3/20
MC 2020314

WILLIAM S. AYER
PRESIDENT AND CHIEF EXECUTIVE OFFICER

March 18, 2002

Hand Delivered and
***Certified Mail** (without enclosures)*
Return Receipt Requested

Ms. Marion Blakey
Chairman
National Transportation Safety Board
490 L'Enfant Plaza East, SW
Washington, D.C. 20594

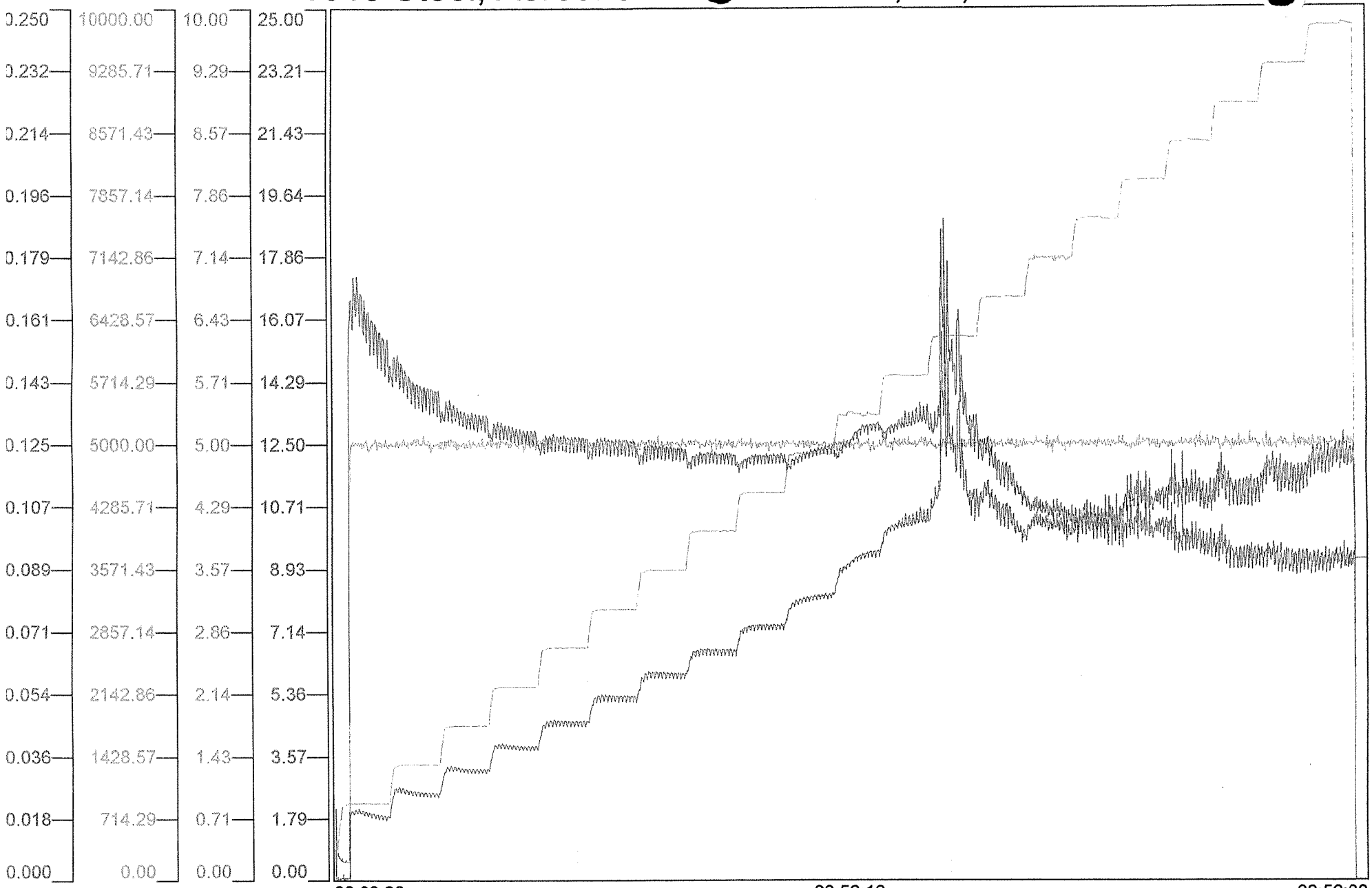
Dear Chairman Blakey:

Thank you for your letter of January 23, 2002, concerning the NTSB's ongoing investigation into the potential role of grease in the tragic accident of Alaska Airlines' Flight 261. Your letter was very helpful to us in assessing the status of the NTSB's investigation on the subject. Frankly, the letter represents the most comprehensive analysis and report that anyone at Alaska has seen to date.

I want you to know that I am greatly encouraged by the open style of communication that it represents. While we all may or may not agree on procedures or protocols, or even conclusions of the investigators, I believe it is critically important that we emphasize communication and information sharing among all of the parties to the investigation.

For my part, I have shared your letter with Captain Terry Clark, Alaska Airlines' Party Coordinator, for his review and comments. More importantly, however, I have determined that this type of open communication warrants extraordinary measures by Alaska Airlines in response. I passed your letter along to a broad cross section of Alaska's employees and consultants, including our representatives in the civil litigation arising out of Flight 261. This was done to ensure that anyone with knowledge or information on this subject had an opportunity to comment. I instructed these people to review all of the information on this subject that has been developed to date by Alaska and to share it with your office. Enclosed with this letter, you will find an Executive Summary of the Grease and Wear Testing that has been performed by our consultants as well as the full report(s) of the test results.

1018 Steel, Aeroshell 33 Weathered, HL, run 2



Description	Batch Name	Scale Range	Eng. Units	00:56:30
COEFFICIENT OF FRICTION	dgstlthrw6	0.000/0.250	Coef	***
SPECIMEN LOAD	dgstlthrw6	0.00/10000.00	N	***
SPECIMEN RPM	dgstlthrw6	0.00/10.00	rpm	***
TORQUE	dgstlthrw6	0.00/25.00	N-m	***

Speed Range	3600
Torque Sensor Range Type	28
Load Range	High 10680
Radius in mm	13.50
Fluid Flow Rate Setpoint	2.00
Gap / Vert. Dist.	
Rigidity Sim Setting (%)	
Repeats	

	Min	Max	Alert	Shutdown	Units
Speed	1	3780	7	10	RPM
Torque	1.4	29.4	20.00	23.00	Nm
Boost	500	11214			N
Chamber Temp	20	300			°C
Chamber Exit Temp	20	450			°C
Interface Temp	20	600			°C
Fluid Flow Dev	0.10	0.50			L of Dev.
Vibration	0.10	20.00			grams
Cof	0.01	2.00			μ

Total Errors:	0		0	0	0	0	0	0	0	0
	Min	Max	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8
Parameter Sequence	See Comment		TLS	TLS	TLS	TLS	TLS	TLS	TLS	TLS
Temperature Setpoint (°C)	20	285	20	20	20	20	20	20	20	20
Allow Temp Overshoot	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
Allow Temp Undershoot	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
Load Setpoint (N)	500	11214	889	1334	1779	2224	2669	3114	3559	4003
Ramp Rate (N/sec)	2	100	50	50	50	50	50	50	50	50
Sec to achieve setpoint			17.78	8.90	8.90	8.90	8.90	8.90	8.90	8.88
Speed Setpoint (RPM)	1	10	5	5	5	5	5	5	5	5
Acc/Dec (RPM/sec)	1	1000	5	5	5	5	5	5	5	5
Step Duration Hours	0	999	0	0	0	0	0	0	0	0
Step Duration Minutes	0	59	1	1	1	1	1	1	1	1
Step Duration Seconds	10	60	60	60	60	60	60	60	60	60
Total Step Seconds			120	120	120	120	120	120	120	120
Start Fast Data	N	Y	N	N	N	N	N	N	N	N

Company:	***Dombroff & Gilmore***	Page:	3
Date:	12/07/01	Project #:	01-111
Technician	N. Pekoc		

Method:	Modified Thrust Washer
Machine:	Falex Multi-Specimen Test Machine, Computer Controlled Version
Serial #:	835000600496

TEST SPECIMENS:

Upper Material:	**1018 Steel**
Finish (rms):	14-18
Hardness (HRc):	15-25
Falex ID #:	4935
Lower Material:	**1018 Steel**
Finish (rms):	14-18
Hardness (HRc):	15-25
Falex ID #:	4936

TEST CONDITIONS:

Test Speed (rpm):	5
Temperature (°C):	Ambient
Duration:	5 min/stage
Test Load (lb):	100 to 800
Mean Test Radius (in):	0.531

Test Results:

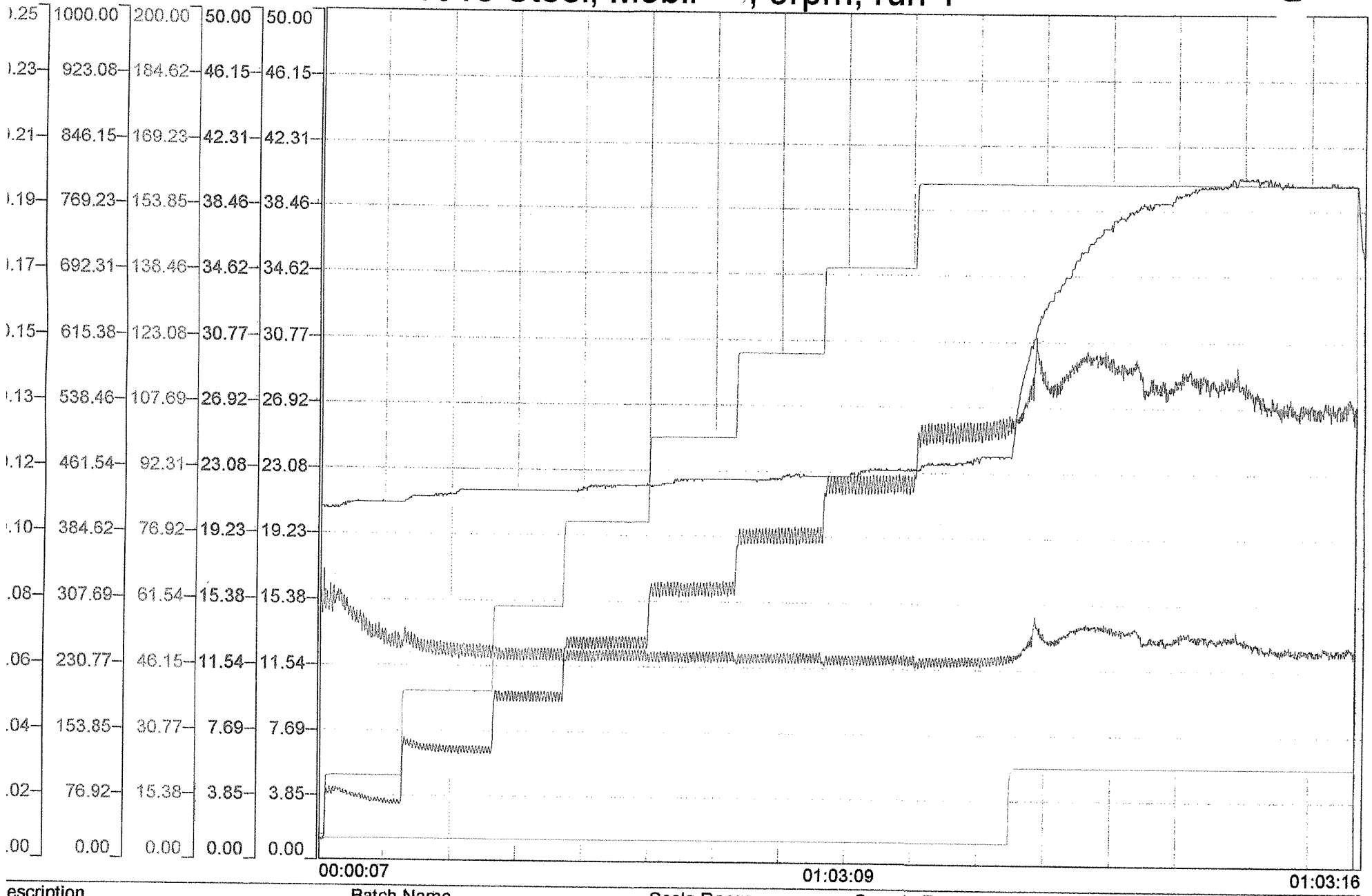
Test Date:	9/11/01	9/11/01	9/11/01
Test Number:	0606378	0606379	0606380
Test Speed (rpm):	5	5	5
Max Specimen Temperature (°C):	40	37	25
Upper Falex ID #:	4935	4935	4935
Lower Falex ID #:	4936	4936	4936
Lubricant:	**Mobil 28**	**Aeroshell 33**	**Aeroshell 33 Weathered**
Lubricant Falex ID #:	4944	4948	4949
SaveFile Name:	D&G05	D&G06	D&G07
Test Program Name:	Manual Control	Manual Control	Manual Control
Mass Loss, Upper (g):	0.0000	0.0003	0.0004
Mass Loss, Lower (g):	0.0012	0.0002	0.0008

Load Step (lbs)	CoF	CoF	CoF
100	0.06	0.06	0.07
200	0.06	0.06	0.07
300	0.06	0.06	0.07
400	0.06	0.06	0.06
500	0.06	0.06	0.06
600	0.06	0.05	0.06
700	0.06	0.06	0.06
800	0.06	0.06	0.06
800 @ 23 rpm	0.07	0.06	N/A

Comments: This is Preliminary testing to find friction characteristics of these greases.
See Graphs for Torque, Friction Coefficient, Load, Speed, and Specimen Temperature trends.

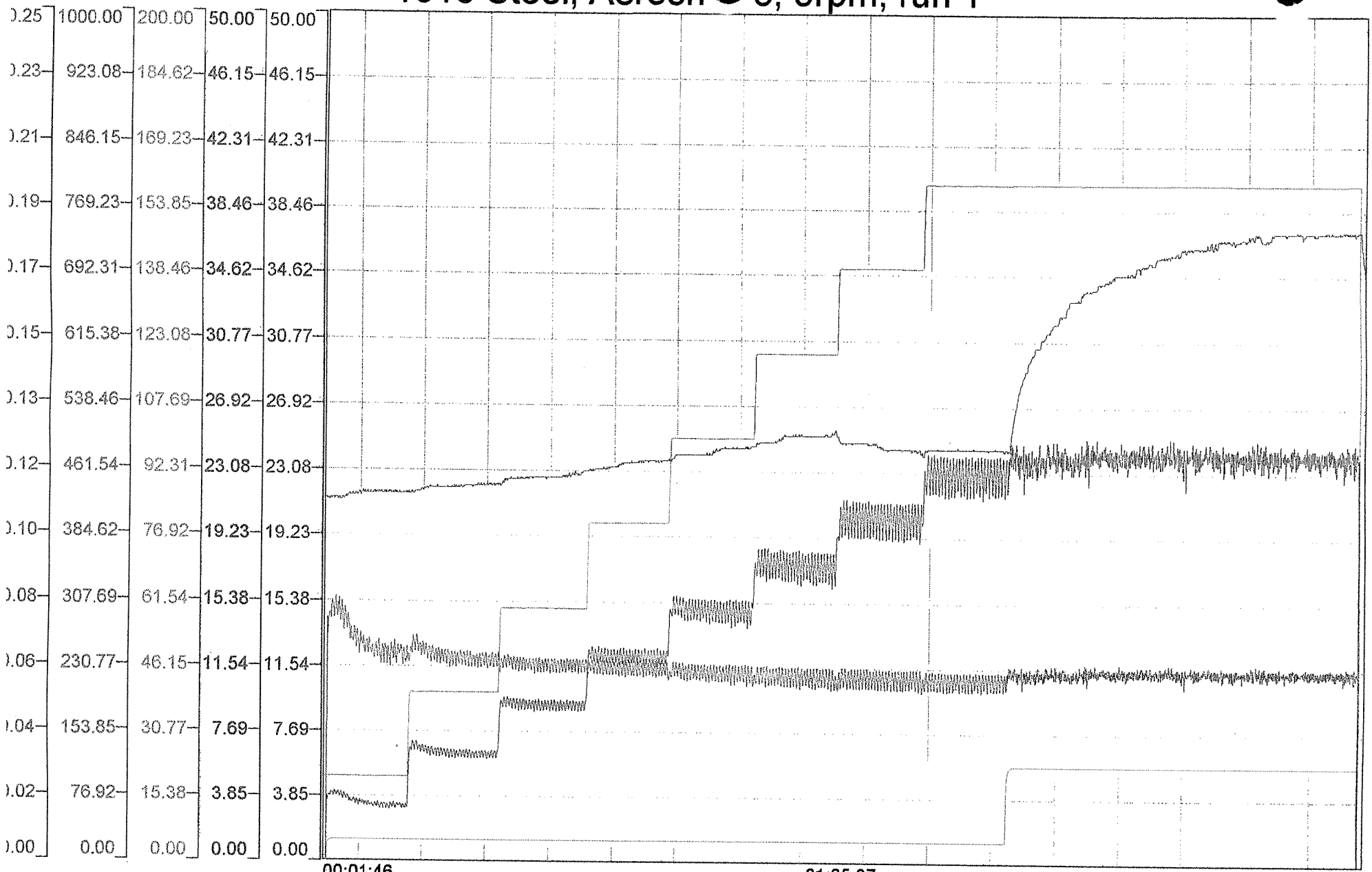
Coefficient of Friction (CoF)
The dimensionless ratio of the friction force (FF) between the upper rotating material and the lower stationary material to the normal force (N) pressing these bodies together.

1018 Steel, Mobil , 5rpm, run 1



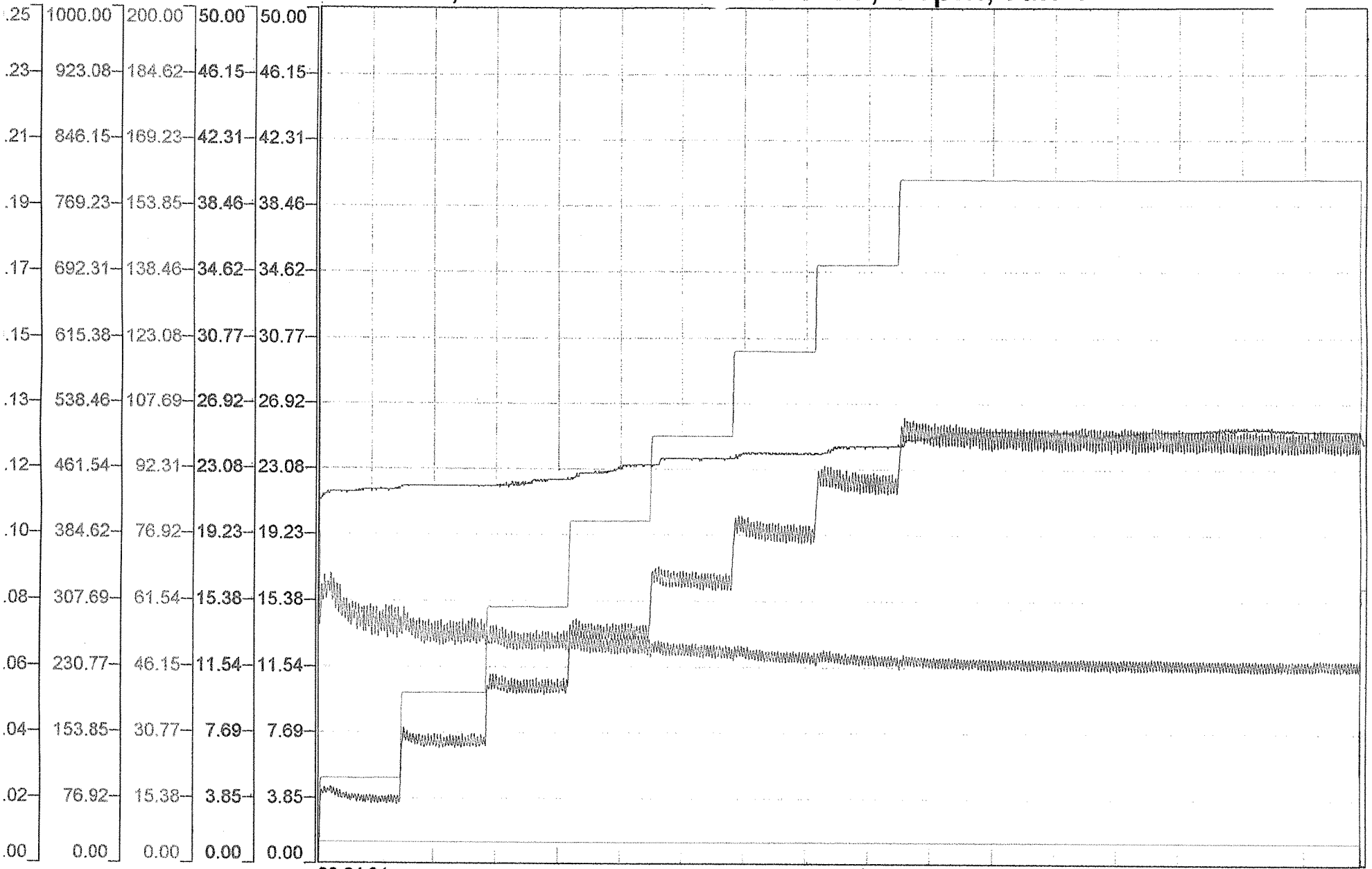
escription	Batch Name	Scale Range	Sample Freq.	Eng. Units	01:03:16
OEF-FRICT	d&g05	0.00/0.25	00:00:01		0.00
OAD	d&g05	0.00/1000.00	00:00:01	LB	-9.37
PEED	d&g05	0.00/200.00	00:00:01	RPM	0.00
EMP-S	d&g05	0.00/50.00	00:00:01	DEG. C	35.13
ORQUE	d&g05	0.00/50.00	00:00:01	LB-IN.	0.00

1018 Steel, Aerosh 3, 5rpm, run 1



Description	Batch Name	Scale Range	Sample Freq.	Eng. Units	01:07:24
COEF-FRICT	d&g06	0.00/0.25	00:00:01		0.00
LOAD	d&g06	0.00/1000.00	00:00:01	LB	-8.97
SPEED	d&g06	0.00/200.00	00:00:01	RPM	0.00
TEMP-S	d&g06	0.00/50.00	00:00:01	DEG. C	34.32
TORQUE	d&g06	0.00/50.00	00:00:01	LB-IN.	0.00

1018 Steel, Aeroshell 33 Weathered, 5 rpm, run 1



escription	Batch Name	Scale Range	Sample Freq.	Eng. Units	01:11:57
OEF-FRICT	d&g07	0.00/0.25	00:00:01		No Data
OAD	d&g07	0.00/1000.00	00:00:01	LB	No Data
PEED	d&g07	0.00/200.00	00:00:01	RPM	No Data
EMP-S	d&g07	0.00/50.00	00:00:01	DEG. C	No Data
ORQUE	d&g07	0.00/50.00	00:00:01	LB-IN.	No Data

Company:	***Dombroff & Gilmore***	Page:	1
Date:	12/07/01	Project #:	01-111
Technician	N. Pekoc		

Method:	Modified Thrust Washer
Machine:	Falex Multi-Specimen Test Machine, Computer Controlled Version
Serial #:	835000600496

TEST SPECIMENS:

Upper Material:	**1018 Steel**
Finish (rms):	14-18
Hardness (HRc):	15-25
Falex ID #:	4935
Lower Material:	**1018 Steel**
Finish (rms):	14-18
Hardness (HRc):	15-25
Falex ID #:	4936

TEST CONDITIONS:

Test Speed (rpm):	**100**
Temperature (°C):	Ambient
Duration:	Variable
Test Load (lb):	Variable
Mean Test Radius (in):	0.531

Test Results:

Test Date:	08/28/01	09/04/01	09/04/01	09/04/01	09/05/01
Test Number:	0606373	0606374	0606375	0606376	0606377
Test Speed (rpm):	100	100	100	100	100
Max Specimen Temperature (°C):	236	124	116	208	184
Test Load (lb):	50-800	200-600	400-600	200-800	400-800
Upper Falex ID #:	4935	4935	4935	4935	4935
Lower Falex ID #:	4936	4936	4936	4935	4935
Lubricant:	**Mobil 28**	**Mobil 28**	**Mobil 28**	**Aeroshell 33**	**Aeroshell 33**
Lubricant Falex ID #:	4944	4944	4944	4948	4948
SaveFile Name:	D&G00	D&G01	D&G02	D&G03	D&G04
Test Program Name:	Manual Control	Manual Control	Manual Control	Manual Control	Manual Control
Mass Loss, Upper (g):	0.0880	0.0472	0.0072	0.0251	0.0127
Mass Loss, Lower (g):	0.0192	0.0223	0.0631	0.0193	0.0427

Load Step (lbs)	CoF	CoF	CoF	CoF	CoF
50	0.12	x	x	x	x
100	0.08	x	x	x	x
150	0.09	x		x	
200	0.11	0.06	x	0.06	x
240	0.11	0.05		0.06	
300	0.12	0.05	x	0.06	x
340	0.11	0.06	x	0.06	x
400	0.16	0.06	0.06	0.06	0.06
440	0.15	0.06	0.06	0.06	0.07
500	0.05	0.06	0.06	0.06	0.06
540	0.06	0.05	0.06	0.06	0.07
600	0.05	0.18	0.11	0.07	0.07
640	0.05	x	x	0.07	0.07
700	0.05	x	x	0.06	0.07
740	0.05	x		0.06	0.07
800	0.06	x	x	0.07	0.07

Comments: This is Preliminary testing to find friction characteristics of these greases.
See Graphs for Torque, Friction Coefficient, Load, Speed, and Specimen Temperature trends.

Company:	***Dombroff & Gilmore***	Page:	2
Date:	12/07/01	Project #:	01-111
Technician	N. Pekoc		

Method:	Modified Thrust Washer
Machine:	Falex Multi-Specimen Test Machine, Computer Controlled Version
Serial #:	835000600496

TEST SPECIMENS:

Upper Material:	**1018 Steel**
Finish (rms):	14-18
Hardness (HRc):	15-25
Falex ID #:	4935
Lower Material:	**1018 Steel**
Finish (rms):	14-18
Hardness (HRc):	15-25
Falex ID #:	4936

TEST CONDITIONS:

Test Speed (rpm):	**100**
Temperature (°C):	Ambient
Duration (sec):	Variable
Test Load (lb):	Variable
Mean Test Radius (in):	0.531

Test Results:

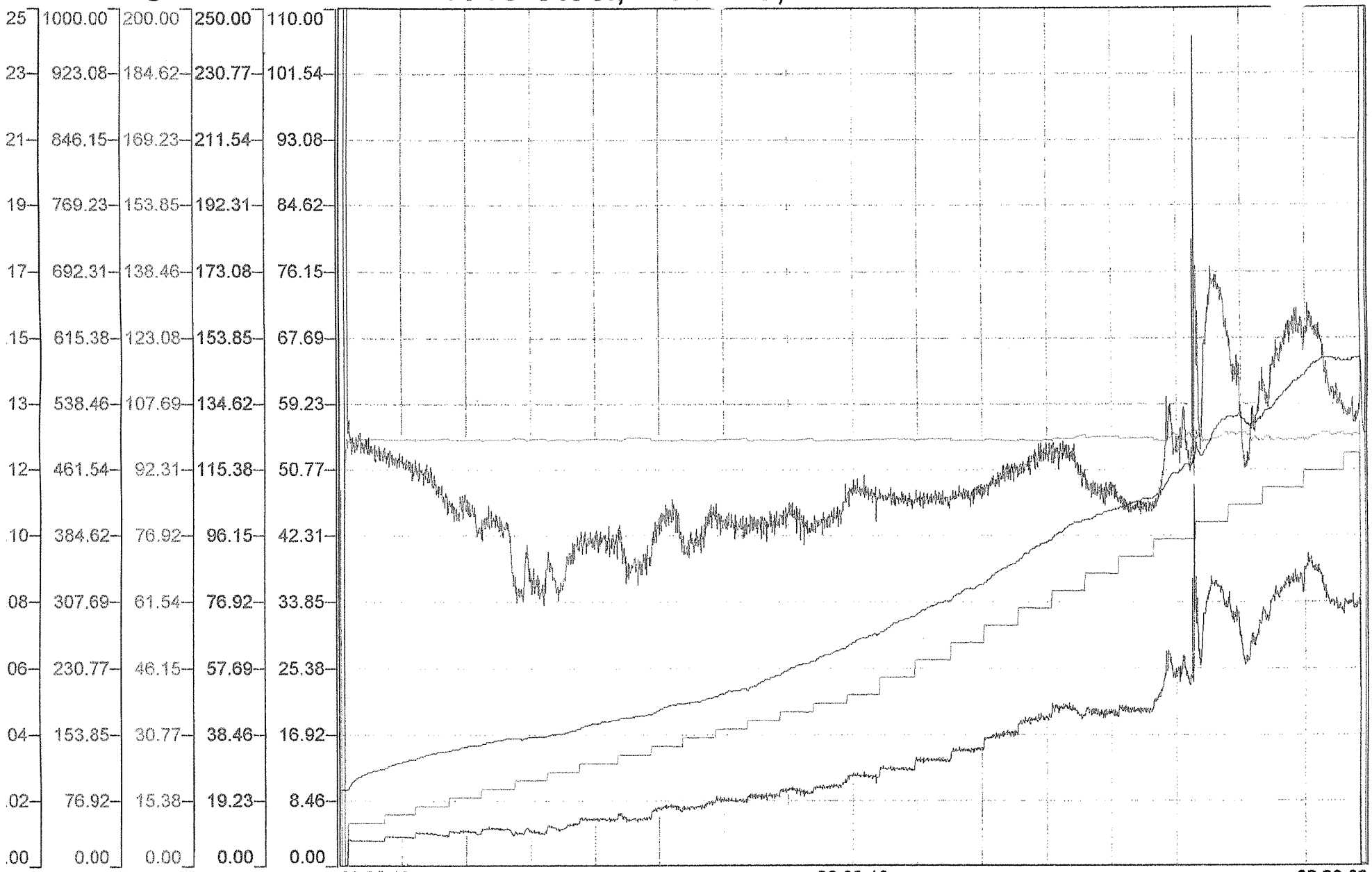
Test Date:	09/25/01	09/25/01
Test Number:	0606381	0606382
Test Speed (rpm):	100	100
Max Specimen Temperature (°C):	86	104
Upper Falex ID #:	4935	4935
Lower Falex ID #:	4936	4936
Lubricant:	**Aeroshell 33 Weathered**	**Aeroshell 33 Weathered**
Lubricant Falex ID #:	4949	4949
SaveFile Name:	D&G08	D&G09
Test Program Name:	Manual Control	Manual Control
Mass Loss, Upper (g):	0.0506	0.0003
Mass Loss, Lower (g):	0.0357	-0.0003

Load Step (lbs)	CoF	CoF
400	0.06	0.06
450	0.06	0.07
500	0.06	0.07
550	0.06	0.07
600	spiked to .18	0.07
700	spiked to .17, stopped due to high friction	stopped due to high temperature
800	x	x

Comments: This is Preliminary testing to find friction characteristics of these greases.
See Graphs for Torque, Friction Coefficient, Load, Speed, and Specimen Temperature trends.

