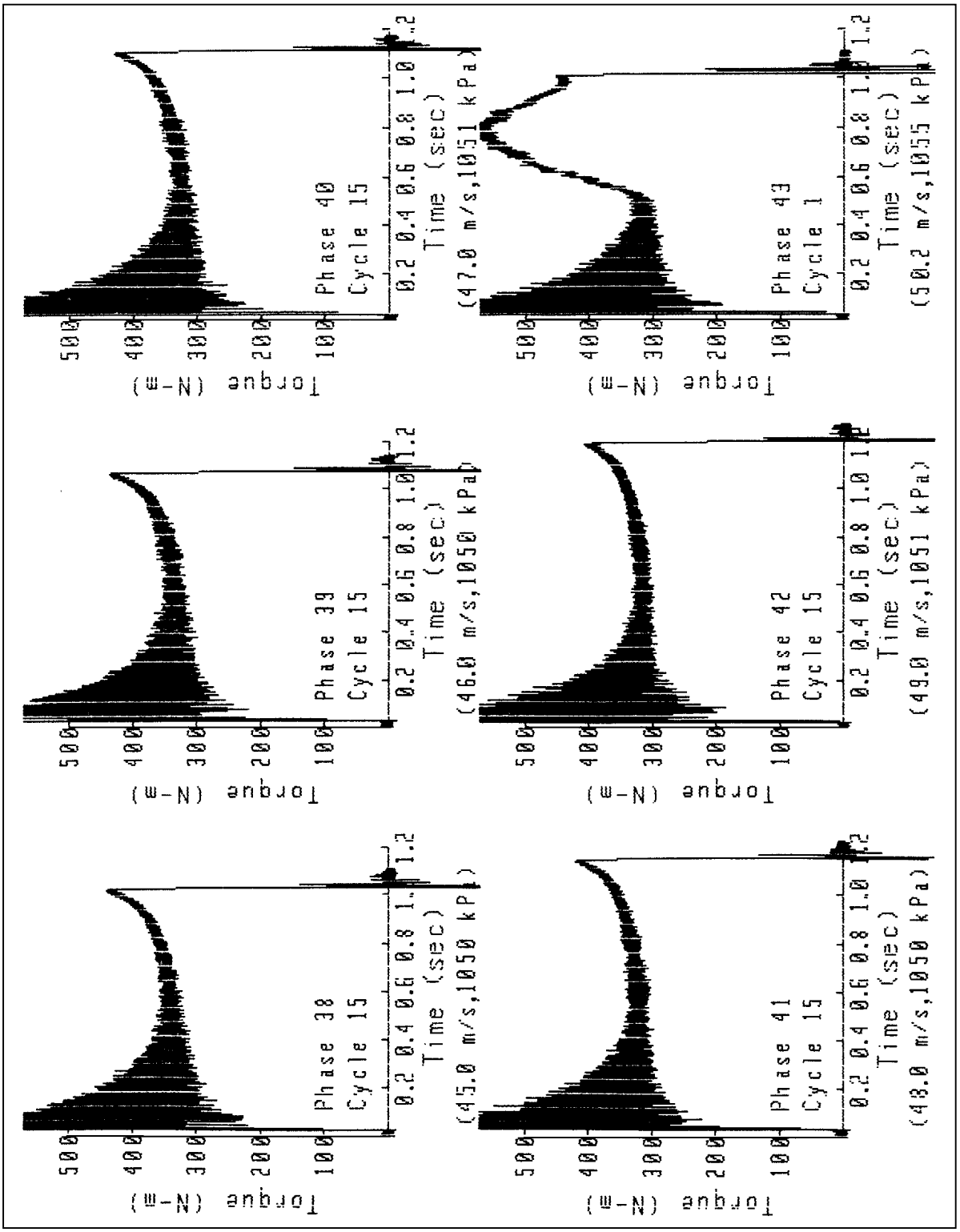



FIGURE 7 – TORQUE VS TIME

## Annex I. Sequence Definitions

Sequence: SEQ1275
Remarks: Use 101-8535 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 I, cont'd. Sequence Definitions

Sequence: SEQ1276
Remarks: Use 190-3534 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 File

| | |
|---|---|
| Name: 101-8535 | Description: High-Energy Paper |
| Material: | Wellman Friction Products 401-3.5 |
| 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 |

| | |
|---|---|
| Name: 190-3534 | Description: Extended-Life Friction Material |
| Material: | Wellman Friction Products 653-4 |
| 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 File

| | |
|---|---|
| Name: 1Y0726 | Description (used with both SEQ1275 and SEQ1276) |
| 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: REP1275 Description: High-Energy Paper

| | | | |
|---|---|---|---|
| 1 | 6 | 0 - 0 | |
| 2 | 3 | 6 - 6 | |
| 3 | 1 | 0 - 0 | 15 - 19 |
| 4 | 2 | 20 - 42 | |
| 5 | 5 | 20 - 42 | |

Name: REP1276 Description: Extended-Life Friction Material

| | | | |
|---|---|---|---|
| 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

| Page | Plot Type | Phase Range 1 | Phase Range 2 |
|---|---|---|---|
| Name: MULT1275 | | | |
| 1 | 6 | 0 - 0 | |
| 2 | 3 | 6 - 6 | |
| 3 | 1 | 0 - 0 | 15 - 19 |
| 4 | 2 | 20 - 42 | |
| Name: MULT1276 | | | |
| 1 | 6 | 0 - 0 | |
| 2 | 3 | 6 - 6 | |
| 3 | 1 | 0 - 0 | 15 - 19 |
| 4 | 2 | 20 - 42 | |