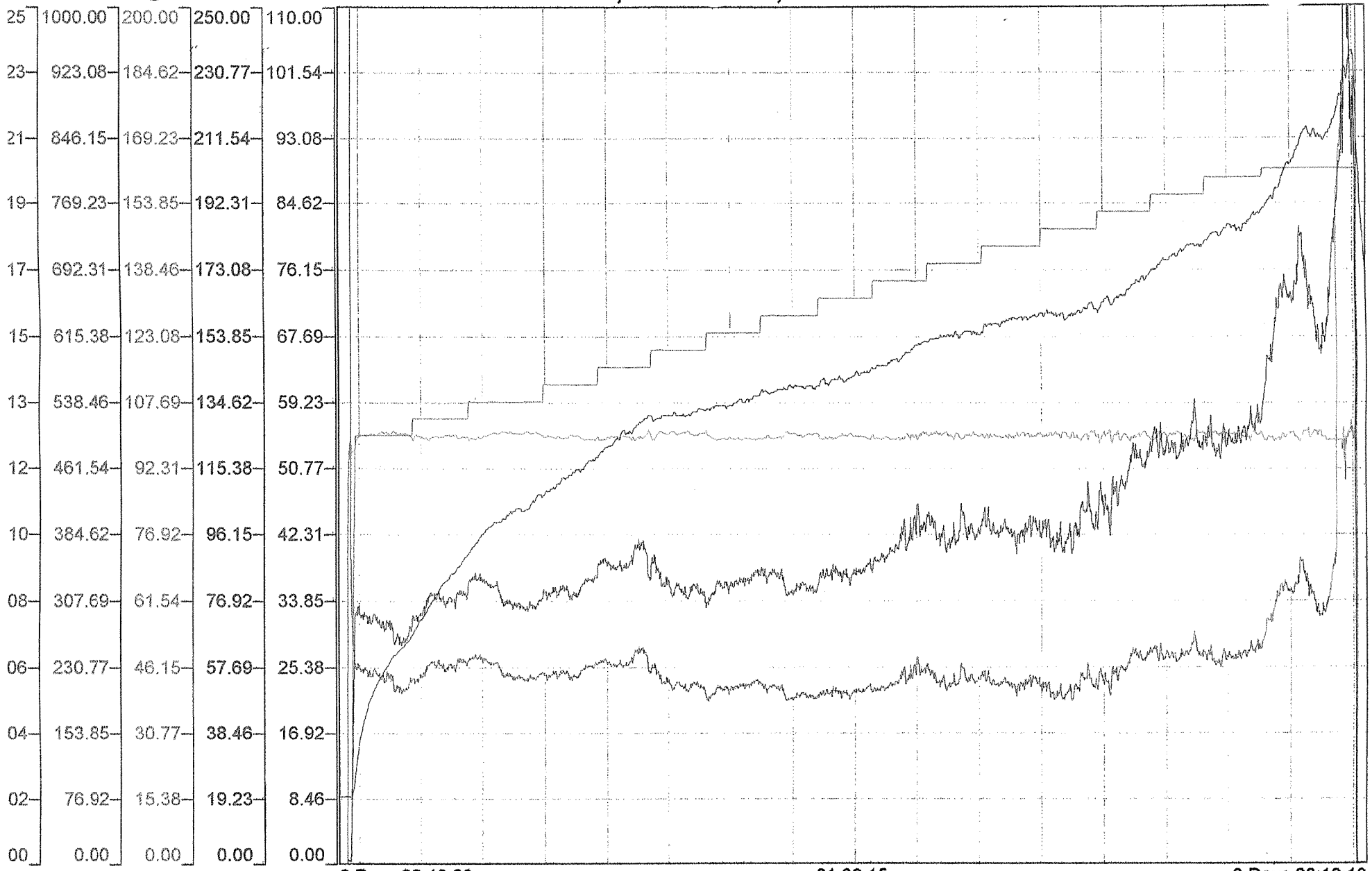
Coefficient of Friction (CoF)
The dimensionless ratio of the friction force (FF) between the upper rotating material and the lower stationary material to the normal force (N) pressing these bodies together.

1018 Steel, Mol 28, run 1-A



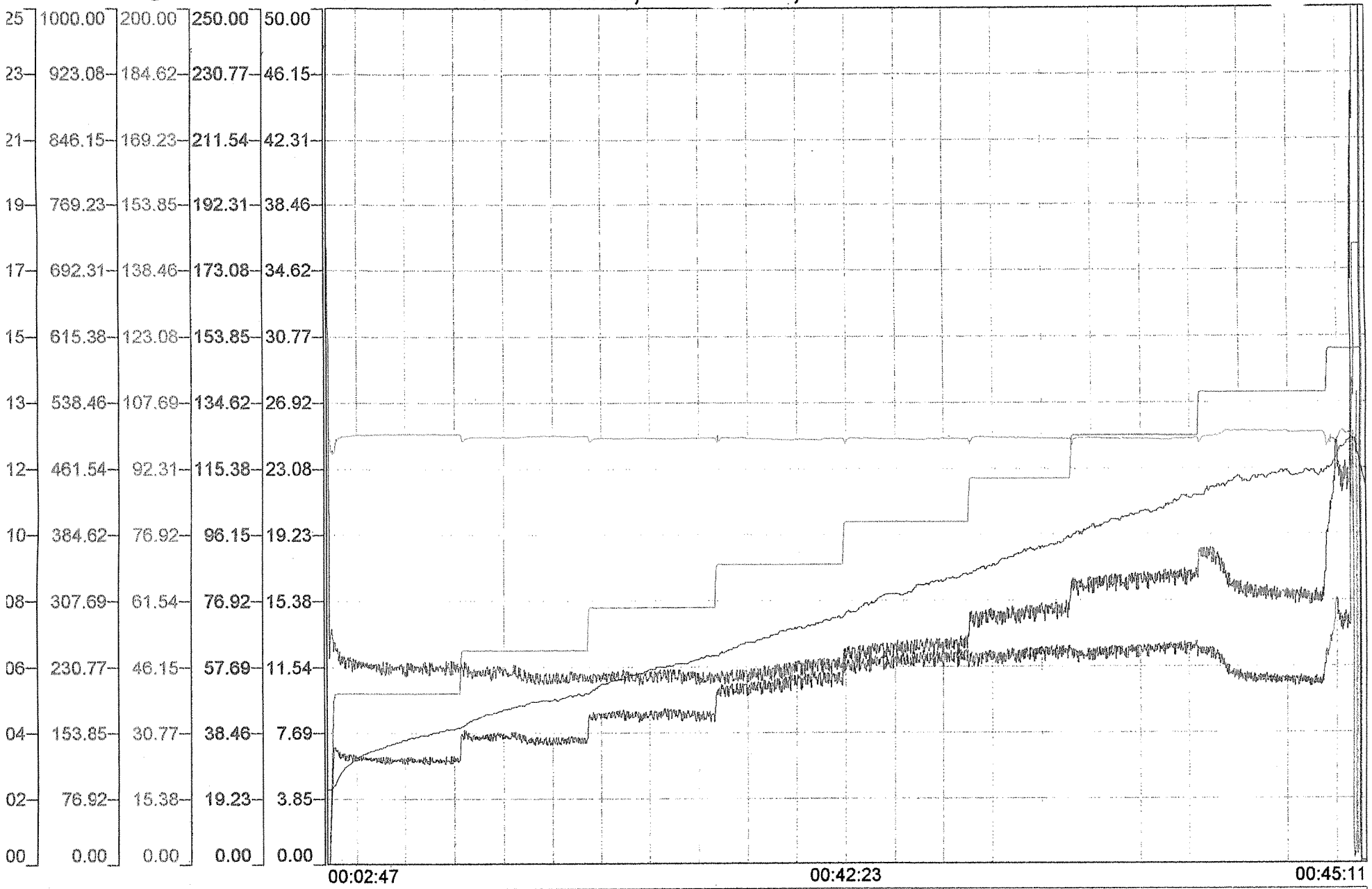
escription	Batch Name	Scale Range	Sample Freq.	Eng. Units	02:39:36
OEF-FRICT	d&g00	0.00/0.25	00:00:01		0.00
OAD	d&g00	0.00/1000.00	00:00:01	LB	-10.32
PEED	d&g00	0.00/200.00	00:00:01	RPM	0.00
EMP-S	d&g00	0.00/250.00	00:00:01	DEG. C	125.48
ORQUE	d&g00	0.00/110.00	00:00:01	LB-IN.	0.00

1018 Steel, Mol 28, run 1-B



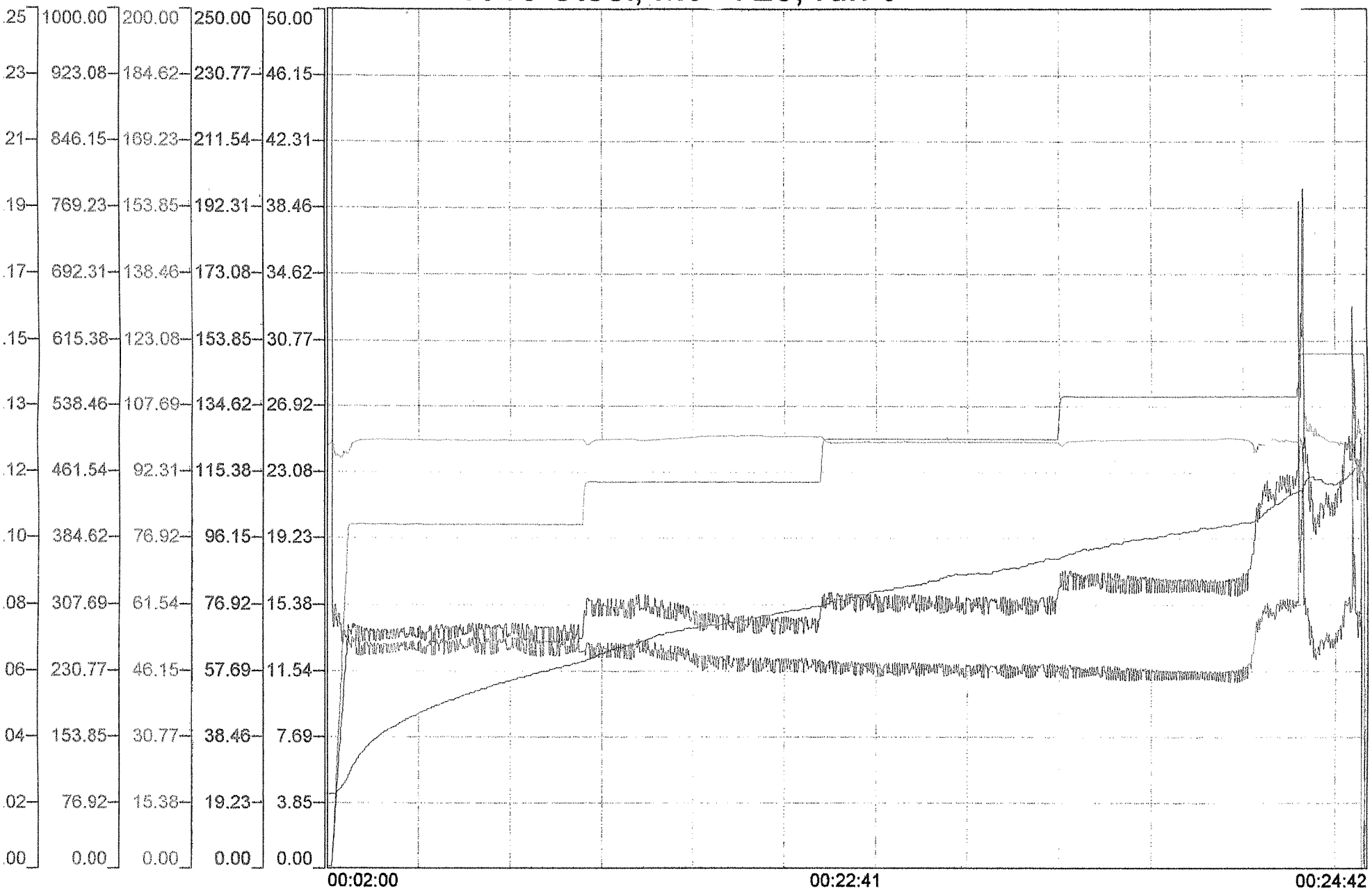
escription	Batch Name	Scale Range	Sample Freq.	Eng. Units	3 Days 00:19:19
DEF-FRICT	d&g00	0.00/0.25	00:00:01		1.25
DAD	d&g00	0.00/1000.00	00:00:01	LB	-9.62
PEED	d&g00	0.00/200.00	00:00:01	RPM	5.40e-11
EMP-S	d&g00	0.00/250.00	00:00:01	DEG. C	172.58
ORQUE	d&g00	0.00/110.00	00:00:01	LB-IN.	0.07

1018 Steel, Mc 28, run 2



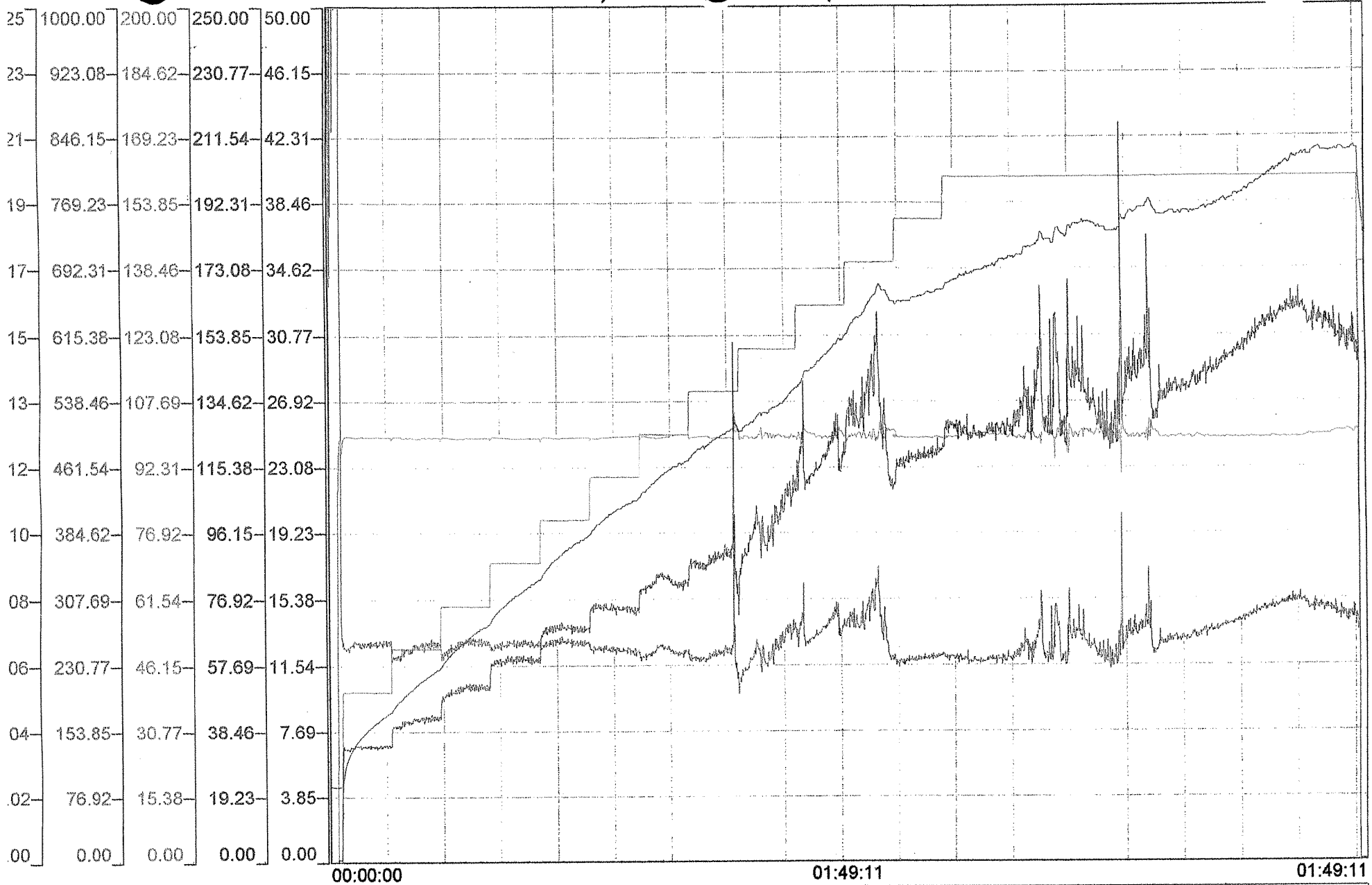
escription	Batch Name	Scale Range	Sample Freq.	Eng. Units	00:45:11
DEF-FRICT	d&g01	0.00/0.25	00:00:01		0.26
OAD	d&g01	0.00/1000.00	00:00:01	LB	-9.83
PEED	d&g01	0.00/200.00	00:00:01	RPM	0.00
EMP-S	d&g01	0.00/250.00	00:00:01	DEG. C	108.97
ORQUE	d&g01	0.00/50.00	00:00:01	LB-IN.	0.11

1018 Steel, Mc[redacted] 28, run 3



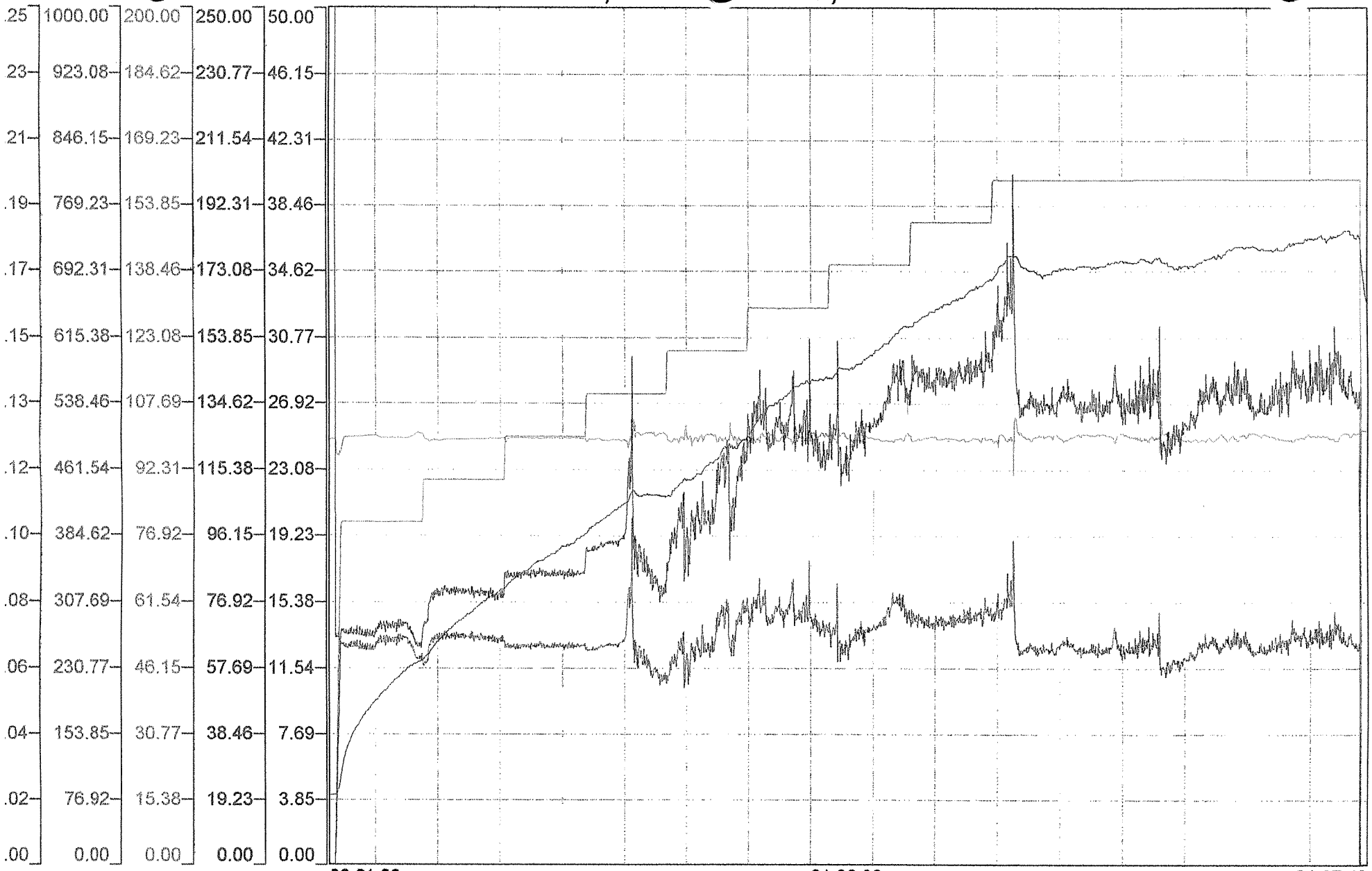
escription	Batch Name	Scale Range	Sample Freq.	Eng. Units	00:24:42
OEF-FRICT	d&g02	0.00/0.25	00:00:01		0.05
OAD	d&g02	0.00/1000.00	00:00:01	LB	-9.51
PEED	d&g02	0.00/200.00	00:00:01	RPM	9.91e-03
EMP-S	d&g02	0.00/250.00	00:00:01	DEG. C	109.78
ORQUE	d&g02	0.00/50.00	00:00:01	LB-IN.	0.09

1018 Steel, Aero[illegible]ell 33, run 1



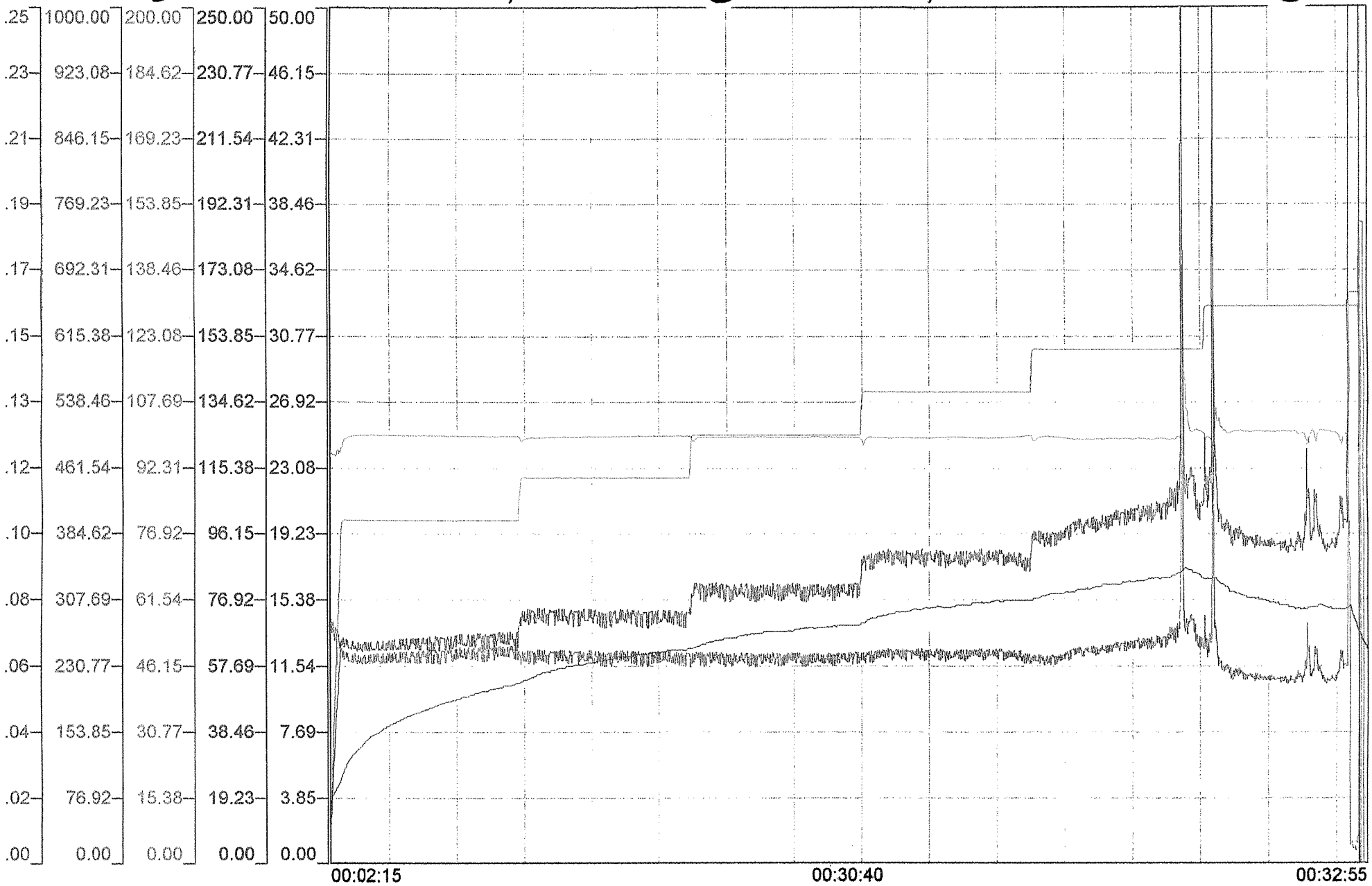
escription	Batch Name	Scale Range	Sample Freq.	Eng. Units	01:49:11
OEF-FRICT	d&g03	0.00/0.25	00:00:01		No Data
OAD	d&g03	0.00/1000.00	00:00:01	LB	No Data
PEED	d&g03	0.00/200.00	00:00:01	RPM	No Data
EMP-S	d&g03	0.00/250.00	00:00:01	DEG. C	No Data
ORQUE	d&g03	0.00/50.00	00:00:01	LB-IN.	No Data

1018 Steel, Aero Shell 33, run 2



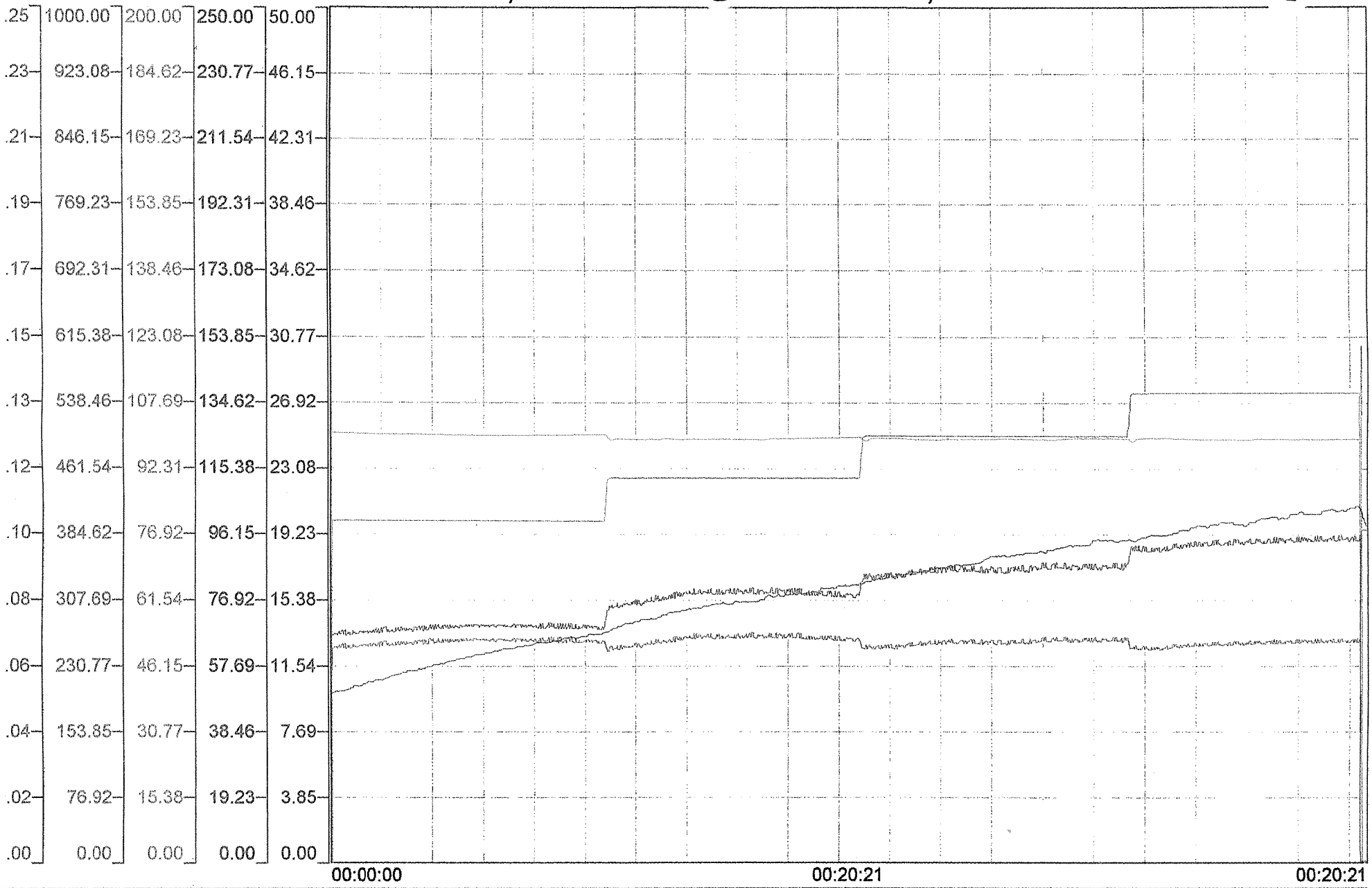
escription	Batch Name	Scale Range	Sample Freq.	Eng. Units	01:07:40
OEF-FRICT	d&g04	0.00/0.25	00:00:01		0.13
OAD	d&g04	0.00/1000.00	00:00:01	LB	-9.32
PEED	d&g04	0.00/200.00	00:00:01	RPM	0.00
EMP-S	d&g04	0.00/250.00	00:00:01	DEG. C	163.00
ORQUE	d&g04	0.00/50.00	00:00:01	LB-IN.	0.06

1018 Steel, Aeroshell 3 Weathered, run 1



Description	Batch Name	Scale Range	Sample Freq.	Eng. Units	00:32:55
COEF-FRICT	d&g08	0.00/0.25	00:00:01		0.00
LOAD	d&g08	0.00/1000.00	00:00:01	LB	-9.65
SPEED	d&g08	0.00/200.00	00:00:01	RPM	0.00
TEMP-S	d&g08	0.00/250.00	00:00:01	DEG. C	62.40
TORQUE	d&g08	0.00/50.00	00:00:01	LB-IN.	0.00

1018 Steel, Aeroshell 3 Weathered, run 2



)escription	Batch Name	Scale Range	Sample Freq.	Eng. Units	00:20:21
:OEF-FRICT	d&g09	0.00/0.25	00:00:01		0.10
OAD	d&g09	0.00/1000.00	00:00:01	LB	-9.60
PEED	d&g09	0.00/200.00	00:00:01	RPM	0.00
EMP-S	d&g09	0.00/250.00	00:00:01	DEG. C	98.03
ORQUE	d&g09	0.00/50.00	00:00:01	LB-IN.	0.09

COMPANY: **Dombroff & Gilmore**
DATE: 10/11/01
TECHNICIAN: M. Rapp

MACHINE: Falex-ISC Pin On Disk Tribometer System, S/N 808020000045
METHOD: ASTM G99 Modified

TEST CONDITIONS:

TEST SPEED (rpm):	20	BALL MATERIAL:	52100 Steel
TEMPERATURE (°C):	Ambient	BALL GRADE:	5
DURATION (min):	75	BALL POSITION:	90
TEST LOAD (grams):	100/ increments of 100	TEST RADIUS (mm):	22
LUBRICANT:	Various		

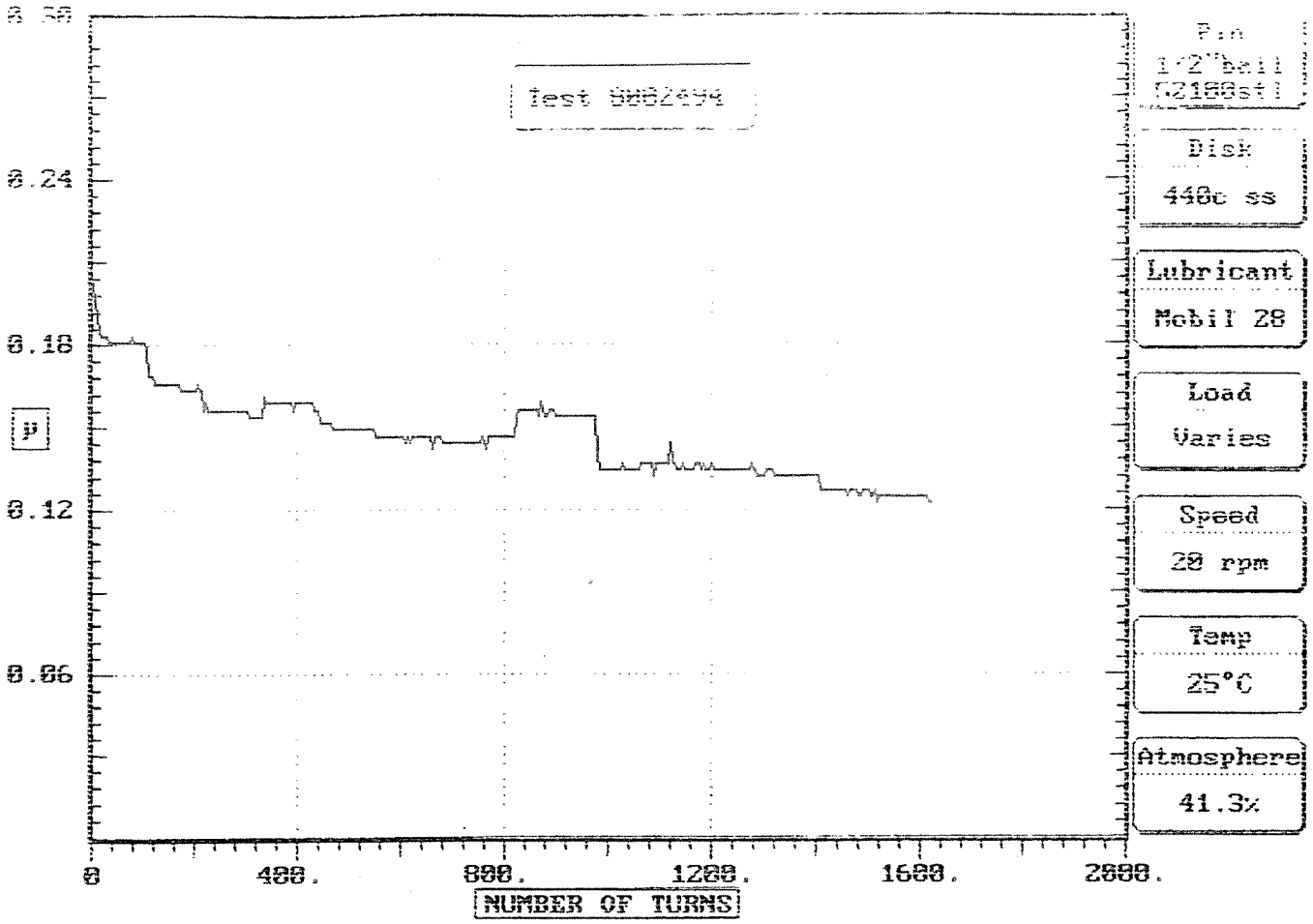
TEST RESULTS:

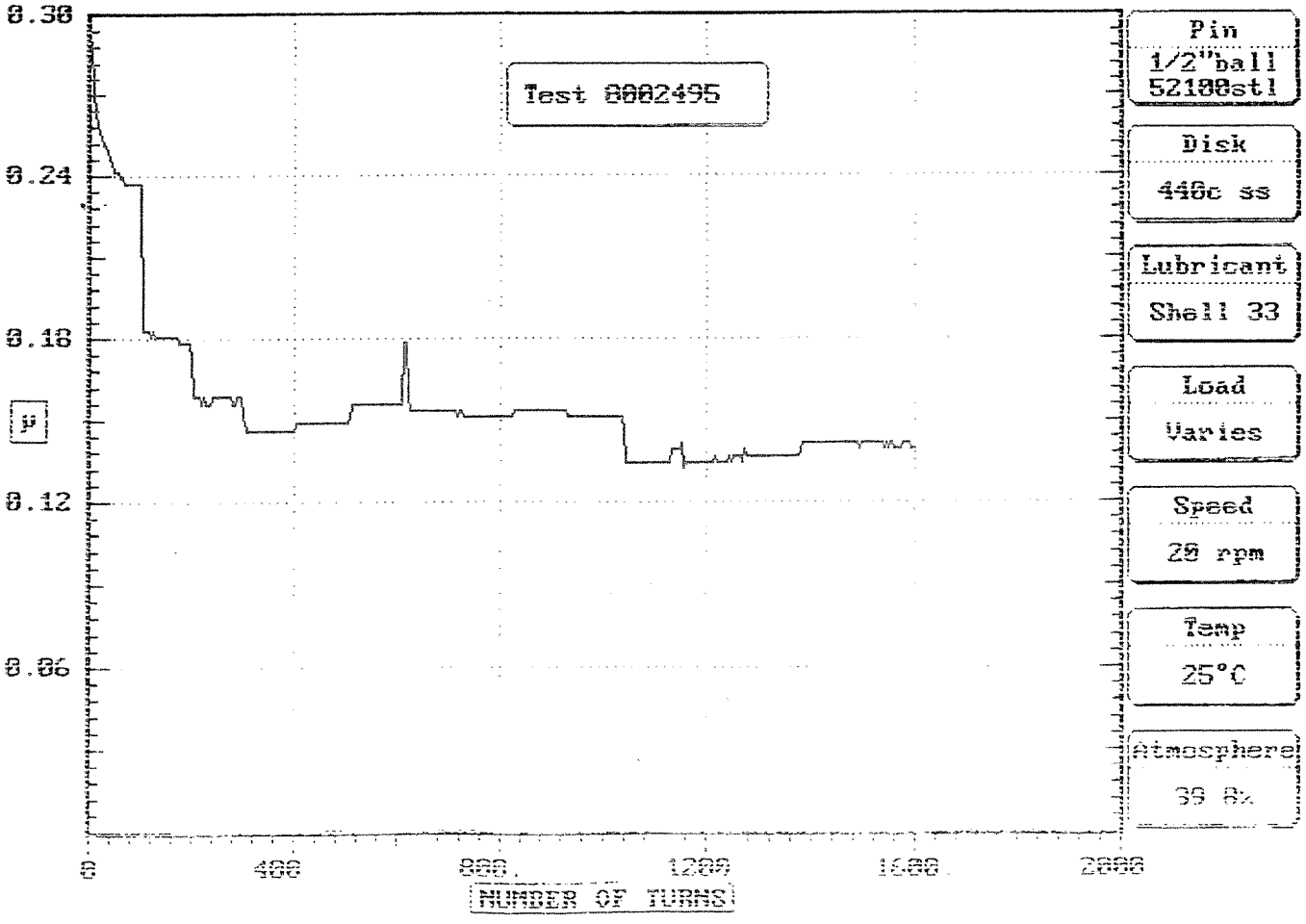
TEST DATE:	09/12/01	09/13/01	09/24/01	09/24/01
TEST NUMBER:	8002494	8002495	8002499	8002500
FILE IDENTIFICATION:	DANDG00	DANDG01	DANDG02	DANDG03
DISK MATERIAL:	440C Stainless	440C Stainless	440C Stainless	440C Stainless
BALL MATERIAL:	52100 Steel	52100 Steel	52100 Steel	52100 Steel
LUBRICANT:	**Mobil 28**	**Aeroshell 33**	**Aeroshell 33 Weathered**	**Aeroshell 33 Weathered**
TOTAL CYCLES:	1621	1603	1579	1631
AVG. BALL SCAR(mm):	0.644	0.726	0.670	0.664

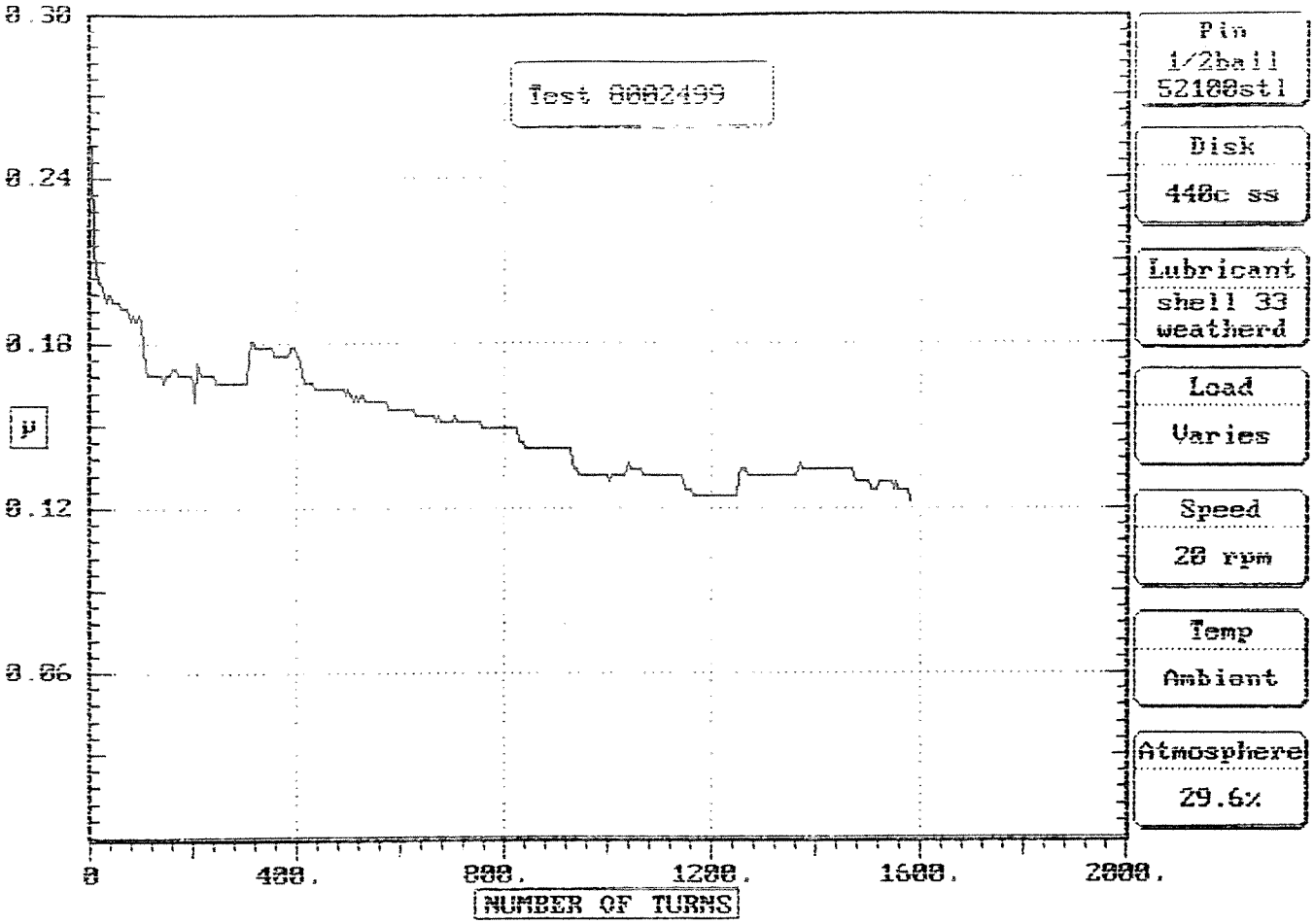
COEFFICIENT OF FRICTION: See Attached Graphs for Friction Traces

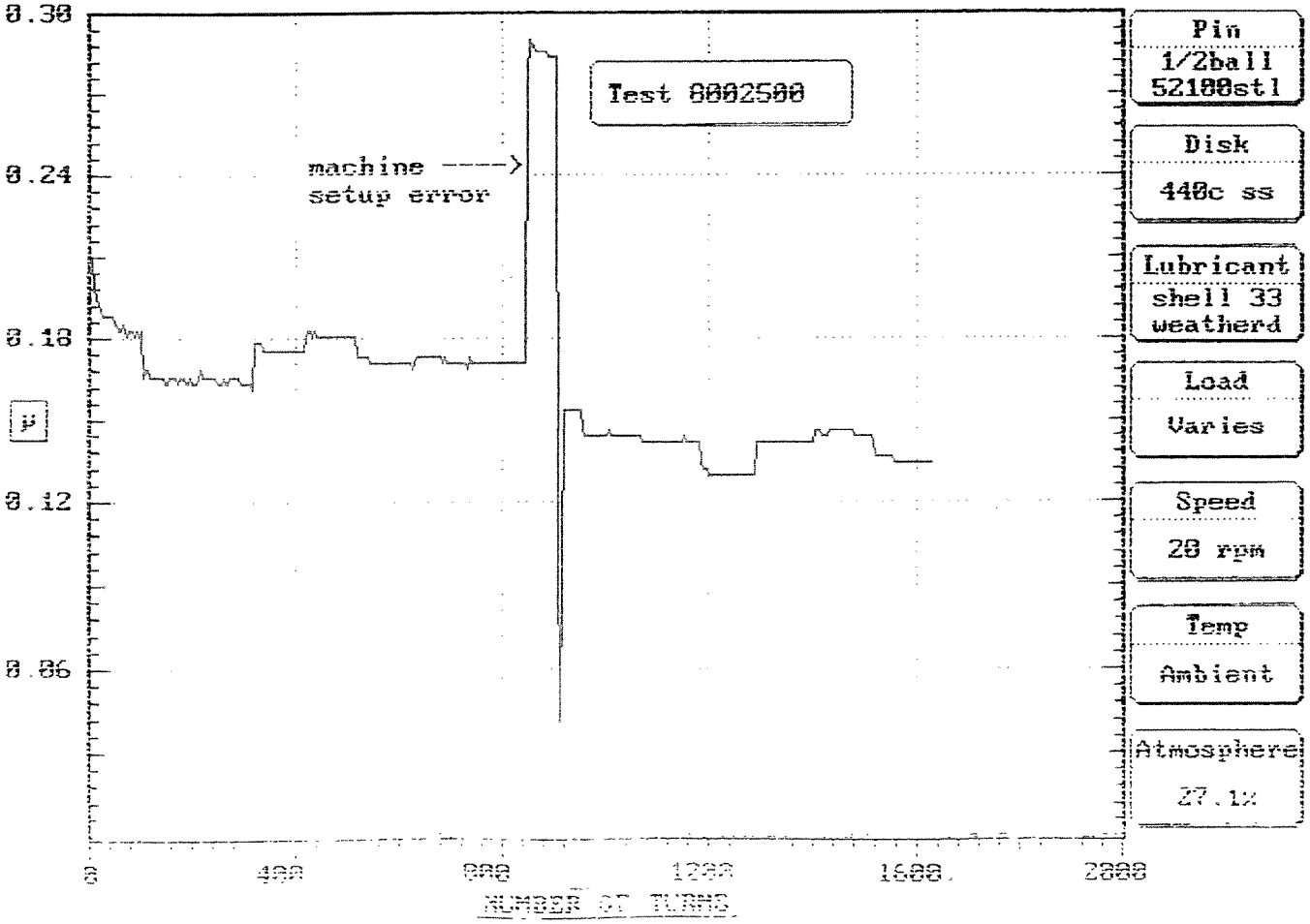
TEST DATE:	09/25/01	09/25/01
TEST NUMBER:	8002501	8002502
FILE IDENTIFICATION:	DANDG04	DANDG05
DISK MATERIAL:	440c Stainless	440c Stainless
PIN MATERIAL:	52100 Steel	52100 Steel
LUBRICANT:	**Mobil 28**	**Aeroshell 33**
TOTAL CYCLES:	1771	1886
AVG. BALL SCAR (mm):	0.637	0.604

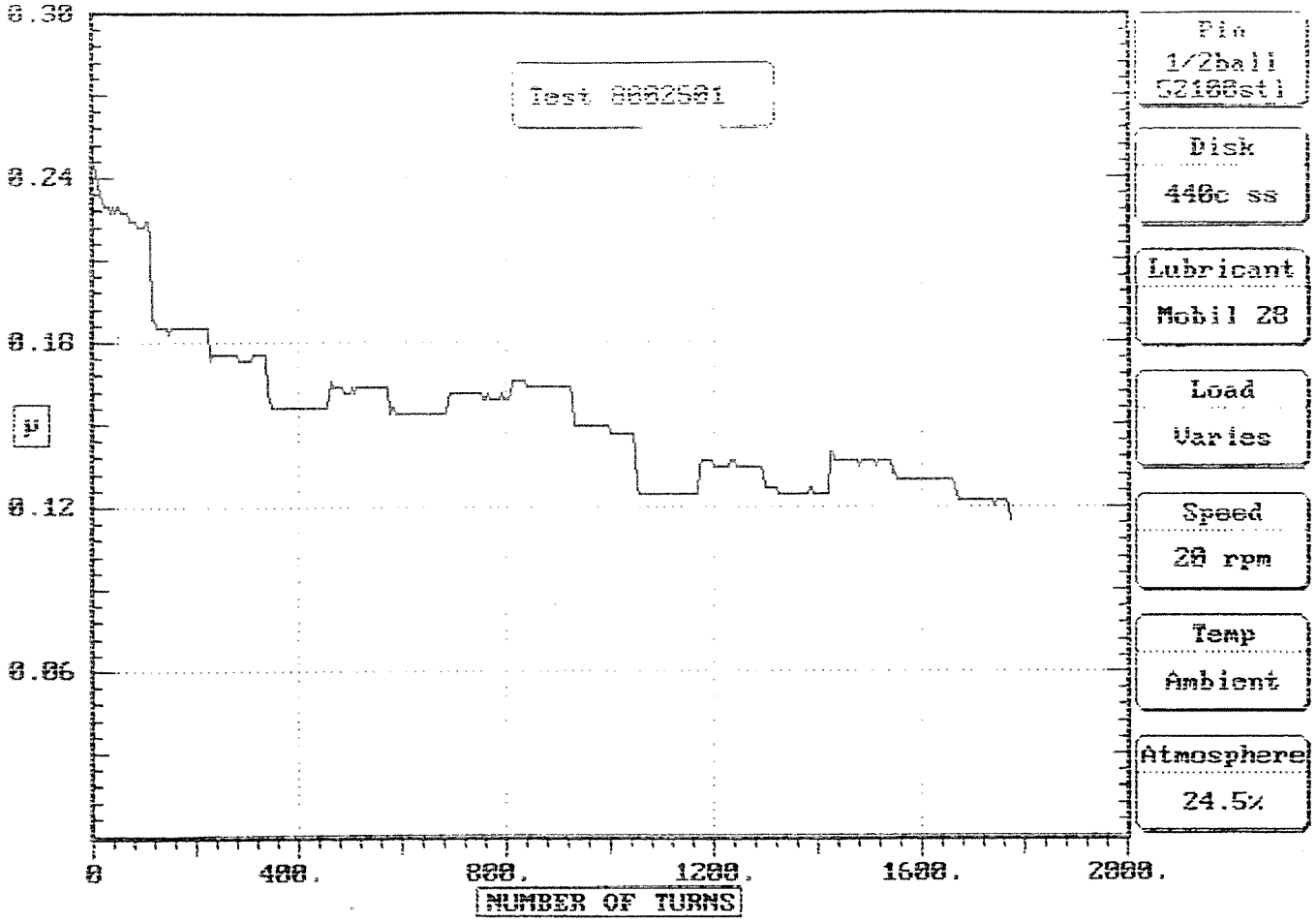
COEFFICIENT OF FRICTION: See Attached Graphs for Friction Traces

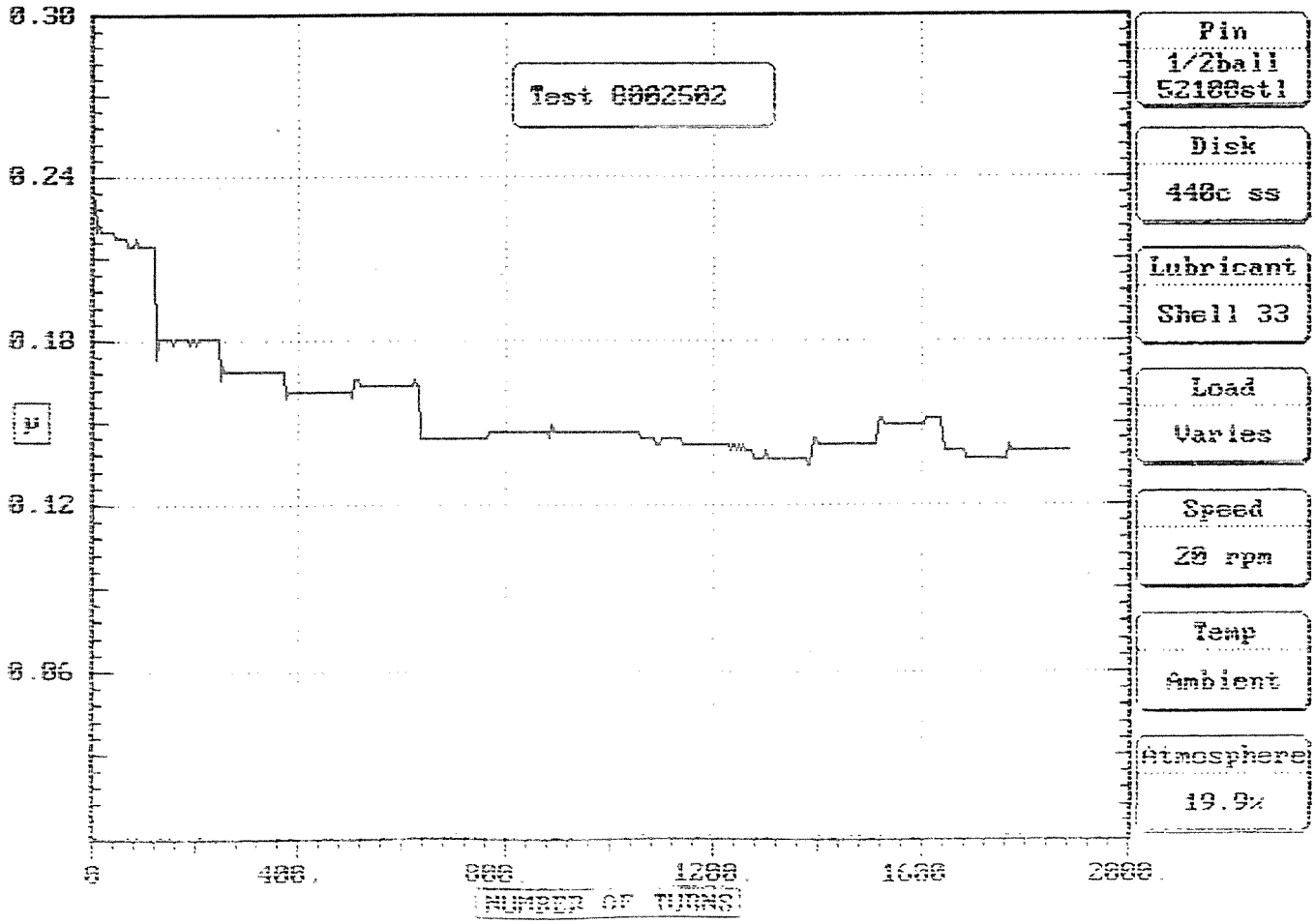

Test 0002494
Pin
1/2"ball
52100stl
Disk
440c ss
Lubricant
Mobil 28
Load
Varies
Speed
20 rpm
Temp
25°C
Atmosphere
41.3%
0.24
0.18
μ
0.12
0.06
0
400.
800.
1200.
1600.
2000.
NUMBER OF TURNS


Test 0002495
Pin
1/2"ball
52100stl
Disk
440c ss
Lubricant
Shell 33
Load
Varies
Speed
20 rpm
Temp
25°C
Atmosphere
0.24
0.18
μ
0.12
0.06
400
800.
1200
1600
2000
NUMBER OF TURNS


Test 0002499
0.30
0.24
0.18
μ
0.12
0.06
0
400.
800.
1200.
1600.
2000.
NUMBER OF TURNS
Pin
1/2ball
52100stl
Disk
440c ss
Lubricant
shell 33
weatherd
Load
Varies
Speed
20 rpm
Temp
Ambient
Atmosphere
29.6%


Test 0002500
machine
setup error
0.30
0.24
0.18
μ
0.12
0.06
0
400
800
1200
1600.
2000
NUMBER OF TURNS
Pin
1/2ball
52100stl
Disk
440c ss
Lubricant
shell 33
weatherd
Load
Varies
Speed
20 rpm
Temp
Ambient
Atmosphere
27.1%


Test 0002501
0.30
0.24
0.18
μ
0.12
0.06
0
400.
800.
1200.
1600.
2000.
NUMBER OF TURNS
Pin
1/2ball
52100stl
Disk
440c ss
Lubricant
Mobil 28
Load
Varies
Speed
20 rpm
Temp
Ambient
Atmosphere
24.5%


Test 0002502
0.30
0.24
0.18
μ
0.12
0.06
0
400.
800.
1200.
1600.
2000.
NUMBER OF TURNS
Pin
1/2ball
52100stl
Disk
440c ss
Lubricant
Shell 33
Load
Varies
Speed
20 rpm
Temp
Ambient
Atmosphere
19.9%

Company:	***Dombroff & Gilmore***	Page:	1
Date:	12/07/01	Project #:	01-111
Technician	D. Hlavacek		

Method:	Three-Ball Microfilm
Machine:	Falex Multi-Specimen Test Machine, Computer Controlled Version
Serial #:	835000600496

TEST SPECIMENS:

Upper Material:	**440C Stainless Steel**
Finish (rms):	1
Hardness (HRc):	56
Falex ID No.:	5026U
Lower Material:	**440C Stainless Steel**
Finish (rms):	1
Hardness (HRc):	56
Falex ID No.:	5026L
Ball Material:	E-52100 Steel
Hardness (HRc):	64-66
Grade:	5
Falex ID#:	Lot 98

TEST CONDITIONS:

Test Speed (rpm):	20
Temperature (°C):	Ambient
Test Load (lb):	400-800 (50 lb steps)
Mean Test Radius (in):	0.672

Test Results:

Test Date:	10/22/01	11/08/01	10/24/01	11/05/01
Test Number:	0606395	0606403	0606397	0606400
Upper Falex ID #:	5026UA	5026UB	5026UC	5026UD
Lower Falex ID #:	5026LA	5026LB	5026LC	5026LD
Lubricant:	**Mobil 28**	**Mobil 28**	**Aeroshell 33**	**Aeroshell 33**
Lubricant Falex ID #:	AA 4944	AA 4944	AA 4948	AA 4948
Test Program Name:	DANDG3BL	DANDG3BL	DANDG3BL	DANDG3BL
SaveFile Name:	D&G3B01	dg3bl07	dg3bl03	dg3bl04

Comments: See Graphs for Friction and additional data.

Coefficient of Friction (CoF)
The dimensionless ratio of the friction force (FF) between the upper rotating material and the lower stationary material to the normal force (N) pressing these bodies together.

Company:	***Dombroff & Gilmore***	Page:	2
Date:	12/07/01	Project #:	01-111
Technician	D. Hlavacek		

Method:	Three-Ball Microfilm
Machine:	Falex Multi-Specimen Test Machine, Computer Controlled Version
Serial #:	835000600496

TEST SPECIMENS:

Upper Material:	**440C Stainless Steel**
Finish (rms):	1
Hardness (HRc):	56
Falex ID #:	5026U
Lower Material:	**440C Stainless Steel**
Finish (rms):	1
Hardness (HRc):	56
Falex ID #:	5026L
Ball Material:	E-52100 Steel
Hardness (HRc):	64-66
Grade:	5
Falex ID #:	Lot 98

TEST CONDITIONS:

Test Speed (rpm):	20
Temperature (°C):	Ambient
Test Load (lb):	400-800 (50 lb steps)
Mean Test Radius (in):	0.672

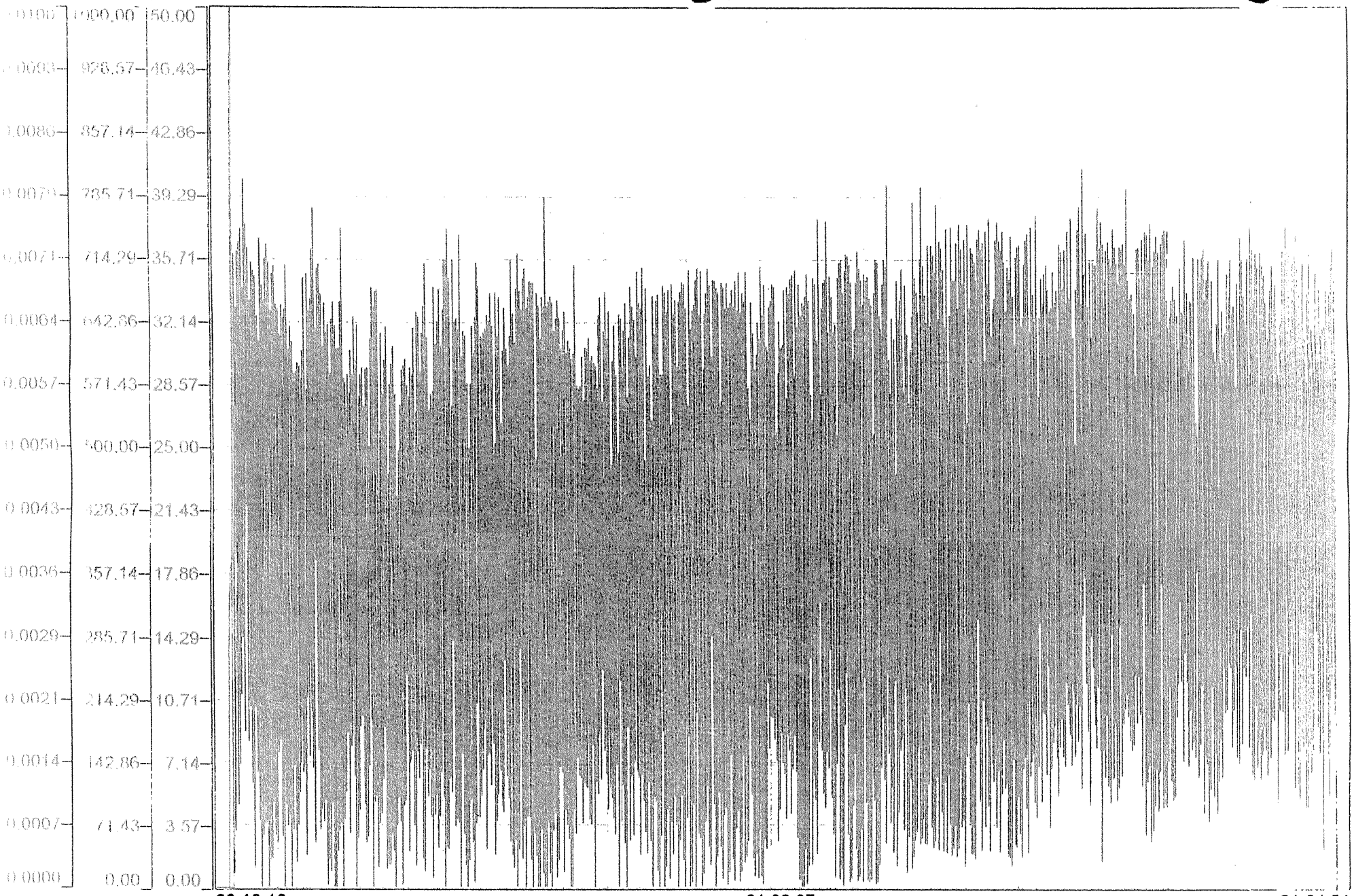
Test Results:

Test Date:	11/05/01	11/08/01
Test Number:	0606401	0606402
Upper Falex ID #:	5026UA	5026UC
Lower Falex ID #:	5026LA	5026LC
Lubricant:	**Aeroshell 33, weathered**	**Aeroshell 33, weathered**
Lubricant Falex ID #:	AA 4949	AA 4949
Test Program Name:	DANDG3BL	DANDG3BL
SaveFile Name:	dg3bl05	dg3bl06

Comments: See Graphs for Friction and additional data.

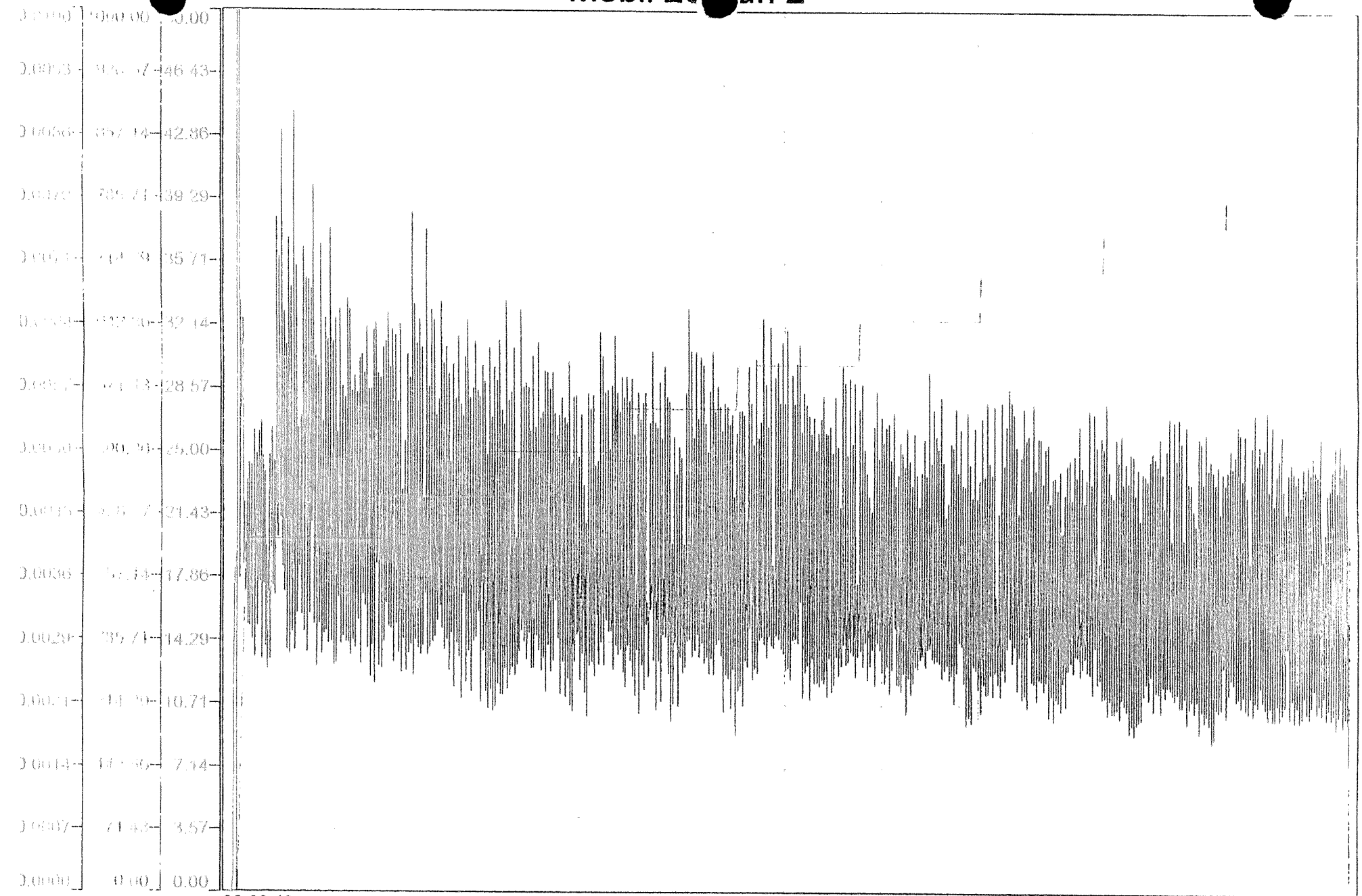
Coefficient of Friction (CoF)
The dimensionless ratio of the friction force (FF) between the upper rotating material and the lower stationary material to the normal force (N) pressing these bodies together.

Mobil 2[illegible] Run 1



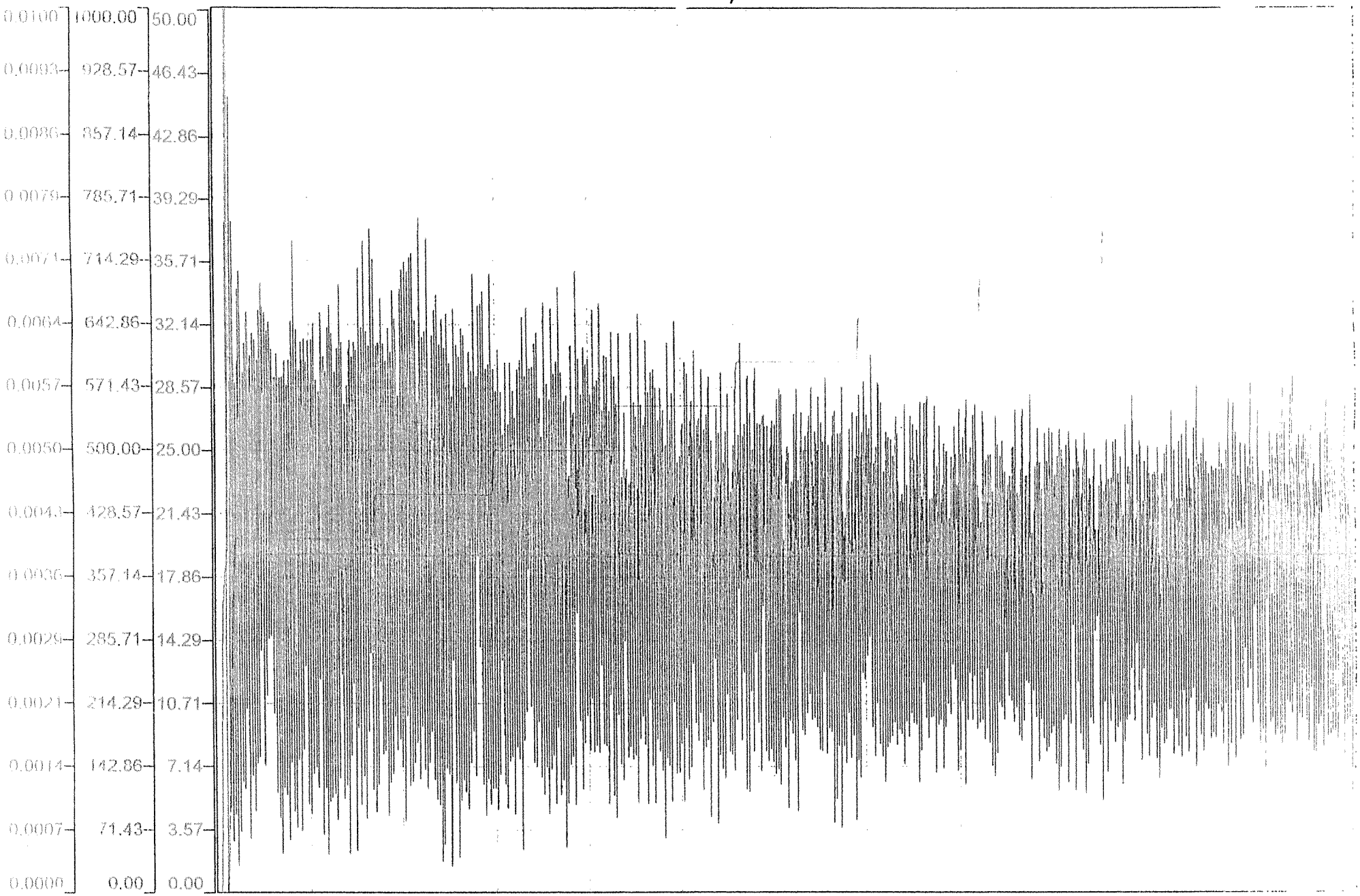
Description	Batch Name	Scale Range	Sample Freq.	Eng. Units	01:24:54
[illegible]OEFFRICT	D&G3B01	0.0000/0.0100	00:00:01		0.0000
[illegible]OAD	D&G3B01	0.00/1000.00	00:00:01	LB	-9.37
[illegible]PEED	D&G3B01	0.00/50.00	00:00:01	RPM	0.00

Mobil 28 Run 2



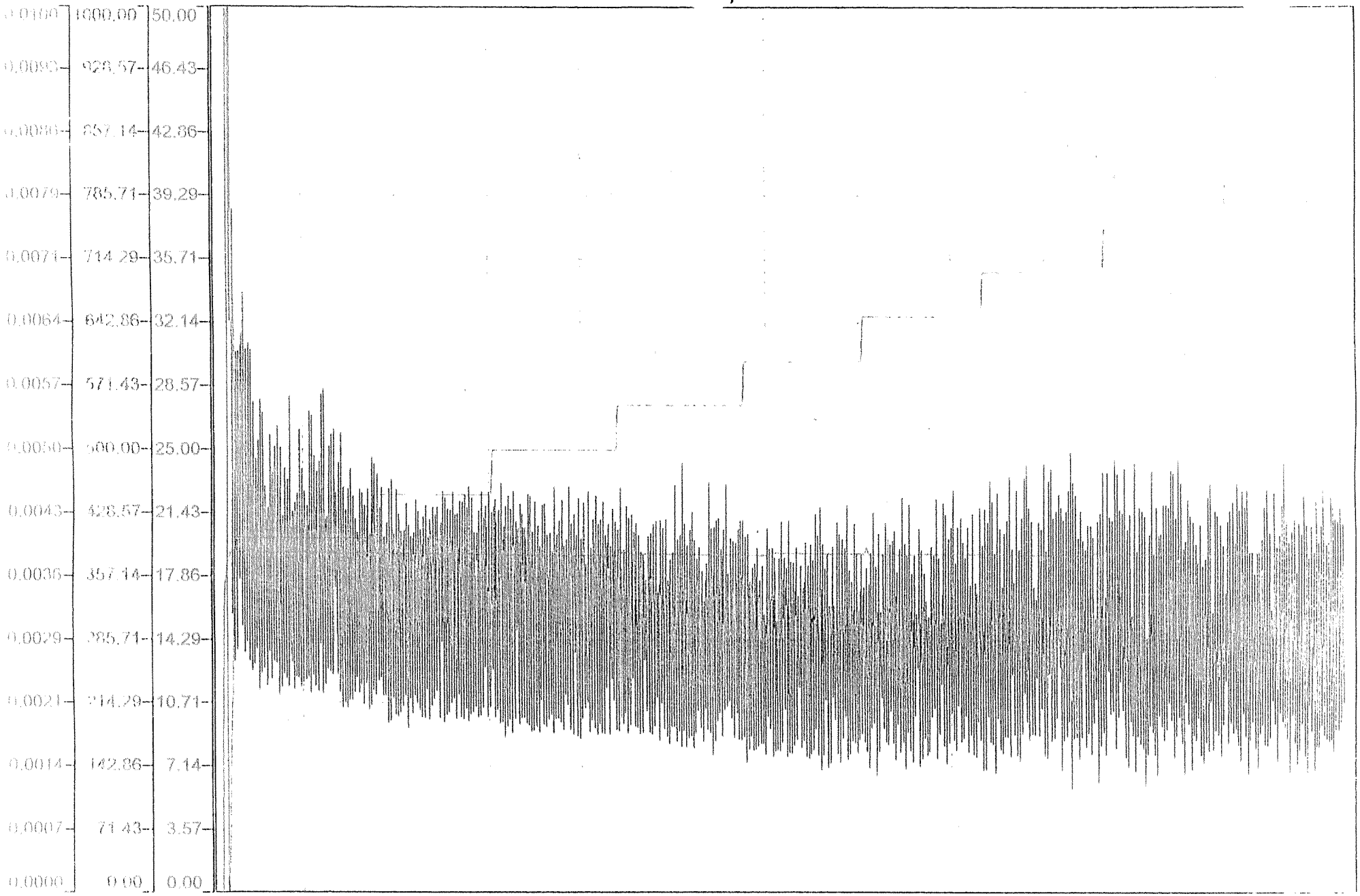
Description	Batch Name	Scale Range	Sample Freq.	Eng. Units	00:55:31
SOLENOID	dg3bl07	0.0000/0.0100	00:00:01		***
	dg3bl07	0.00/1000.00	00:00:01	LB	***
	dg3bl07	0.00/50.00	00:00:01	RPM	***

Aeroshe[redacted]3, run 1



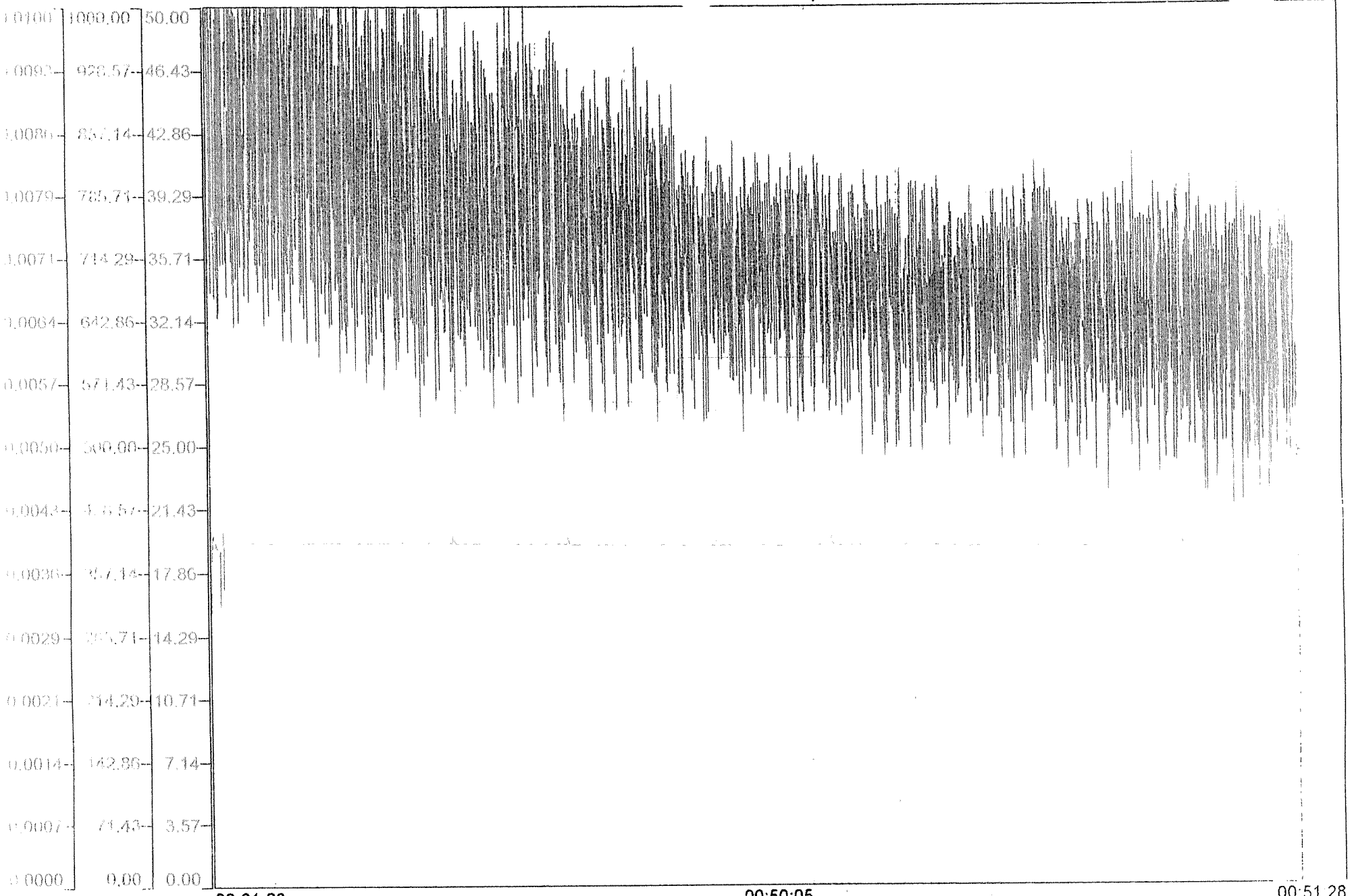
Description	Batch Name	Scale Range	Sample Freq.	Eng. Units	00:48:52
COEF-FRICT	dg3bl03	0.0000/0.0100	00:00:01		***
LOAD	dg3bl03	0.00/1000.00	00:00:01	LB	***
SPEED	dg3bl03	0.00/50.00	00:00:01	RPM	***

Aeroshell , run 2



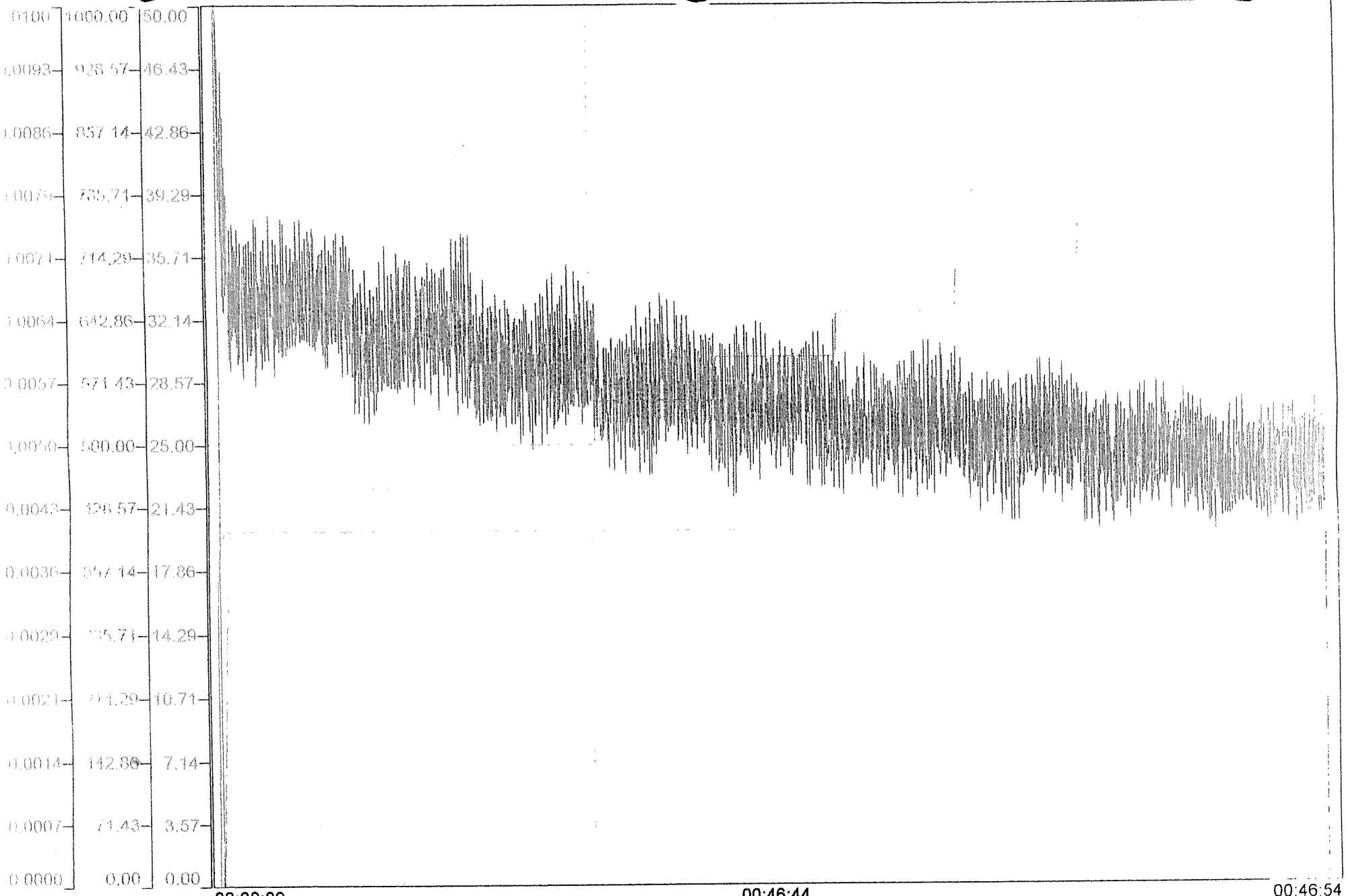
Description	Batch Name	Scale Range	Sample Freq.	Eng. Units	00:49:14
COEFFICT	dg3bl04	0.0000/0.0100	00:00:01		***
LOAD	dg3bl04	0.00/1000.00	00:00:01	LB	***
SPEED	dg3bl04	0.00/50.00	00:00:01	RPM	***

Weathered Aero[redacted]ell 33, run 1



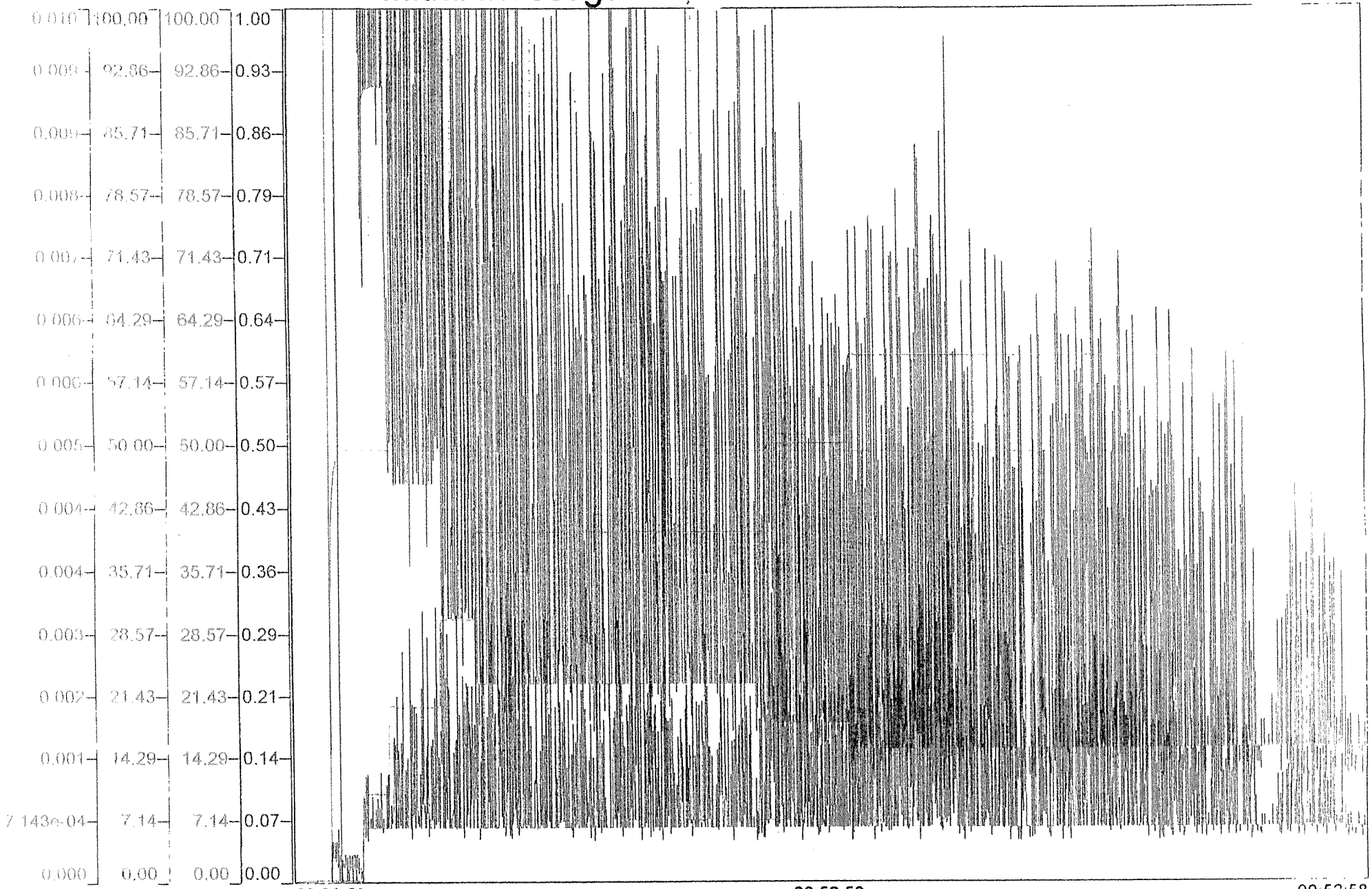
Description	Batch Name	Scale Range	Sample Freq.	Eng. Units	00:51:28
COEF-FRICT	dg3bl05	0.0000/0.0100	00:00:01		***
LOAD	dg3bl05	0.00/1000.00	00:00:01	LB	***
SPEED	dg3bl05	0.00/50.00	00:00:01	RPM	***

Weathered Aero[illegible]ell 33, run 2



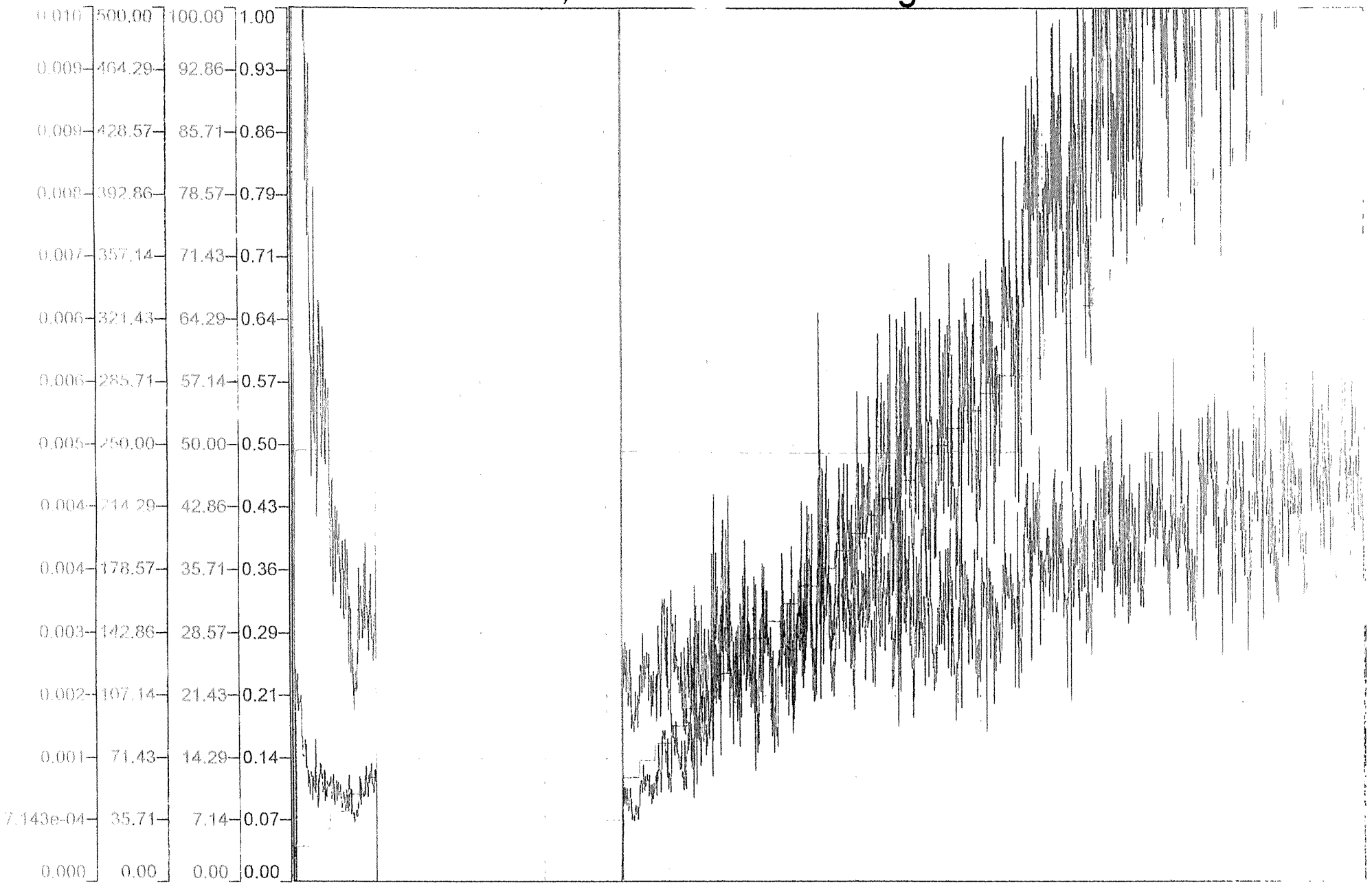
Description	Batch Name	Scale Range	Sample Freq.	Eng. Units
COEF-FRICT	dg3bl06	0.0000/0.0100	00:00:01	
LOAD	dg3bl06	0.00/1000.00	00:00:01	LB
[illegible]	dg3bl06	0.00/50.00	00:00:01	RPM

Initial Investigation, Mobil 28 to 60 lb



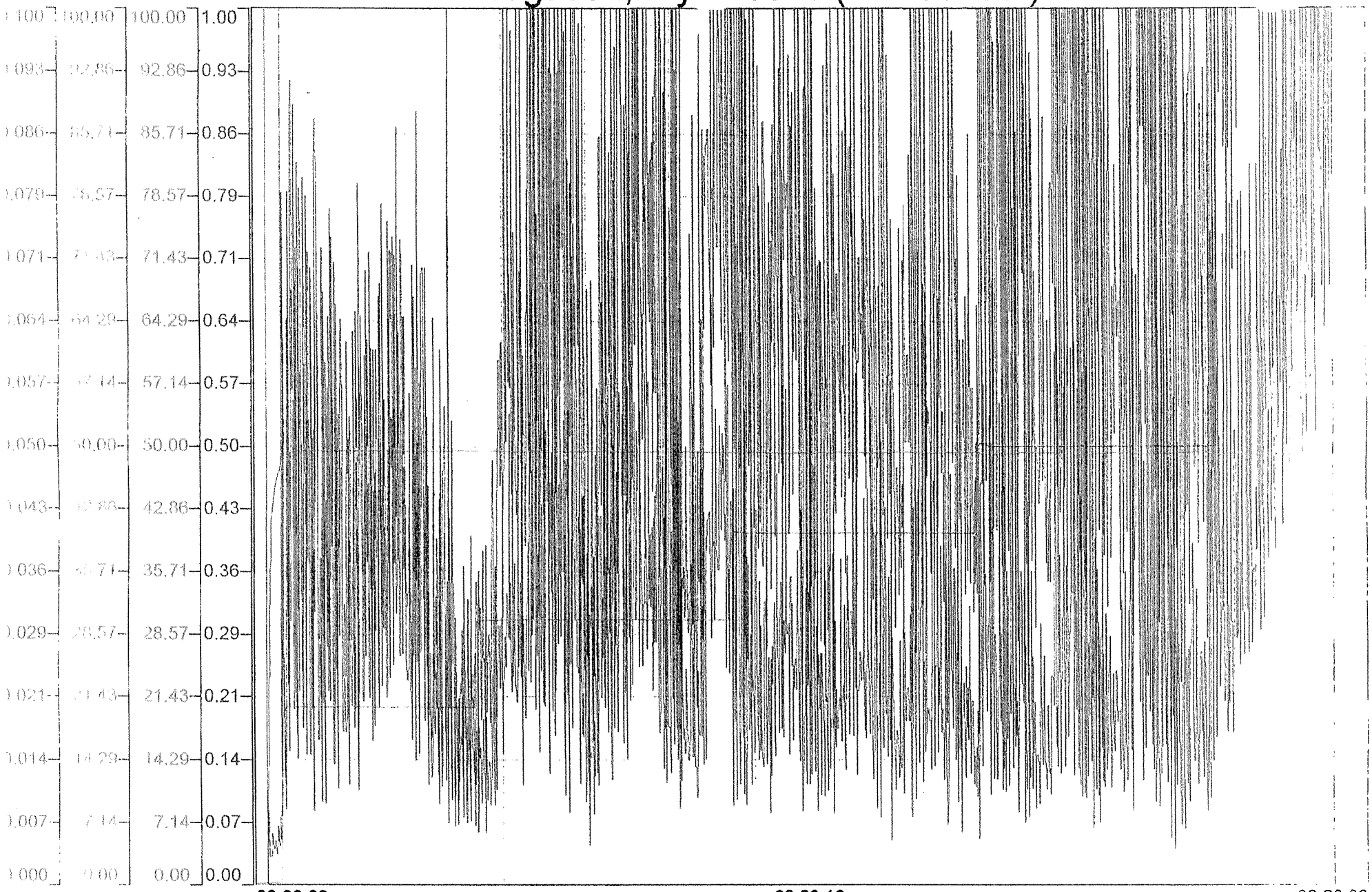
Description	Batch Name	Scale Range	Sample Freq.	Eng. Units	00:52:58
COEF-FRICT	d&g10	0.000/0.010	00:00:01		No Data
LOAD	d&g10	0.00/100.00	00:00:01	LB	No Data
SPEED	d&g10	0.00/100.00	00:00:01	RPM	No Data
TORQUE	d&g10	0.00/1.00	00:00:01	LB-IN.	No Data

Mobil 28, low to [redacted]h load range



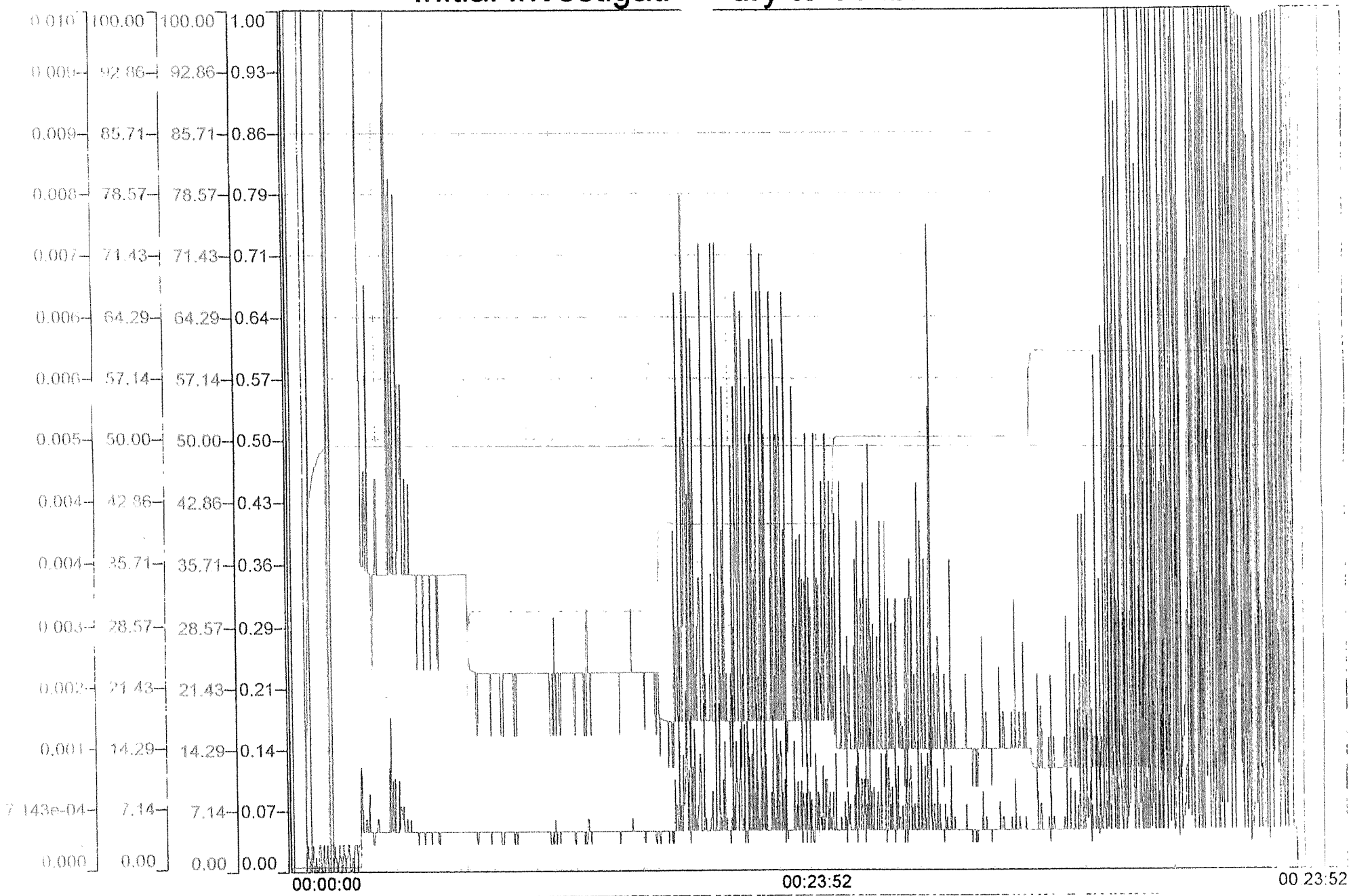
Description	Batch Name	Scale Range	Sample Freq.	Eng. Units	05:41:30
COEF-FRICT	D&G3B00	0.000/0.010	00:00:01		No Data
LOAD	D&G3B00	0.00/500.00	00:00:01	LB	No Data
SPEED	D&G3B00	0.00/100.00	00:00:01	RPM	No Data
TORQUE	D&G3B00	0.00/1.00	00:00:01	LB-IN.	No Data

Initial investigation, dry 60 lb (10# sensor)



Description	Batch Name	Scale Range	Sample Freq.	Eng. Units	00:26:26
COEF-FRICT	3ball10#	0.000/0.100	00:00:01		0.000
VAD	3ball10#	0.00/100.00	00:00:01	LB	-11.25
SPEED	3ball10#	0.00/100.00	00:00:01	RPM	0.00
TORQUE	3ball10#	0.00/1.00	00:00:01	LB-IN.	0.00

Initial Investigati dry to 60 lb.



Description	Batch Name	Scale Range	Sample Freq.	Eng. Units	00:23:52
COEF-FRICT	checkout3ball	0.000/0.010	00:00:01		No Data
LOAD	checkout3ball	0.00/100.00	00:00:01	LB	No Data
SPEED	checkout3ball	0.00/100.00	00:00:01	RPM	No Data
TORQUE	checkout3ball	0.00/1.00	00:00:01	LB-IN.	No Data

B R

Company:	**Dombroff & Gilmore**	Page:	3
Date:	11/9/01	Project #:	01-111
Technician:	M. Rapp		

Test Method:	ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine:	Falex Computer Controlled Block on Ring Test Machine
Serial #:	800135004198

Testing Specimens:

Sample ID:	**Mobil 28**
Falex ID #:	4944
Block Type:	HP Test Block
Material:	C95500 Al Bronze
Finish (µin):	32
Hardness (BHN):	112-123
Falex ID #:	5060
Ring Type:	Falex test ring w/ black oxide coating
Material:	AISI 4140 steel
Finish (µin):	32
Condition	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/8/01
Test Number:	0107406

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3970	22.3889
Final	7.3959	22.3884
Loss	0.0011	0.0005

Block Scar Data

Measurement 1 (mm):	2.920
Measurement 2 (mm):	2.925
Measurement 3 (mm):	2.892
Average Scar (mm):	2.912 = 0.1146"
Standared Deviation:	0.015
Coefficient of Variation (%)	0.499
Volumetric Wear (mm^3):	0.7487
Final Pressure (psi):	12,559

Comments:

Test file: 3704_360.xls
Save file: D&G19

$\left[\frac{87.5\ cpm}{5000}\right]^{-1} = 57\ min$

BR

Company:	**Dombroff & Gilmore**	Page:	6
Date:	11/9/01	Project #:	01-111
Technician:	M. Rapp		

Test Method: ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine: Falex Computer Controlled Block on Ring Test Machine
Serial #: 800135004198

Testing Specimens:

Sample ID: **Mobil 28**
Falex ID #: 4944

Block Type: HP Test Block
Material: C95500 Al Bronze
Finish (µin): 32
Hardness (BHN): 112-123
Falex ID #: 5060
Ring Type: Falex test ring w/ black oxide coating
Material: AISI 4140 steel
Finish (µin): 32
Condition: Nitride, case depth .003-.005
Core strength 160-180 KSI
Falex ID #: 5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/9/01
Test Number:	0107409

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3832	22.3948
Final	7.3731	22.3953
Loss	0.0101	-0.0005

Block Scar Data

Measurement 1 (mm):	3.772
Measurement 2 (mm):	3.745
Measurement 3 (mm):	3.728
Average Scar (mm):	3.748
Standared Deviation:	0.018
Coefficient of Variation (%)	0.483
Volumetric Wear (mm^3):	1.5984
Final Pressure (psi):	9,758

Comments:

Test file: 3704_360.xls
Save file: D&G22

BR

Company:	**Dombroff & Gilmore**	Page:	1
Date:	11/9/01	Project #:	01-111
Technician:	M. Rapp		

Test Method: ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine: Falex Computer Controlled Block on Ring Test Machine
Serial #: 800135004198

Testing Specimens:

Sample ID: **Aeroshell 33**
Falex ID #: 4948

Block Type: HP Test Block
Material: C95500 Al Bronze
Finish (µin): 32
Hardness (BHN): 112-123
Falex ID #: 5060
Ring Type: Falex test ring w/ black oxide coating
Material: AISI 4140 steel
Finish (µin): 32
Condition: Nitride, case depth .003-.005
Core strength 160-180 KSI
Falex ID #: 5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/7/01
Test Number:	0107404

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3967	22.3395
Final	7.3835	22.3386
Loss	0.0132	0.0009

Block Scar Data

Measurement 1 (mm):	3.994
Measurement 2 (mm):	3.965
Measurement 3 (mm):	3.942
Average Scar (mm):	3.967
Standared Deviation:	0.021
Coefficient of Variation (%)	0.536 ✓
Volumetric Wear (mm^3):	1.8956
Final Pressure (psi):	9,220

Comments:

Test file: 3704_360.xls
Save file: D&G17

BR

Company:	**Dombroff & Gilmore**	Page:	4
Date:	11/9/01	Project #:	01-111
Technician:	M. Rapp		

Test Method: ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine: Falex Computer Controlled Block on Ring Test Machine
Serial #: 800135004198

Testing Specimens:

Sample ID: **Aeroshell 33**
Falex ID #: 4948

Block Type: HP Test Block
Material: C95500 Al Bronze
Finish (µin): 32
Hardness (BHN): 112-123
Falex ID #: 5060
Ring Type: Falex test ring w/ black oxide coating
Material: AISI 4140 steel
Finish (µin): 32
Condition: Nitride, case depth .003-.005
Core strength 160-180 KSI
Falex ID #: 5150

Testing Conditions:

Speed (cpm): 87.5
Temperature (°C): Ambient
Load (lb): 360
Duration (cycles): 5000
Oscillation Angle: 90°

Test Date: 11/8/01
Test Number: 0107407

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.4128	22.3062
Final	7.4017	22.3065
Loss	0.0111	-0.0003

Block Scar Data

Measurement 1 (mm):	3.919
Measurement 2 (mm):	3.850
Measurement 3 (mm):	3.768
Average Scar (mm):	3.846
Standared Deviation:	0.062
Coefficient of Variation (%)	1.605
Volumetric Wear (mm^3):	1.7265
Final Pressure (psi):	9,511

Comments:

Test file: 3704_360.xls
Save file: D&G20

BR

Company:	**Dombroff & Gilmore**	Page:	2
Date:	11/9/01	Project #:	01-111
Technician:	M. Rapp		

Test Method:	ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine:	Falex Computer Controlled Block on Ring Test Machine
Serial #:	800135004198

Testing Specimens:

Sample ID:	**Weathered Aeroshell 33**
Falex ID #:	4949
Block Type:	HP Test Block
Material:	C95500 Al Bronze
Finish (µin):	32
Hardness (BHN):	112-123
Falex ID #:	5060
Ring Type:	Falex test ring w/ black oxide coating
Material:	AISI 4140 steel
Finish (µin):	32
Condition	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/8/01
Test Number:	0107405

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3742	22.3452
Final	7.3658	22.3440
Loss	0.0084	0.0012

Block Scar Data

Measurement 1 (mm):	3.952
Measurement 2 (mm):	3.927
Measurement 3 (mm):	3.923
Average Scar (mm):	3.934
Standared Deviation:	0.013
Coefficient of Variation (%)	0.326
Volumetric Wear (mm^3):	1.8486
Final Pressure (psi):	9,297

Comments:

Test file: 3704_360.xls
Save file: D&G18

Company:	**Dombroff & Gilmore**	Page:	5
Date:	11/9/01	Project #:	01-111
Technician:	M. Rapp		

Test Method:	ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine:	Falex Computer Controlled Block on Ring Test Machine
Serial #:	800135004198

Testing Specimens:

Sample ID:	**Weathered Aeroshell 33**
Falex ID #:	4949
Block Type:	HP Test Block
Material:	C95500 Al Bronze
Finish (µin):	32
Hardness (BHN):	112-123
Falex ID #:	5060
Ring Type:	Falex test ring w/ black oxide coating
Material:	AISI 4140 steel
Finish (µin):	32
Condition	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/9/01
Test Number:	0107408

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3900	22.3492
Final	7.3788	22.3489
Loss	0.0112	0.0003

Block Scar Data

Measurement 1 (mm):	3.823
Measurement 2 (mm):	3.821
Measurement 3 (mm):	3.801
Average Scar (mm):	3.815
Standared Deviation:	0.010
Coefficient of Variation (%)	0.260
Volumetric Wear (mm^3):	1.6855
Final Pressure (psi):	9,587

Comments:

Test file: 3704_360.xls
Save file: D&G21

Company:	**Dombroff & Gilmore**	Page:	8
Date:	11/19/01	Project #:	01-111
Technician:	D. Hlavacek		

Method:	ASTM D 2509, Measurement of Load-Carrying Capacity of Lubricating Grease
Machine:	Falex Timken Test Machine
Serial #:	002-93-574

Test Specimen:

Sample ID:	**Mobil 28**
Falex ID #:	4944
Block Material:	Alu. Brnz. #C95500
Finish (µin):	32
Hardness (Rc):	As Supplied
Falex ID:	5061
Ring Material:	4140 Steel
Finish (µin):	32 (Black Oxide)
Hardness (Rc):	Case, 160-180-KSI

Test Conditions:

Speed (rpm):	800 (± 5)
Temperature (°C):	37.8 (± 2.8)
Load (lb):	Various
Break-In (sec):	30
Duration (min):	10 / load stage
Test Date:	11/13/01
Test Number:	0202117

Test Results:

Applied Load, lb	Block Number	Result, (P)ass/(F)ail	Average Scar, mm	Coefficient of Friction
30	1	P	3.828	0.081
40	1	P	4.594	
50	1	P	5.222	
60	1	P	6.075	

OK Load (lb):	**60**	Contact Pressure at OK load: 5017.3
Score Load (lb):	**N/A**	
Scar Width at OK Load (mm):	**6.075**	

Comments:

OK Load Value
The maximum load added to the lever system at which no scoring or seizure occurs. This load reflects the load carrying capacity of the lubricant.

Score Load Value
The minimum load added to the lever system at which scoring or seizure occurs.

Scar Width at OK Load
The average scar width at the load corresponding to the OK Load Value.

Company:	**Dombroff & Gilmore**	Page:	2
Date:	12/4/01	Project #:	01-111
Technician:	D. Hlavacek		

Method:	ASTM D 2509, Measurement of Load-Carrying Capacity of Lubricating Grease
Machine:	Falex Timken Test Machine
Serial #:	002-93-574

Test Specimen:

Sample ID:	**Mobil 28**
Falex ID #:	4944
Block Material:	Alu. Brnz. #C95500
Finish (µin):	32
Hardness (Rc):	As Supplied
Falex ID:	5061
Ring Material:	4140 Steel
Finish (µin):	32 (Black Oxide)
Hardness (Rc):	Case, 160-180-KSI

Test Conditions:

Speed (rpm):	800 (± 5)
Temperature (°C):	37.8 (± 2.8)
Load (lb):	Various
Break-In (sec):	30
Duration (min):	10 / load stage
Test Date:	12/3/01
Test Number:	0202120

Test Results:

Applied Load, lb	Block Number	Result, (P)ass/(F)ail	Average Scar, mm	Coefficient of Friction
30	1	P	4.075	0.079
40	1	P	3.863	0.0690
50	1	P	4.880	0.059
60	1	P	6.155	

OK Load (lb):	**60**
Score Load (lb):	**N/A**
Scar Width at OK Load (mm):	**6.155**

Contact Pressure at OK load: 4952.1

Comments:

OK Load Value
The maximum load added to the lever system at which no scoring or seizure occurs. This load reflects the load carrying capacity of the lubricant.

Score Load Value
The minimum load added to the lever system at which scoring or seizure occurs.

Scar Width at OK Load
The average scar width at the load corresponding to the OK Load Value.

Company:	**Dombroff & Gilmore**	Page:	7
Date:	11/19/01	Project #:	01-111
Technician:	D. Hlavacek		

Method:	ASTM D 2509, Measurement of Load-Carrying Capacity of Lubricating Grease
Machine:	Falex Timken Test Machine
Serial #:	002-93-574

Test Specimen:

Sample ID:	**Aeroshell 33**
Falex ID #:	4948
Block Material:	Alu. Brnz. #C95500
Finish (µin):	32
Hardness (Rc):	As Supplied
Falex ID:	5061
Ring Material:	4140 Steel
Finish (µin):	32 (Black Oxide)
Hardness (Rc):	Case, 160-180-KSI

Test Conditions:

Speed (rpm):	800 (± 5)
Temperature (°C):	37.8 (± 2.8)
Load (lb):	Various
Break-In (sec):	30
Duration (min):	10 / load stage
Test Date:	11/13/01
Test Number:	0202116

Test Results:

Applied Load, lb	Block Number	Result, (P)ass/(F)ail	Average Scar, mm	Coefficient of Friction
30	1	P	5.702	0.153
40	1	P	N/A	
50	1	P	N/A	
60	1	P	N/A	

OK Load (lb):	**30**	Contact Pressure at OK load:
Score Load (lb):	**N/A**	2672.8
Scar Width at OK Load (mm):	**5.702**	

Comments: 40, 50, and 60 Lb. loads produced immesureable scars, where the scar continued off the edge of the block.

OK Load Value
The maximum load added to the lever system at which no scoring or seizure occurs. This load reflects the load carrying capacity of the lubricant.

Score Load Value
The minimum load added to the lever system at which scoring or seizure occurs.

Scar Width at OK Load
The average scar width at the load corresponding to the OK Load Value.

Company:	**Dombroff & Gilmore**	Page:	1
Date:	12/4/01	Project #:	01-111
Technician:	D. Hlavacek		

Method:	ASTM D 2509, Measurement of Load-Carrying Capacity of Lubricating Grease
Machine:	Falex Timken Test Machine
Serial #:	002-93-574

Test Specimen:

Sample ID:	**Aeroshell 33**
Falex ID #:	4948
Block Material:	Alu. Brnz. #C95500
Finish (µin):	32
Hardness (Rc):	As Supplied
Falex ID:	5061
Ring Material:	4140 Steel
Finish (µin):	32 (Black Oxide)
Hardness (Rc):	Case, 160-180-KSI

Test Conditions:

Speed (rpm):	800 (± 5)
Temperature (°C):	37.8 (± 2.8)
Load (lb):	Various
Break-In (sec):	30
Duration (min):	10 / load stage
Test Date:	11/30/01
Test Number:	0202119

Test Results:

Applied Load, lb	Block Number	Result, (P)ass/(F)ail	Average Scar, mm	Coefficient of Friction
30	1	P	5.453	0.152

OK Load (lb):	**30**	Contact Pressure at OK load: 2794.8
Score Load (lb):	**N/A**	
Scar Width at OK Load (mm):	**5.453**	

Comments:

OK Load Value
The maximum load added to the lever system at which no scoring or seizure occurs. This load reflects the load carrying capacity of the lubricant.

Score Load Value
The minimum load added to the lever system at which scoring or seizure occurs.

Scar Width at OK Load
The average scar width at the load corresponding to the OK Load Value.

Company:	**Dombroff & Gilmore**	Page:	9
Date:	11/19/01	Project #:	01-111
Technician:	D. Hlavacek		

Method:	ASTM D 2509, Measurement of Load-Carrying Capacity of Lubricating Grease
Machine:	Falex Timken Test Machine
Serial #:	002-93-574

Test Specimen:

Sample ID:	**Aeroshell 33 Weathered**
Falex ID #:	4944
Block Material:	Alu. Brnz. #C95500
Finish (µin):	32
Hardness (Rc):	As Supplied
Falex ID:	5061
Ring Material:	4140 Steel
Finish (µin):	32 (Black Oxide)
Hardness (Rc):	Case, 160-180-KSI

Test Conditions:

Speed (rpm):	800 (± 5)
Temperature (°C):	37.8 (± 2.8)
Load (lb):	Various
Break-In (sec):	30
Duration (min):	10 / load stage
Test Date:	11/14/01
Test Number:	0202118

Test Results:

Applied Load, lb	Block Number	Result, (P)ass/(F)ail	Average Scar, mm	Coefficient of Friction
30	1	P	5.267	0.152
40	1	P	5.992	0.1370
50	1	P	6.238	

OK Load (lb):	**50**	Contact Pressure at OK load: 4071.8
Score Load (lb):	**0**	
Scar Width at OK Load (mm):	**6.238**	

Comments:

OK Load Value
The maximum load added to the lever system at which no scoring or seizure occurs. This load reflects the load carrying capacity of the lubricant.

Score Load Value
The minimum load added to the lever system at which scoring or seizure occurs.

Scar Width at OK Load
The average scar width at the load corresponding to the OK Load Value.

Company:	**Dombroff & Gilmore**	Page:	1
Date:	12/4/01	Project #:	01-111
Technician:	D. Hlavacek		

Method:	ASTM D 2509, Measurement of Load-Carrying Capacity of Lubricating Grease
Machine:	Falex Timken Test Machine
Serial #:	002-93-574

Test Specimen:

Sample ID:	**Aeroshell 33 Weathered**
Falex ID #:	4950
Block Material:	Alu. Brnz. #C95500
Finish (µin):	32
Hardness (Rc):	As Supplied
Falex ID:	5061
Ring Material:	4140 Steel
Finish (µin):	32 (Black Oxide)
Hardness (Rc):	Case, 160-180-KSI

Test Conditions:

Speed (rpm):	800 (± 5)
Temperature (°C):	37.8 (± 2.8)
Load (lb):	Various
Break-In (sec):	30
Duration (min):	10 / load stage
Test Date:	12/3/01
Test Number:	0202121

Test Results:

Applied Load, lb	Block Number	Result, (P)ass/(F)ail	Average Scar, mm	Coefficient of Friction
30	1	P	5.194	0.146

OK Load (lb):	**30**	Contact Pressure at OK load: 2934.2
Score Load (lb):	**0**	
Scar Width at OK Load (mm):	**5.194**	

Comments:

OK Load Value
The maximum load added to the lever system at which no scoring or seizure occurs. This load reflects the load carrying capacity of the lubricant.

Score Load Value
The minimum load added to the lever system at which scoring or seizure occurs.

Scar Width at OK Load
The average scar width at the load corresponding to the OK Load Value.

T. W.

Company:	***Dombroff & Gilmore***	Page:	1
Date:	12/10/01	Project #:	01-111
Technician	N. Pekoc		

Method:	Modified Thrust Washer
Machine:	Falex High Performance Multi-Specimen Test Machine, Computer Controlled Version
Serial #:	809C35001108

TEST SPECIMENS:

Upper Material:	**C95500 Al Bronze**
Finish (μ in.):	32
Hardness (BHN):	112-123
Falex ID #:	5172
Lower Material:	**AISI 4140 Steel, oxide coated**
Finish (μ in.):	32
Hardness:	Nitride, case depth .003-.005 core strength 160-180 ksi
Falex ID #:	5164

TEST CONDITIONS:

Test Speed (rpm):	5
Temperature (°C):	Ambient
Duration:	1 min/stage
Test Load (lb):	**200 to 2200**
Mean Test Radius (in):	0.531

Test Results:

Test Date:	11/20/01	11/21/01	11/21/01	11/21/01
Test Number:	09042	09045	09043	09046
Lubricant:	**Mobil 28**	**Mobil 28**	**Aeroshell 33**	**Aeroshell 33**
Lubricant Falex ID #:	4944	4944	4948	4948
SaveFile Name:	DGBRNZTHRW1	DGBRNZTHRW4	DGBRNZTHRW2	DGBRNZTHRW5
Test Program Name:	DGSTLTHRW	DGSTLTHRW	DGSTLTHRW	DGSTLTHRW
Mass Loss, Upper (g):	0.0002	0.0005	0.0001	0.0007
Mass Loss, Lower (g):	0.0012	0.0006	0.001	0.0017
Load Step, N	CoF	CoF	CoF	CoF
889 (200 lb.)	0.151	0.144	0.136	0.133
1334 (300 lb.)	0.130	0.135	0.133	0.130
1779 (400 lb.)	0.126	0.141	0.128	0.126
2224 (500 lb.)	0.125	0.141	0.126	0.121
2669 (600 lb.)	0.125	0.138	0.121	0.115
3114 (700 lb.)	0.124	0.133	0.122	0.112
3559 (800 lb.)	0.122	0.132	0.125	0.122
4003 (900 lb.)	0.118	0.131	0.129	0.118
4448 (1000 lb.)	0.116	0.127	0.130	0.116
4893 (1100 lb.)	0.114	0.117	0.129	0.117
5338 (1200 lb.)	0.110	0.118	0.129	0.120
5783 (1300 lb.)	0.107	0.119	0.125	0.125
6228 (1400 lb.)	0.106	0.112	0.126	0.131
6672 (1500 lb.)	0.106	0.104	0.128	0.133
7117 (1600 lb.)	0.105	0.104	0.128	0.155
7562 (1700 lb.)	0.106	0.108	0.129	0.152
8007 (1800 lb.)	0.112	0.100	0.129	0.150
8452 (1900 lb.)	0.128	0.098	0.128	0.173
8896 (2000 lb.)	0.161	0.098	0.130	0.168
9341 (2100 lb.)		0.101	0.135	0.168
9786 (2200 lb.)		0.143	0.140	0.171

Comments: This is Preliminary testing to find friction characteristics of these greases.
See Graphs for Torque, Friction Coefficient, Load, Speed, and Specimen Temperature trends.

T. W.

Company:	***Dombroff & Gilmore***	Page:	2
Date:	12/10/01	Project #:	01-111
Technician	N. Pekoc		

Method:	Modified Thrust Washer
Machine:	Falex High Performance Multi-Specimen Test Machine, Computer Controlled Version
Serial #:	809C35001108

TEST SPECIMENS:

Upper Material:	**C95500 Al Bronze**
Finish (μ in.):	32
Hardness (BHN):	112-123
Falex ID #:	5172
Lower Material:	**AISI 4140 Steel, oxide coated**
Finish (μ in.):	32
Hardness:	Nitride, case depth .003-.005 *core strength 160-180 ksi*
Falex ID #:	5164

TEST CONDITIONS:

Test Speed (rpm):	5
Temperature (°C):	Ambient
Duration:	1 min/stage
Test Load (lb):	**200 to 2200**
Mean Test Radius (in):	0.531

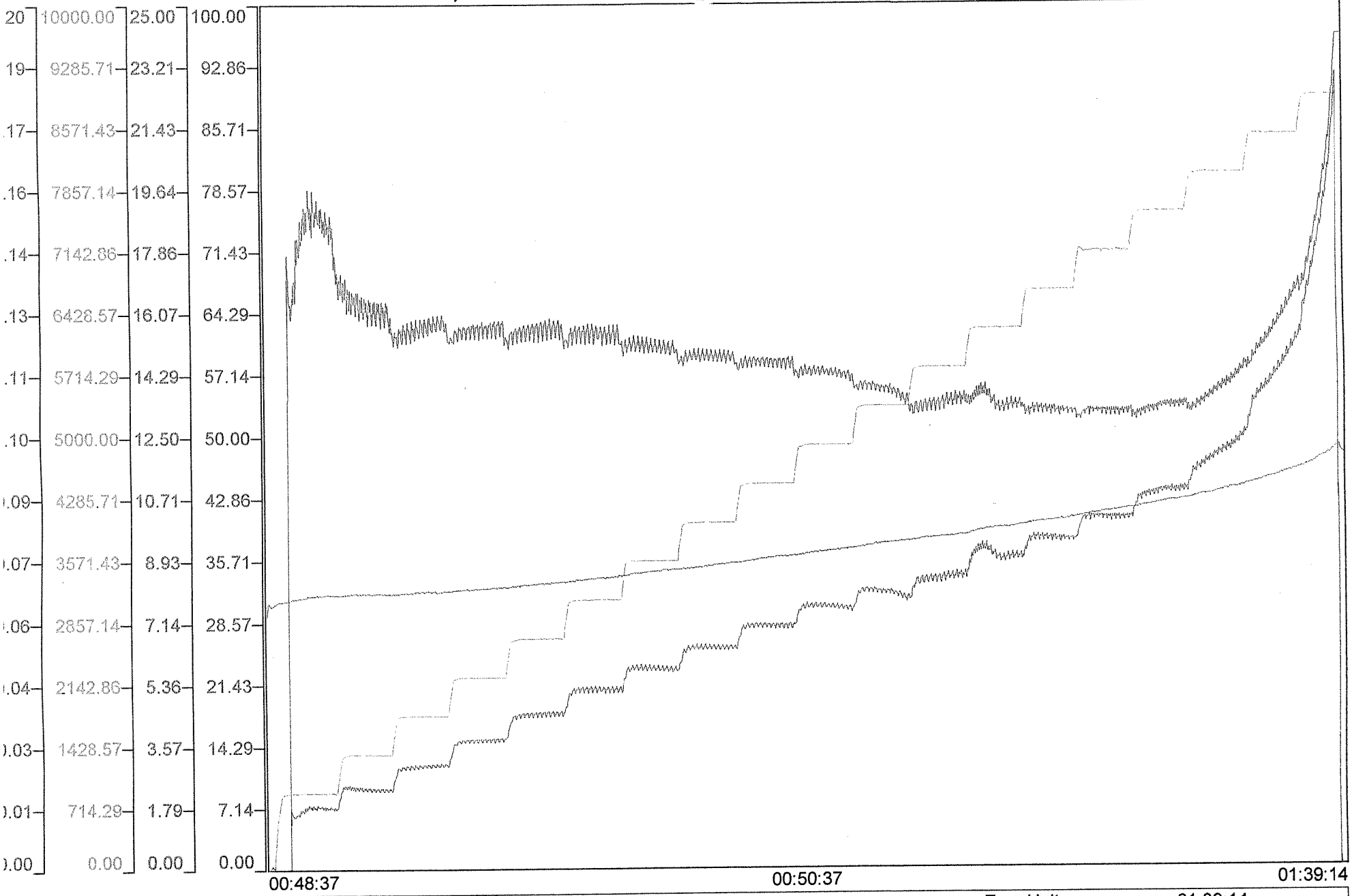
Test Results:

Test Date:	11/21/01	11/21/01
Test Number:	9044	9047
Lubricant:	**Aeroshell 33 weathered**	**Aeroshell 33 weathered**
Lubricant Falex ID #:		
SaveFile Name:	DGBRNZTHRW3	DGBRNZTHRW6
Test Program Name:	DGSTLTHRW	DGSTLTHRW
Mass Loss, Upper (g):	-0.0006	0.0003
Mass Loss, Lower (g):	-0.0008	0.0007

Load Step, N	CoF	CoF
889 (200 lb.)	0.144	0.143
1334 (300 lb.)	0.136	0.145
1779 (400 lb.)	0.136	0.136
2224 (500 lb.)	0.140	0.127
2669 (600 lb.)	0.129	0.120
3114 (700 lb.)	0.153	0.117
3559 (800 lb.)	0.192	0.117
4003 (900 lb.)	0.219	0.119
4448 (1000 lb.)		0.121
4893 (1100 lb.)		0.129
5338 (1200 lb.)		0.120
5783 (1300 lb.)		0.110
6228 (1400 lb.)		0.116
6672 (1500 lb.)		0.143
7117 (1600 lb.)		0.139
7562 (1700 lb.)		0.171
8007 (1800 lb.)		0.167
8452 (1900 lb.)		0.180
8896 (2000 lb.)		
9341 (2100 lb.)		
9786 (2200 lb.)		

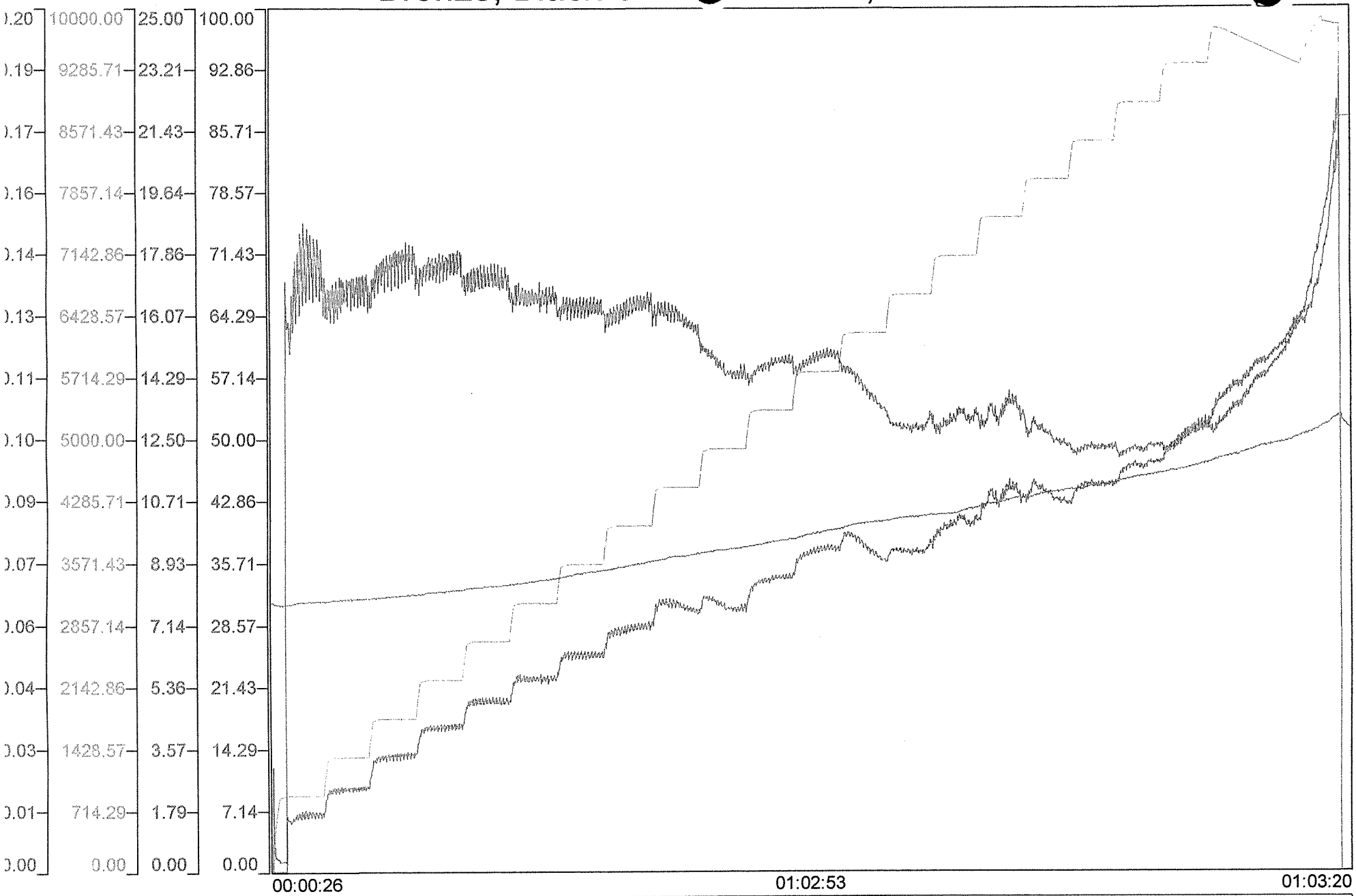
Comments: This is Preliminary testing to find friction characteristics of these greases.
See Graphs for Torque, Friction Coefficient, Load, Speed, and Specimen Temperature trends.

Bronze, Black Oxide, Mobil 28, HL, run 1



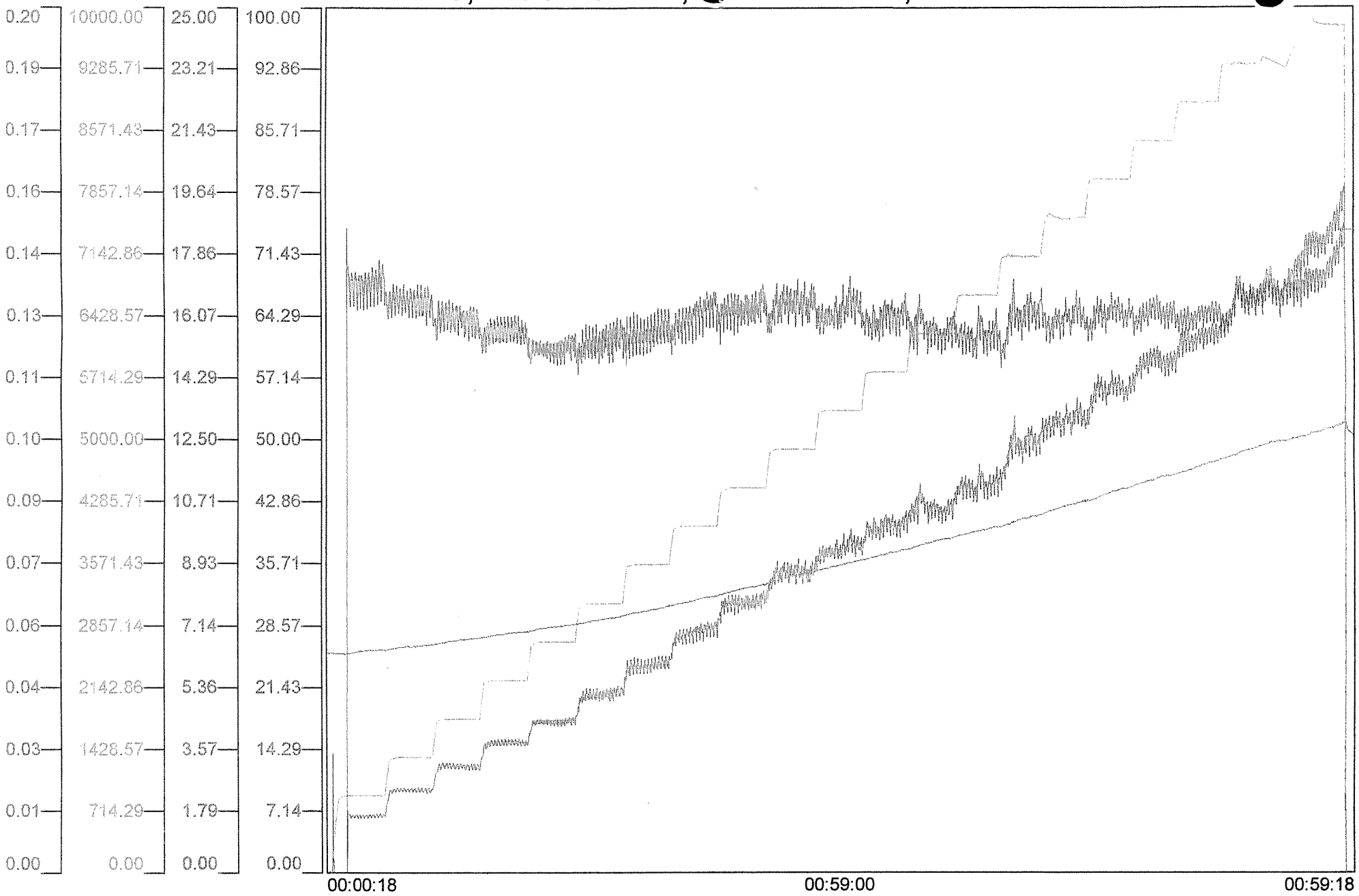
Description	Batch Name	Scale Range	Eng. Units	01:39:14
COEFFICIENT OF FRICTION	dgbrnzthrw1	0.00/0.20	Coef	0.19
SPECIMEN LOAD	dgbrnzthrw1	0.00/10000.00	N	0.00
TORQUE	dgbrnzthrw1	0.00/25.00	N-m	-6.93e-03
INTERFACE TEMP.	dgbrnzthrw1	0.00/100.00	DEG.C	47.38

Bronze, Black Oxid Mobil 28, run 2



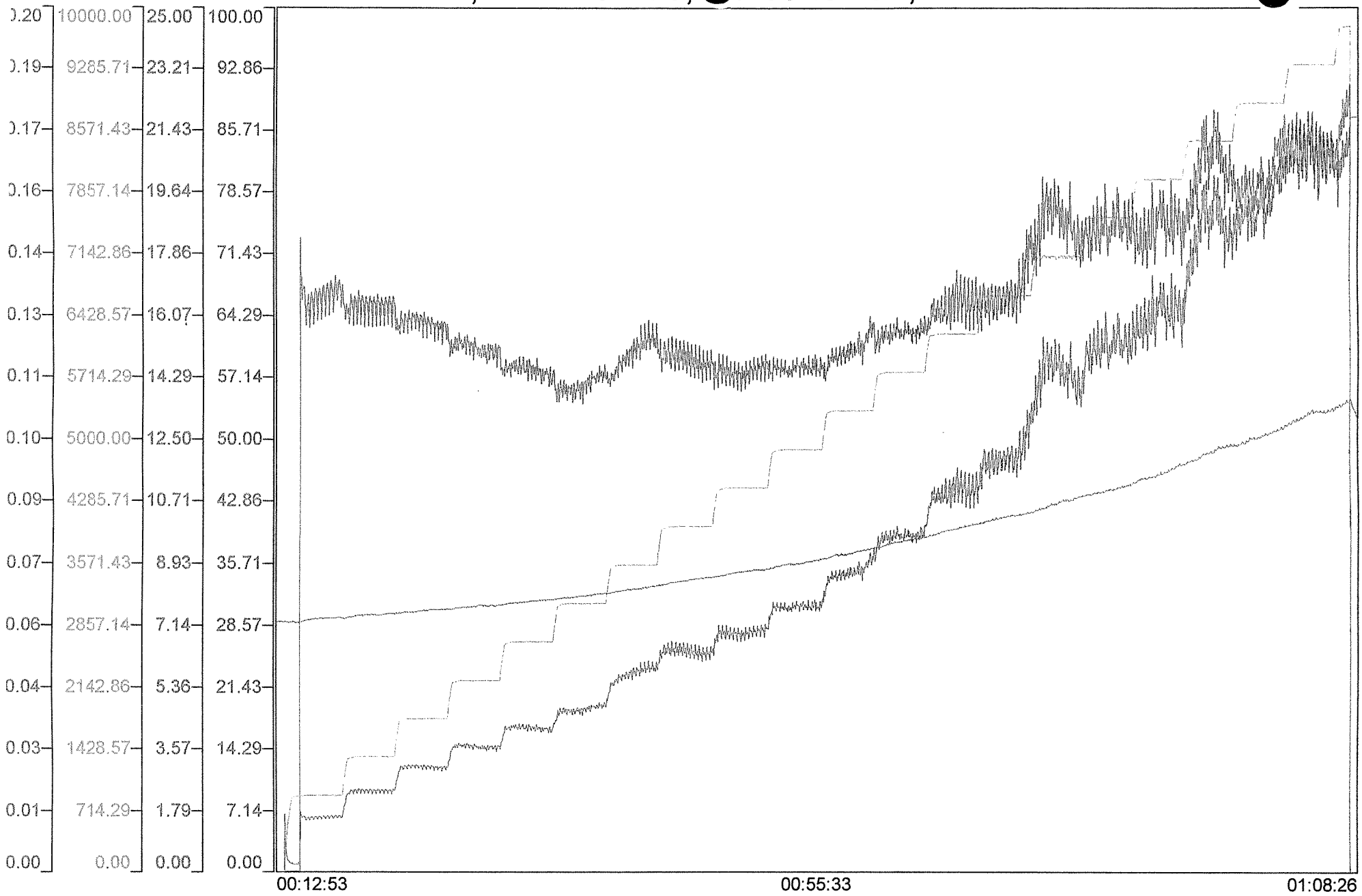
Description	Batch Name	Scale Range	Eng. Units	01:03:20
COEFFICIENT OF FRICTION	dgbrnzthrw4	0.00/0.20	Coef	0.17
SPECIMEN LOAD	dgbrnzthrw4	0.00/10000.00	N	0.00
TORQUE	dgbrnzthrw4	0.00/25.00	N-m	0.00
NTERFACE TEMP.	dgbrnzthrw4	0.00/100.00	DEG.C	50.99

Bronze, Black Oxide, [illegible]eroshell 33, run 1



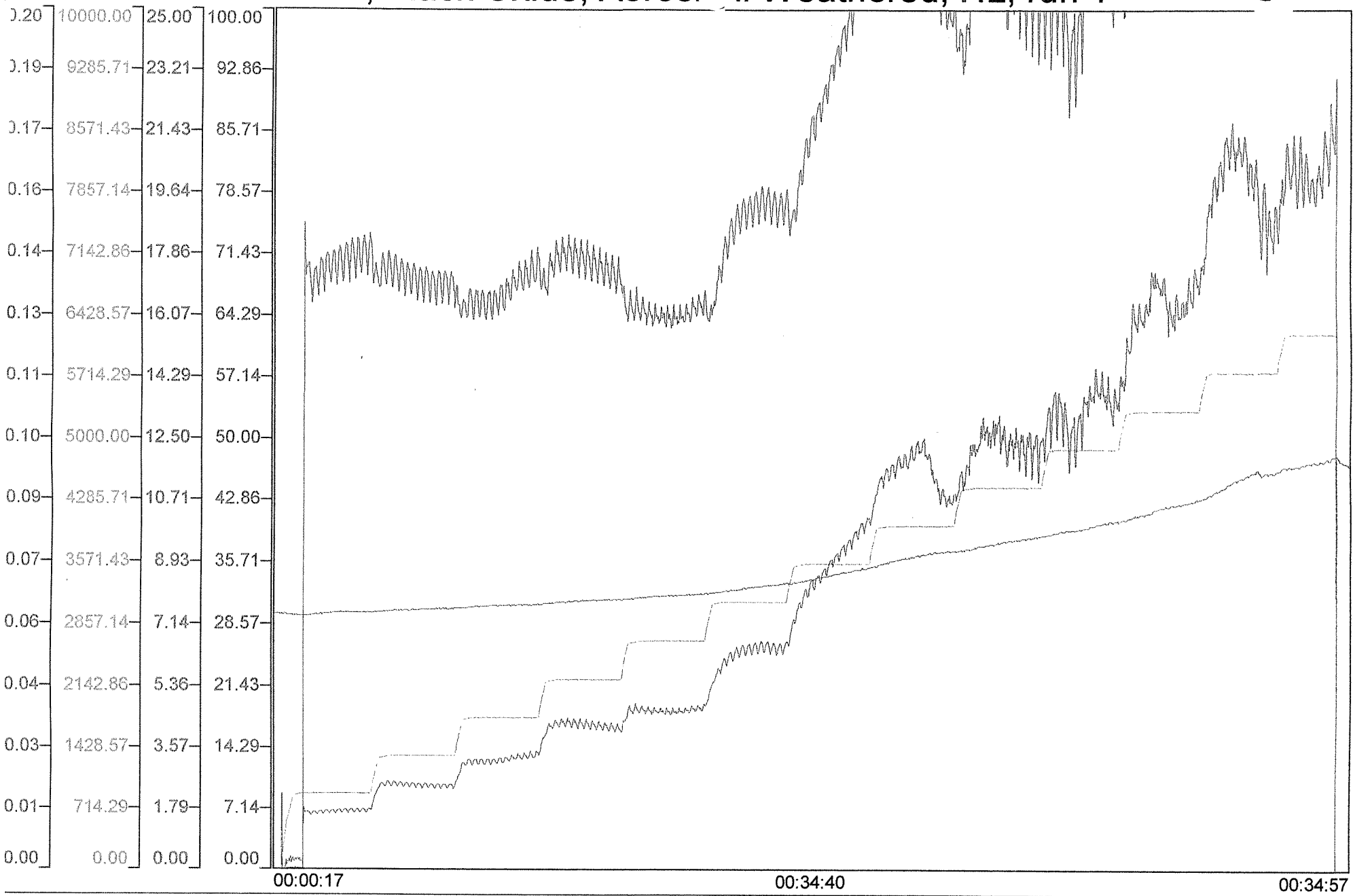
Description	Batch Name	Scale Range	Eng. Units	00:59:18
COEFFICIENT OF FRICTION	dgbrnzthrw2	0.00/0.20	Coef	***
SPECIMEN LOAD	dgbrnzthrw2	0.00/10000.00	N	***
TORQUE	dgbrnzthrw2	0.00/25.00	N-m	***
INTERFACE TEMP.	dgbrnzthrw2	0.00/100.00	DEG.C	***

Bronze, Black Oxide, [illegible]eroshell 33, run 2



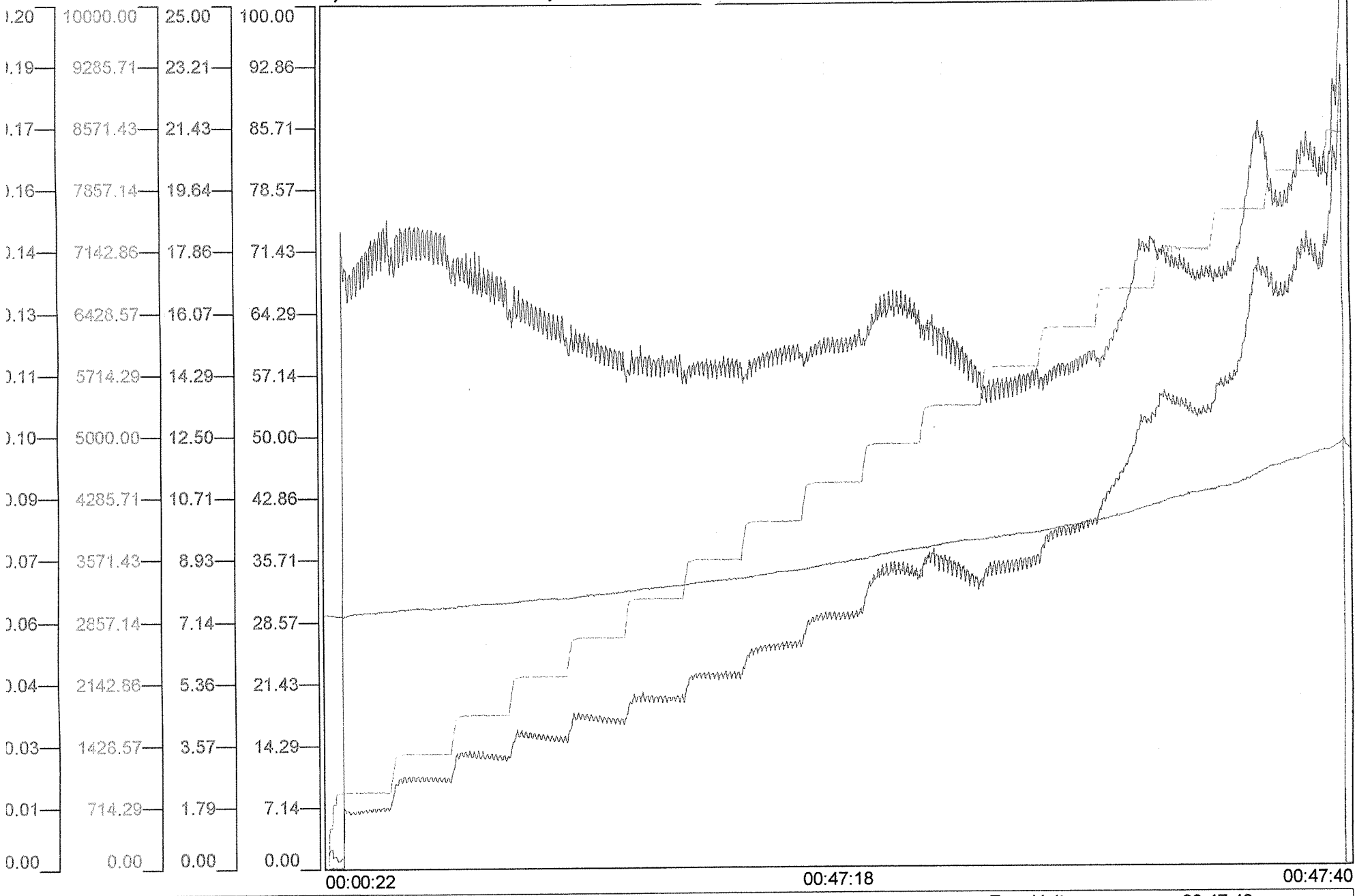
Description	Batch Name	Scale Range	Eng. Units	01:08:26
COEFFICIENT OF FRICTION	dgbrnzthrw5	0.00/0.20	Coef	0.17
SPECIMEN LOAD	dgbrnzthrw5	0.00/10000.00	N	0.00
TORQUE	dgbrnzthrw5	0.00/25.00	N-m	5.98e-04
INTERFACE TEMP.	dgbrnzthrw5	0.00/100.00	DEG.C	52.40

Bronze, Black Oxide, Aeros[illegible]ll Weathered, HL, run 1



Description	Batch Name	Scale Range	Eng. Units	00:34:57
COEFFICIENT OF FRICTION	dgbrnzthrw3	0.00/0.20	Coef	0.28
SPECIMEN LOAD	dgbrnzthrw3	0.00/10000.00	N	0.00
TORQUE	dgbrnzthrw3	0.00/25.00	N-m	0.00
NTERFACE TEMP.	dgbrnzthrw3	0.00/100.00	DEG.C	46.91

Bronze, Black Oxide, Aeroshe 33 Weathered, HL, run 2



Description	Batch Name	Scale Range	Eng. Units	00:47:40
COEFFICIENT OF FRICTION	dgbrnzthrw6	0.00/0.20	Coef	***
SPECIMEN LOAD	dgbrnzthrw6	0.00/10000.00	N	***
TORQUE	dgbrnzthrw6	0.00/25.00	N-m	***
NTERFACE TEMP.	dgbrnzthrw6	0.00/100.00	DEG.C	***

Pin on Disk

COMPANY: **Dombroff & Gilmore**
DATE: 12/6/01
TECHNICIAN: M. Rapp

MACHINE: Falex-ISC Pin On Disk Tribometer System, S/N 808020000045
METHOD: ASTM G99 Modified

TEST CONDITIONS:

TEST SPEED (rpm):	20	PIN MATERIAL:	Al Bronze
TEMPERATURE (°C):	Ambient	PIN GRADE:	C95500
DURATION (min):	75	PIN POSITION:	90
TEST LOAD (grams):	100/ increments of 100	PIN TL#	5028
LUBRICANT:	Various	TEST RADIUS (mm):	22

TEST RESULTS:

TEST DATE:	11/17/01	11/19/01	11/19/01	11/19/01
TEST NUMBER:	8002548	8002549	8002550	8002551
FILE IDENTIFICATION:	DANDG06	DANDG07	DANDG08	DANDG09
DISK MATERIAL:	4140 oxide	4140 oxide	4140 oxide	4140 oxide
PIN MATERIAL:	Al Bronze	Al Bronze	Al Bronze	Al Bronze
LUBRICANT:	**Mobil 28**	**Aeroshell 33**	**Aeroshell 33 Weathered**	**Mobil 28**
TOTAL CYCLES:	1602	1637	1749	1856
AVG. BALL SCAR (mm):	0.440	0.560	0.550	0.664

COEFFICIENT OF FRICTION: See Attached Graphs for Friction Traces

TEST DATE:	11/27/01	11/27/01
TEST NUMBER:	8002552	8002559
FILE IDENTIFICATION:	DANDG10	DANDG11
DISK MATERIAL:	4140 oxide	4140 oxide
PIN MATERIAL:	Al Bronze	Al Bronze
LUBRICANT:	**Aeroshell 33**	**Aeroshell 33 Weathered**
TOTAL CYCLES:	1677	1742
AVG. BALL SCAR (mm):	0.500	0.600

COEFFICIENT OF FRICTION: See Attached Graphs for Friction Traces

COMPANY: **Dombroff & Gilmore**
DATE: 12/6/01
TECHNICIAN: M. Rapp
PROJ#: 01-111

MACHINE: Falex-ISC Pin On Disk Tribometer System, S/N 808020000045
METHOD: ASTM G99 Modified

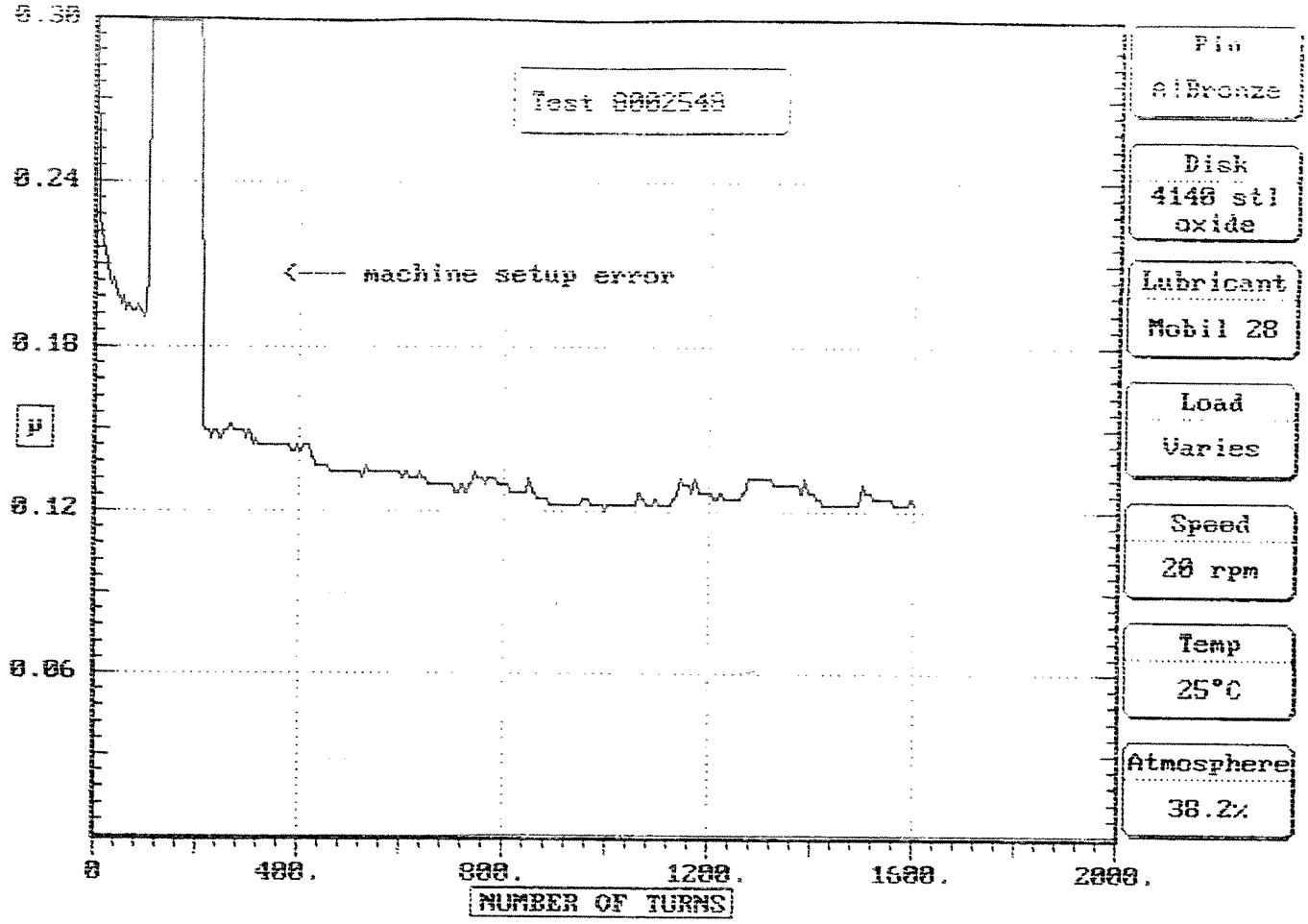
TEST CONDITIONS:

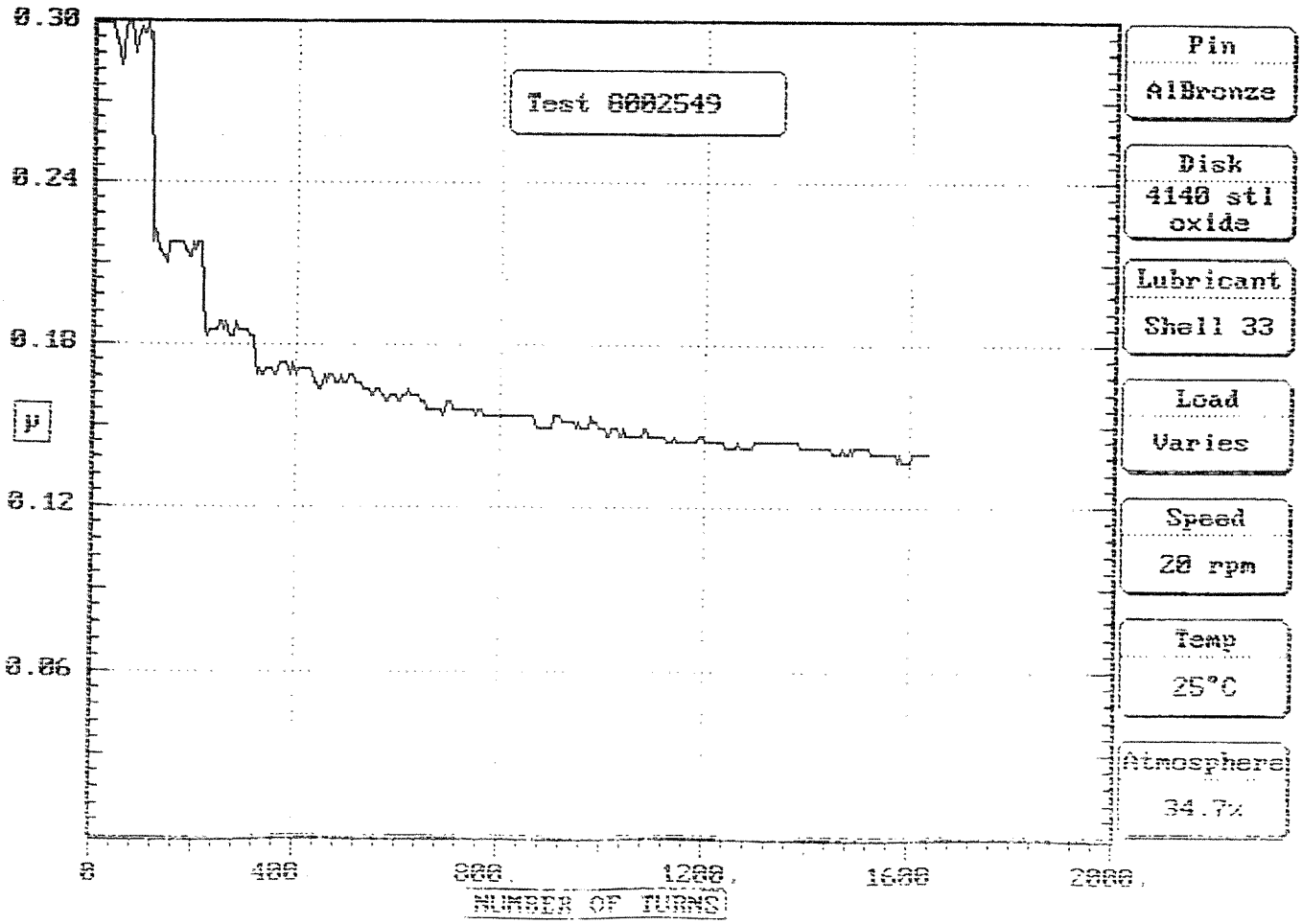
TEST SPEED (rpm):	20	PIN MATERIAL:	Al Bronze
TEMPERATURE (°C):	Ambient	PIN GRADE:	C95500
DURATION (min):	75	PIN POSITION:	90
TEST LOAD (grams):	100/ increments of 100	PIN TL#	5028
LUBRICANT:	Aeroshell 33, and Mobil 28	TEST RADIUS (mm):	22

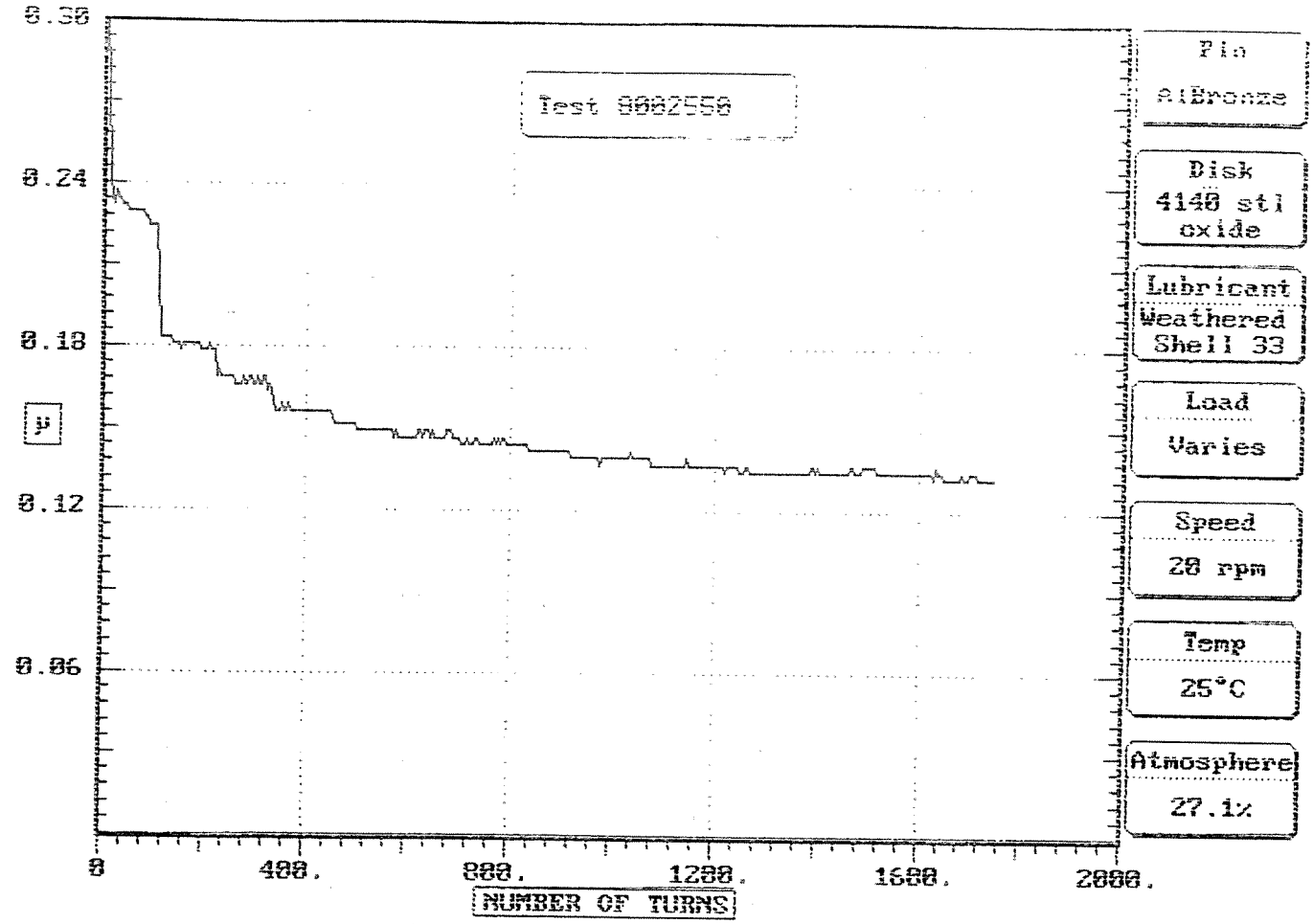
TEST RESULTS:

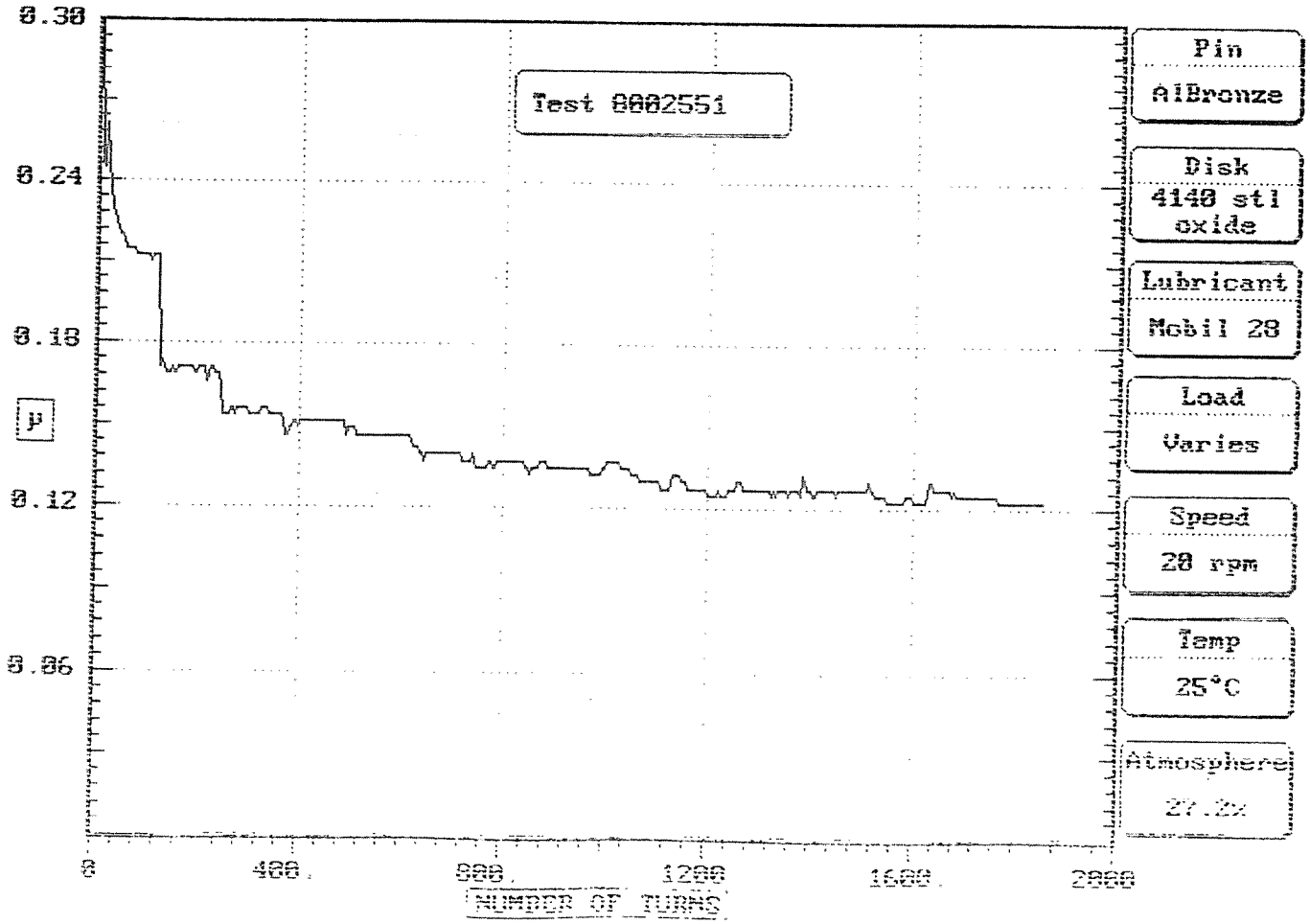
TEST DATE:	11/17/01	11/19/01	11/19/01	11/19/01
TEST NUMBER:	8002548	8002549	8002550	8002551
FILE IDENTIFICATION:	DANDG06	DANDG07	DANDG08	DANDG09
DISK MATERIAL:	4140 oxide	4140 oxide	4140 oxide	4140 oxide
PIN MATERIAL:	Al Bronze	Al Bronze	Al Bronze	Al Bronze
LUBRICANT:	**Mobil 28**	**Aeroshell 33**	**Aeroshell 33 Weathered**	**Mobil 28**
TOTAL CYCLES:	1602	1637	1749	1856
AVG. BALL SCAR:	0.440	0.560	0.550	0.664
COEFFICIENT OF FRICTION:	See Attached Graphs for Friction Traces			

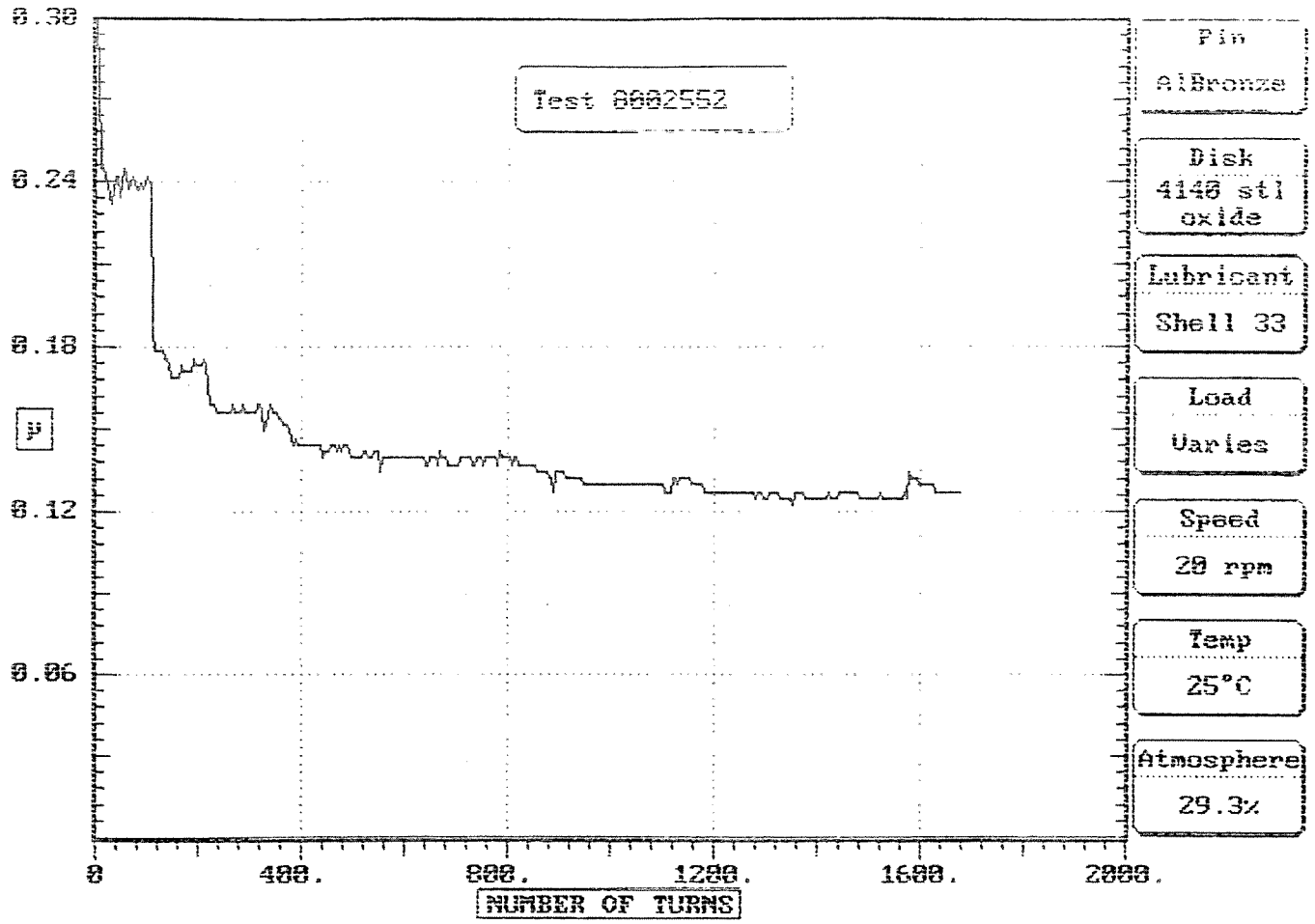
TEST DATE:	11/27/01	11/27/01
TEST NUMBER:	8002552	8002559
FILE IDENTIFICATION:	DANDG10	DANDG11
DISK MATERIAL:	4140 oxide	4140 oxide
PIN MATERIAL:	Al Bronze	Al Bronze
LUBRICANT:	**Aeroshell 33**	**Aeroshell 33 Weathered**
TOTAL CYCLES:	1677	1742
AVG. BALL SCAR:	0.500	0.600
COEFFICIENT OF FRICTION:	See Attached Graphs for Friction Traces	

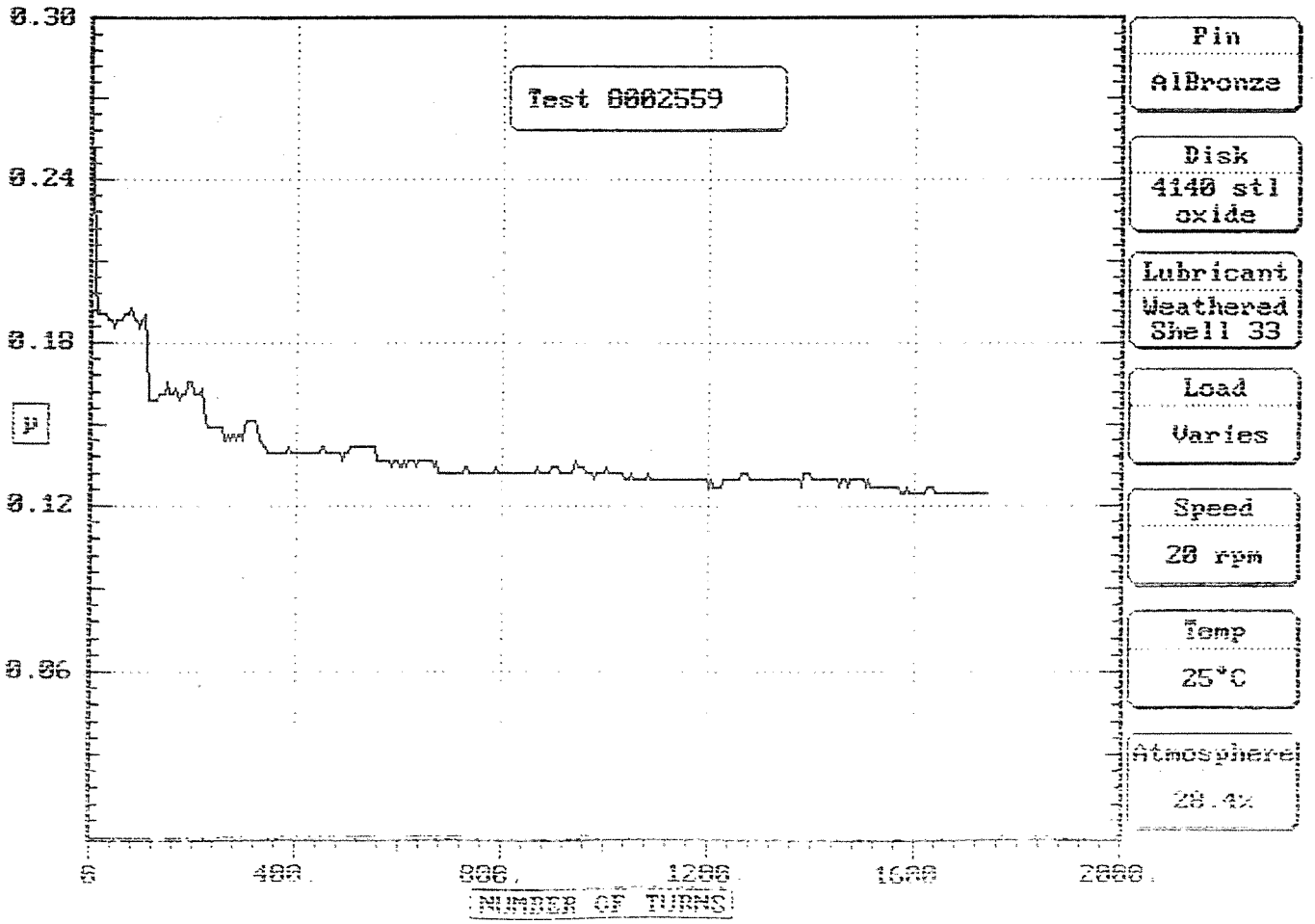

Test 0002548
<--- machine setup error
0.30
0.24
0.18
μ
0.12
0.06
0
400.
800.
1200.
1600.
2000.
NUMBER OF TURNS
Pin
AlBronze
Disk
4140 stl
oxide
Lubricant
Mobil 28
Load
Varies
Speed
20 rpm
Temp
25°C
Atmosphere
38.2%


Test 0002549
0.30
0.24
0.18
μ
0.12
0.06
0
400
800.
1200.
1600
2000.
NUMBER OF TURNS
Pin
AlBronze
Disk
4140 stl
oxide
Lubricant
Shell 33
Load
Varies
Speed
20 rpm
Temp
25°C
Atmosphere
34.7%


Test 0002550
0.30
0.24
0.18
μ
0.12
0.06
0
400.
800.
1200.
1600.
2000.
NUMBER OF TURNS
Pin
AlBronze
Disk
4140 stl
oxide
Lubricant
Weathered
Shell 33
Load
Varies
Speed
20 rpm
Temp
25°C
Atmosphere
27.1%


Test 0002551
0.30
0.24
0.18
μ
0.12
0.06
0
400.
800.
1200.
1600.
2000.
NUMBER OF TURNS
Pin
AlBronze
Disk
4140 stl
oxide
Lubricant
Mobil 28
Load
Varies
Speed
20 rpm
Temp
25°C
Atmosphere
27.2%


Test 0002552
0.30
0.24
0.18
0.12
0.06
μ
0
400.
800.
1200.
1600.
2000.
NUMBER OF TURNS
Pin
AlBronze
Disk
4140 stl
oxide
Lubricant
Shell 33
Load
Varies
Speed
20 rpm
Temp
25°C
Atmosphere
29.3%


Test 0002559
0.30
0.24
0.18
0.12
0.06
μ
0
400.
800.
1200.
1600.
2000.
NUMBER OF TURNS
Pin
AlBronze
Disk
4140 stl
oxide
Lubricant
Weathered
Shell 33
Load
Varies
Speed
20 rpm
Temp
25°C
Atmosphere
29.4%

Company:	***Dombroff & Gilmore***	Page:	1
Date:	12/07/01	Project #:	01-111
Technician	D. Hlavacek		

Method:	Three-Ball Microfilm
Machine:	Falex Multi-Specimen Test Machine, Computer Controlled Version
Serial #:	835000600496

TEST SPECIMENS:

Upper Material:	**C95500 Al Bronze**
Finish ($_u$ in.):	32
Hardness (BHN):	112-123
Falex ID #:	AA-5174
Lower Material:	**C95500 Al Bronze**
Finish ($_u$ in.):	32
Hardness (BHN):	112-123
Falex ID #:	AA-5173
Ball Material:	E-52100 Steel, black oxide coated
Hardness (HRc):	64-66
Grade:	5
Falex ID #:	Lot 99

TEST CONDITIONS:

Test Speed (rpm):	20
Temperature (°C):	Ambient
Test Load (lb):	400-800 (50 lb steps)
Mean Test Radius (in):	0.672

Test Results:

Test Date:	11/15/01	11/15/01	11/28/01
Test Number:	0606404	0606405*	0606415
Upper Falex ID #:	AA-5174	AA-5174	AA-5174
Lower Falex ID #:	AA-5173	AA-5173	AA-5173
Lubricant:	**Mobil 28**	**Mobil 28**	**Mobil 28**
Lubricant Falex ID #:	AA 4944	AA 4944	AA 4944
Test Program Name:	DANDG3BL	DANDG3BL	DNG3BL2
SaveFile Name:	dg3bl08	dg3bl09	dg3bl18

Comments: See Graphs for Friction and additional data.
*Test conducted on same sample specimen set as 0606404.

Coefficient of Friction (CoF)
The dimensionless ratio of the friction force (FF) between the upper rotating material and the lower stationary material to the normal force (N) pressing these bodies together.

Company:	***Dombroff & Gilmore***	Page:	2
Date:	12/07/01	Project #:	01-111
Technician	D. Hlavacek		

Method:	Three-Ball Microfilm
Machine:	Falex Multi-Specimen Test Machine, Computer Controlled Version
Serial #:	835000600496

TEST SPECIMENS:

Upper Material:	**C95500 Al Bronze**
Finish ($_u$ in.):	32
Hardness (BHN):	112-123
Falex ID #:	AA-5174
Lower Material:	**C95500 Al Bronze**
Finish ($_u$ in.):	32
Hardness (BHN):	112-123
Falex ID #:	AA-5173
Ball Material:	E-52100 Steel, black oxide coated
Hardness (HRc):	64-66
Grade:	5
Falex ID #:	Lot 99

TEST CONDITIONS:

Test Speed (rpm):	20
Temperature (°C):	Ambient
Test Load (lb):	400-800 (50 lb steps)
Mean Test Radius (in):	0.672

Test Results:

Test Date:	11/16/01	11/19/01	11/29/01
Test Number:	0606407	0606408*	0606419
Upper Falex ID #:	AA-5174	AA-5174	AA-5174
Lower Falex ID #:	AA-5173	AA-5173	AA-5173
Lubricant:	**Aeroshell 33**	**Aeroshell 33**	**Aeroshell 33**
Lubricant Falex ID #:	AA 4948	AA 4948	AA 4948
Test Program Name:	DNG3BL2	DNG3BL2	DNG3BL2
SaveFile Name:	dg3bl10	dg3bl11	dg3bl22

Comments: See Graphs for Friction and additional data.
*Test conducted on same sample specimen set as 0606407.

Coefficient of Friction (CoF)
The dimensionless ratio of the friction force (FF) between the upper rotating material and the lower stationary material to the normal force (N) pressing these bodies together.

Company:	***Dombroff & Gilmore***	Page:	3
Date:	12/07/01	Project #:	01-111
Technician	D. Hlavacek		

Method:	Three-Ball Microfilm
Machine:	Falex Multi-Specimen Test Machine, Computer Controlled Version
Serial #:	835000600496

TEST SPECIMENS:

Upper Material:	**C95500 Al Bronze**
Finish ($_u$ in.):	32
Hardness (BHN):	112-123
Falex ID #:	AA-5174
Lower Material:	**C95500 Al Bronze**
Finish ($_u$ in.):	32
Hardness (BHN):	112-123
Falex ID #:	AA-5173
Ball Material:	E-52100 Steel, black oxide coated
Hardness (HRc):	64-66
Grade:	5
Falex ID #:	Lot 99

TEST CONDITIONS:

Test Speed (rpm):	20
Temperature (°C):	Ambient
Test Load (lb):	400-800 (50 lb steps)
Mean Test Radius (in):	0.672

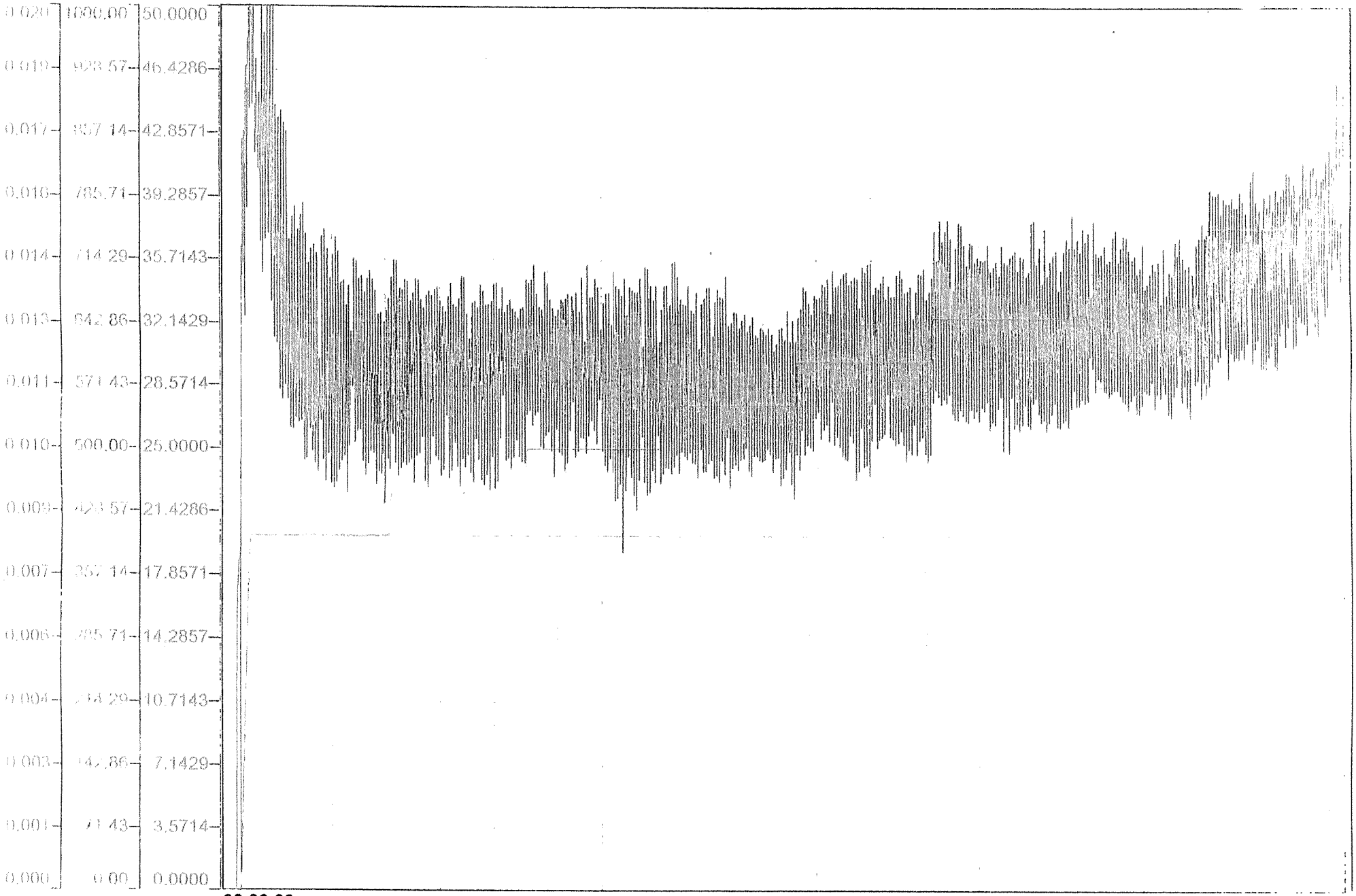
Test Results:

Test Date:	11/19/01	11/19/01	11/21/01	11/29/01
Test Number:	0606409	0606410*	0606413	0606418
Upper Falex ID #:	AA-5174	AA-5174	AA-5174	AA-5174
Lower Falex ID #:	AA-5173	AA-5173	AA-5173	AA-5173
Lubricant:	**Aeroshell 33 weathered**	**Aeroshell 33 weathered**	**Aeroshell 33 weathered**	**Aeroshell 33 weathered**
Lubricant Falex ID #:	AA 4949	AA 4949	AA 4949	AA 4949
Test Program Name:	DNG3BL2	DNG3BL2	DNG3BL2	DNG3BL2
SaveFile Name:	dg3bl12	dg3bl13	dg3bl16	dg3bl21

Comments: See Graphs for Friction and additional data.
*Test conducted on same sample specimen set as 0606409.
Data file dg3bl12 not saved.

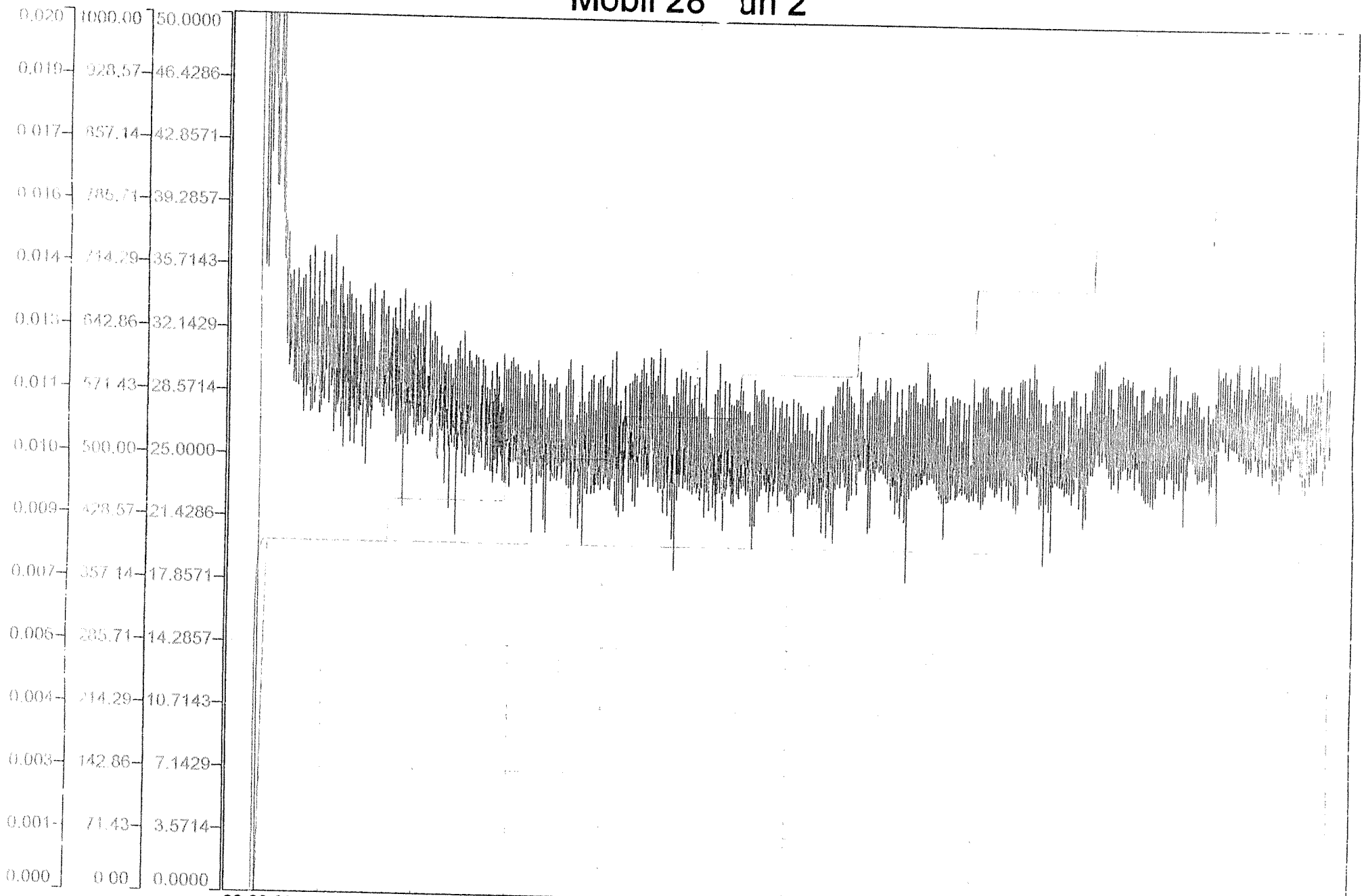
Coefficient of Friction (CoF)
The dimensionless ratio of the friction force (FF) between the upper rotating material and the lower stationary material to the normal force (N) pressing these bodies together.

Mobil 2 Run 1



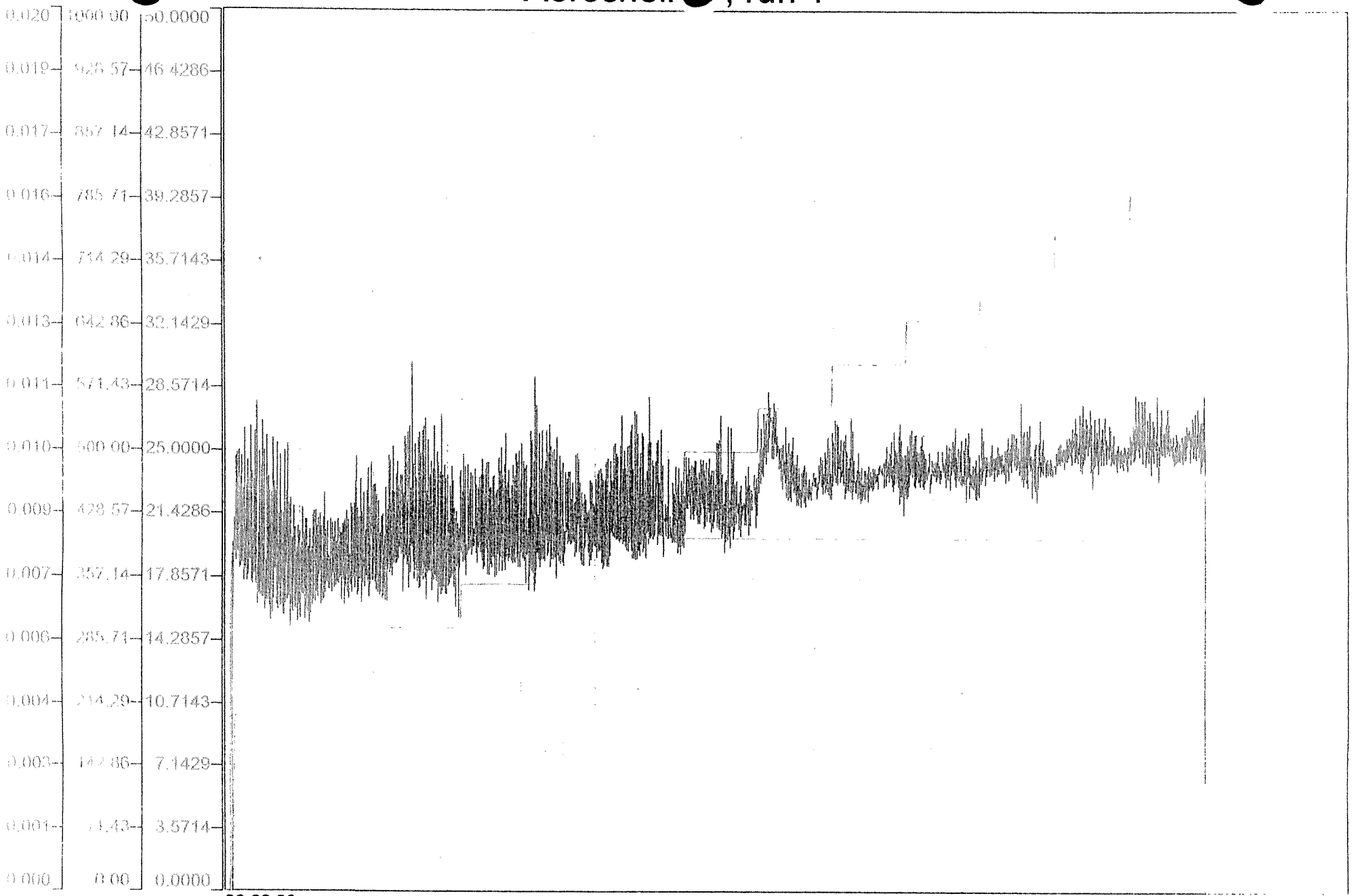
Description	Batch Name	Scale Range	Sample Freq.	Eng. Units	00:41:39
COEF-FRICT	dg3bl08	0.000/0.020	00:00:01		***
LOAD	dg3bl08	0.00/1000.00	00:00:01	LB	***
SPEED	dg3bl08	0.0000/50.0000	00:00:01	RPM	***

Mobil 28 un 2



Description	Batch Name	Scale Range	Sample Freq.	Eng. Units	00:48:01
COEF-FRICT	dg3bl09	0.000/0.020	00:00:01		***
LOAD	dg3bl09	0.00/1000.00	00:00:01	LB	***
SPEED	dg3bl09				

Aerosnell[illegible], run 1

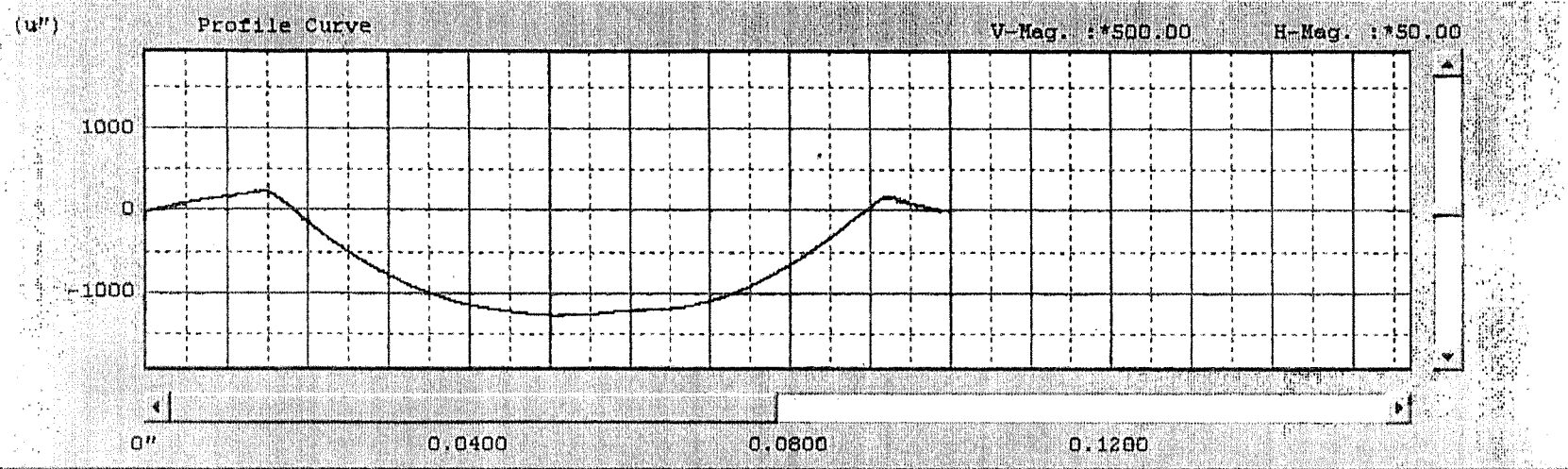


Description	Batch Name	Scale Range	Sample Freq.	Eng. Units	01:15:54
COEF-FRICT	dg3bl10	0.000/0.020	00:00:01		No Data
LOAD	dg3bl10	0.00/1000.00	00:00:01	LB	No Data
SPEED	dg3bl10	0.0000/50.0000	00:00:01	RPM	No Data

Roughness Analysis

File(F) Condition(C) Parameter(P) Analysis(A) Display(D) Measurement(M) Integrated Analysis(U) Window(W) Others(O)

V-Mag 500 | H-Mag. AUTO | ○1 ○2 ○3 ◉4 ○5 ○6 ○7 ○8 ○9 ○10 ○0.1 | Ana/Result | Meas



Parameter name	Value	Unit
Pt	1515.745	u"
*Rz.J	1480.115	u"
Tilt A	-0.316	deg
AVH	142.283	u"
Hmax	253.937	u"
Hmin	40.157	u"
AREA	3.476E+06	u"2

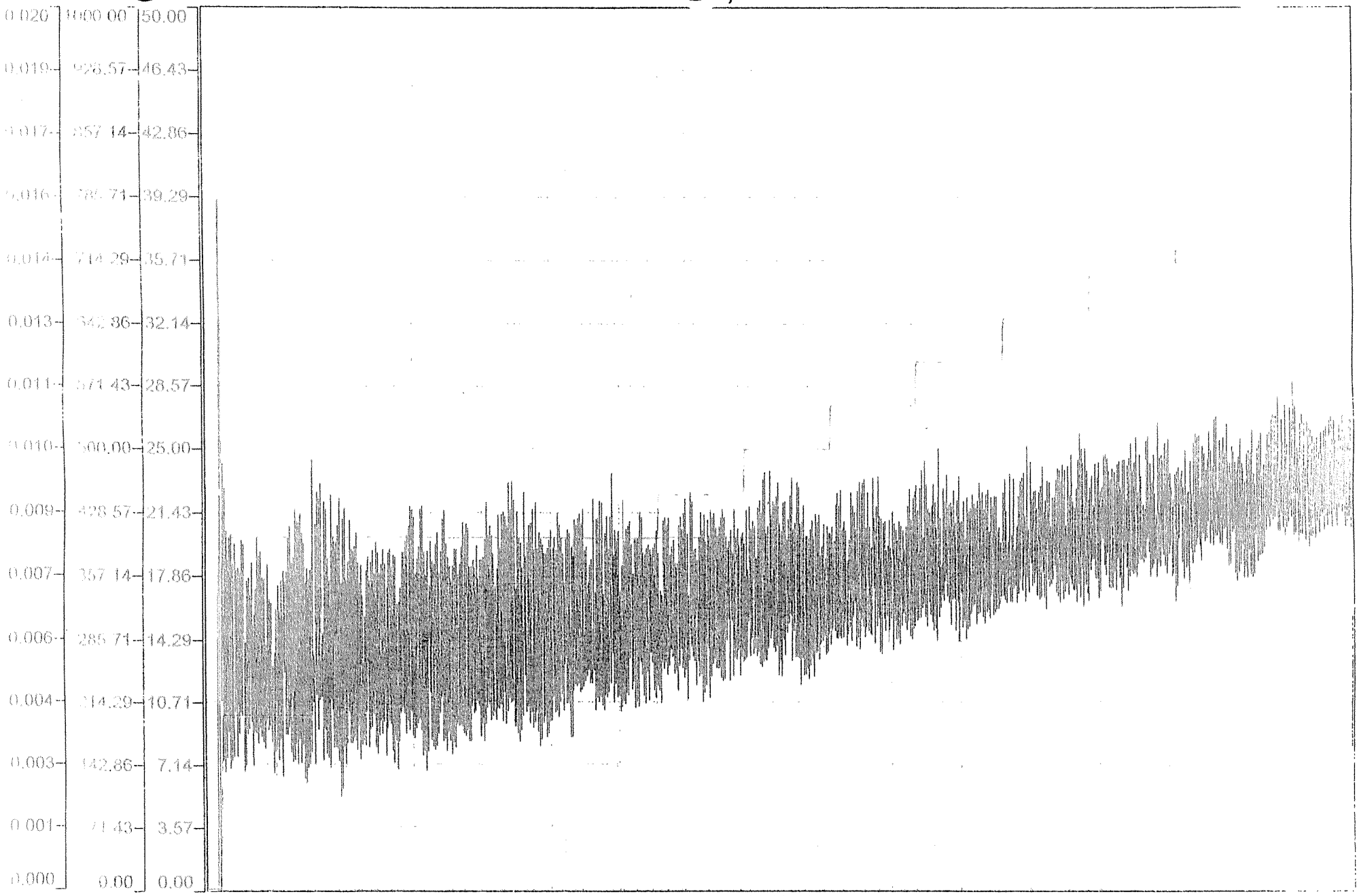
Item name	Set value 1	Set va...
Company Name	D&G Project	
Purpose	Aeroshell 33	
Part's Name	3 ball Micro ~~upper~~ Lower	
Material	Al.Bronze/Oxide balls	
Date	01/11/19	
Time	09:05:11	
Orientation	across path, at thermocouple	
Lot No.		
Sample No.	01	
Output Unit	",u"	
Polarity	Positive	
Pickup	Standard Pickup	
Standard	ANSI	
Measurement Type	Profile	
Measurement Length	0.1"	
Cutoff Wavelength		
Measurement Mag.	* 1K	

01 11/19/01 9:06 AM

D&3BL10 0606407

AEROSHELL #3

Aerosnell ; run 2

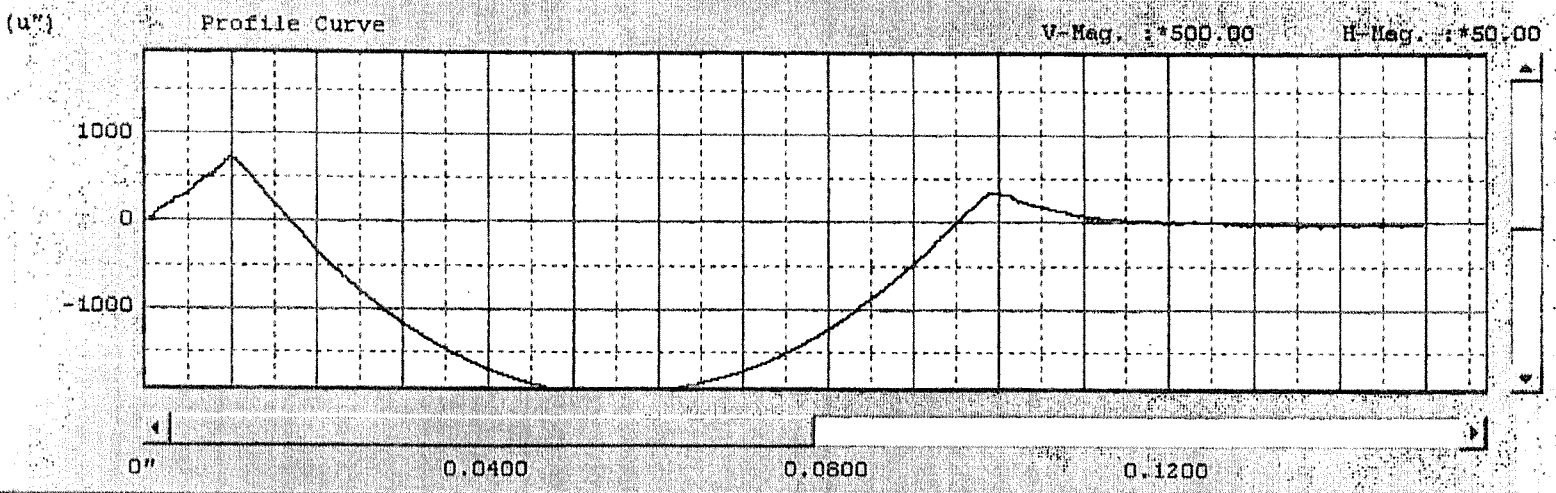


Description	Batch Name	Scale Range	Sample Freq.	Eng. Units	01:06:41
COEF-FRICT	dg3bl11	0.000/0.020	00:00:01		***
LOAD	dg3bl11	0.00/1000.00	00:00:01	LB	***
SPEED	dg3bl11	0.00/50.00	00:00:01	RPM	***

Roughness Analysis

File(F) Condition(C) Parameter(P) Analysis(A) Display(D) Measurement(M) Integrated Analysis(U) Window(W) Others(Q)

V-Mag. 500 H-Mag. AUTO ○1 ○2 ○3 ○4 ◉5 ○ ○ ○ ○ ○ ○0.1 Ana/Result Meas



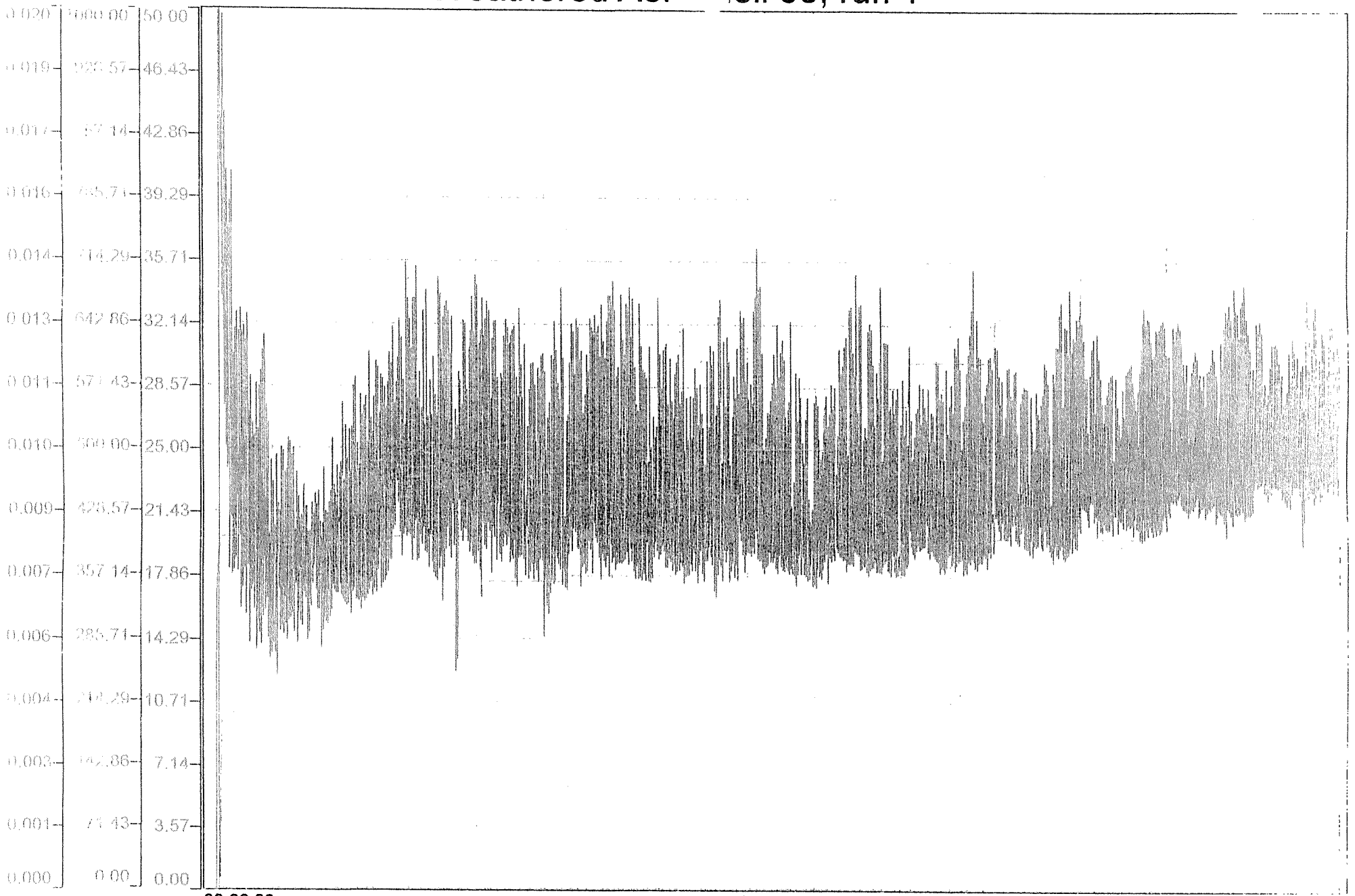
Parameter name	Value	Unit
Pt	2748.420	u"
Rz.J	663.888	u"
Tilt A	-0.636	deg
AVH	270.891	u"
Hmax	758.896	u"
Hmin	40.787	u"
AREA	9.915E+06	u"2

Item name	Set value 1	Set va...
Company Name	D&G Project	
Purpose	Aeroshell 33	
Part's Name	3 ball Micro ~~upper~~ LOWER	
Material	Al.Bronze/Oxide balls	
Date	01/11/19	
Time	15:51:32	
Orientation	across path, at thermocouple	
Lot No.		
Sample No.	07	
Output Unit	",u"	
Polarity	Positive	
Pickup	Standard Pickup	
Standard	ANSI	
Measurement Type	Profile	
Measurement Length	0.15"	
Cutoff Wavelength		
Measurement Mag.	* 10K	

07 11/19/01 3:52 PM

DG3BL11 0606408

Weathered Aer[illegible]ell 33, run 1

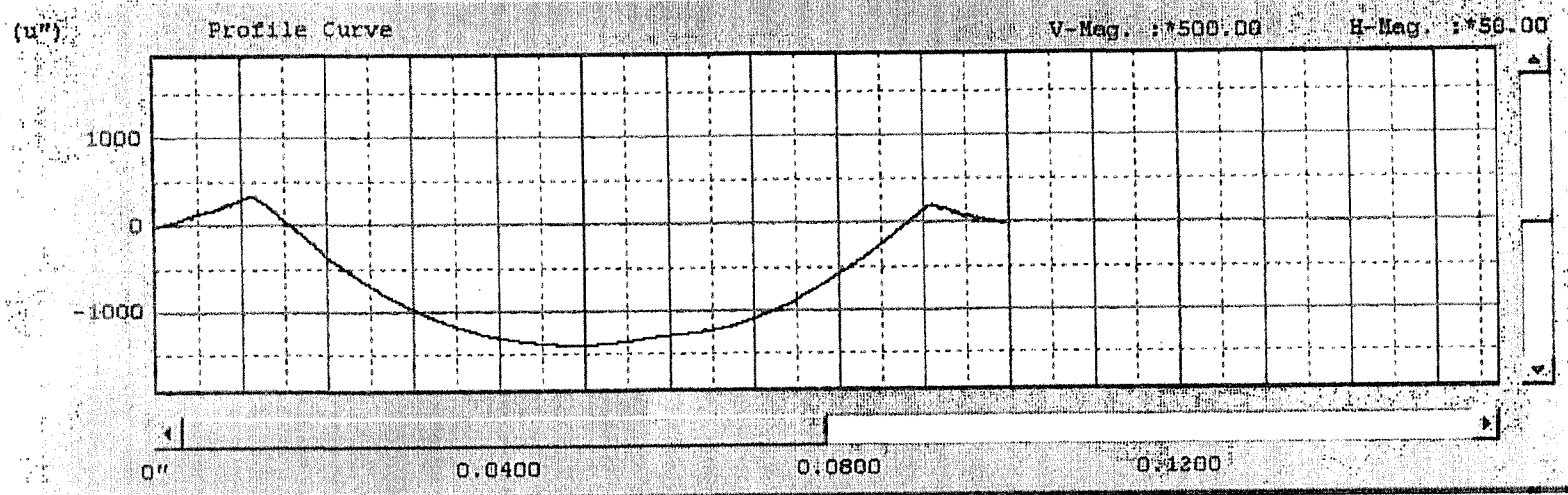


Description	Batch Name	Scale Range	Sample Freq.	Eng. Units	01:07:08
[illegible]OEF-FRICT	dg3bl12	0.000/0.020	00:00:01		***
[illegible]OAD	dg3bl12	0.00/1000.00	00:00:01	LB	***
[illegible]PEED	dg3bl12	0.00/50.00	00:00:01	RPM	***

Roughness Analysis

File(F) Condition(C) Parameter(P) Analysis(A) Display(D) Measurement(M) Integrated Analysis(U) Window(W) Others(Q)

V-Mag. AUTO H-Mag. AUTO ○1 ○2 ○3 ○4 ○5 ◉6 ○7 ○8 ○9 ○10 ○0 ○L Ana/Result Meas



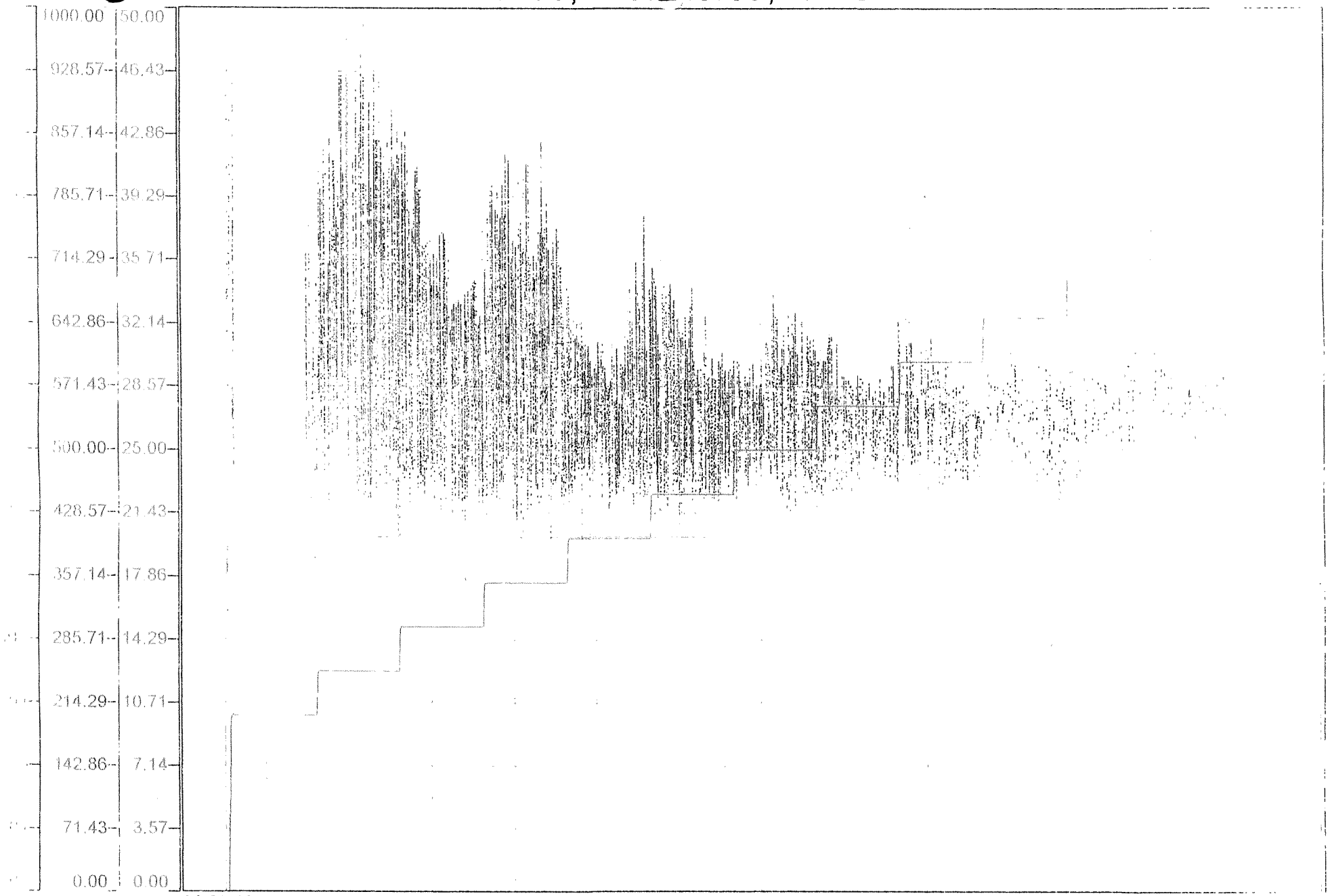
Parameter name	Value	Unit
Pt	1743.776	u"
*Rz.J	984.053	u"
Tilt A	-0.308	deg
AVH	173.958	u"
Hmax	350.314	u"
Hmin	40.787	u"
AREA	3.932E+06	u"2

Item name	Set value 1	Set va...
Company Name	D&G Project	
Purpose	Aeroshell 33 Weathered	
Part's Name	3 ball Micro ~~upper~~ LOWER	
Material	Al:Bronze/Oxide balls	
Date	01/11/19	
Time	15:23:22	
Orientation	across path, at thermocouple	
Lot No.		
Sample No.	03	
Output Unit	",u"	
Polarity	Positive	
Pickup	Standard Pickup	
Standard	ANSI	
Measurement Type	Profile	
Measurement Length	0.1"	
Cutoff Wavelength		
Measurement Mag.	* 10K	

03 11/19/01 3:24 PM

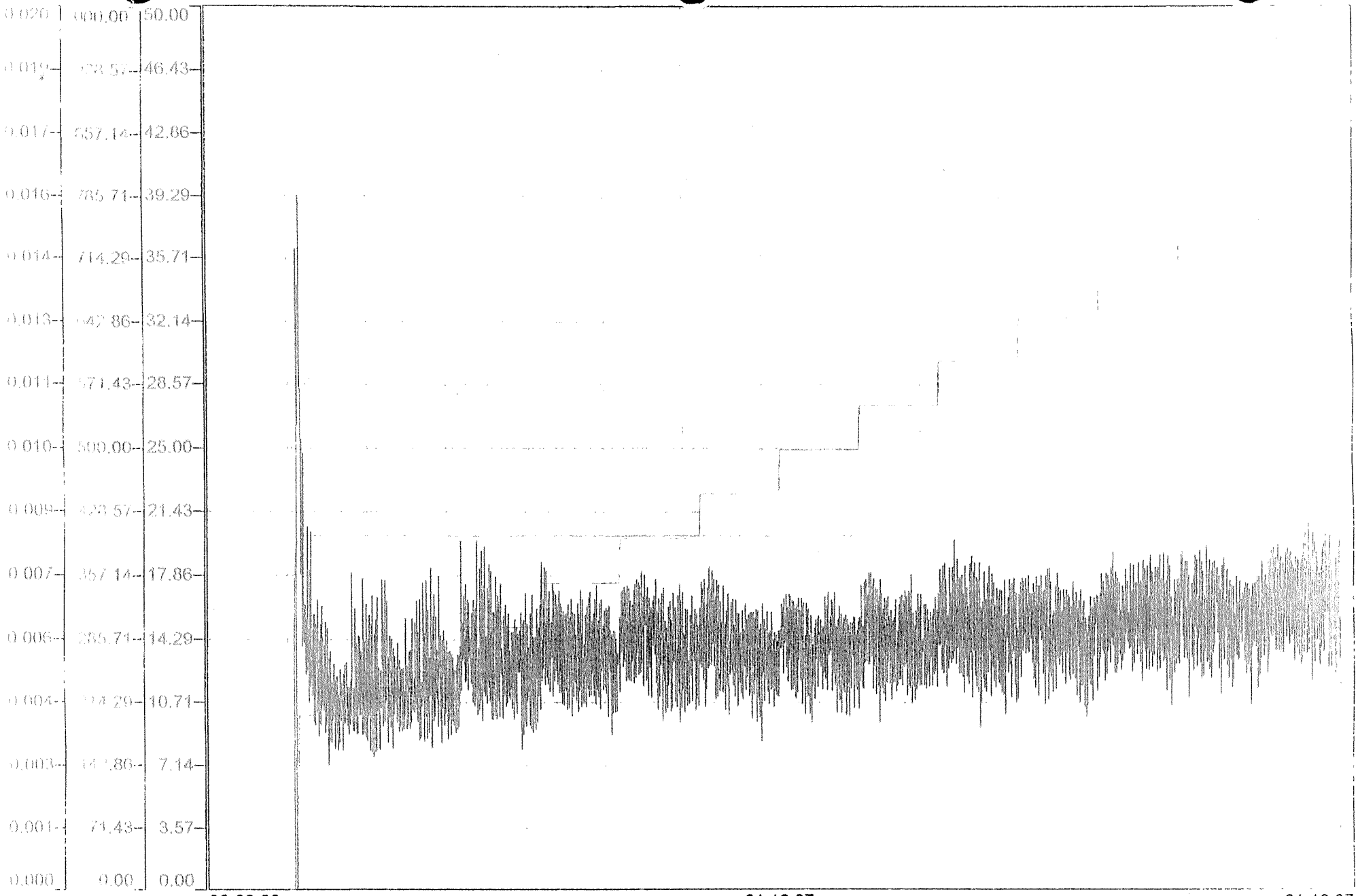
DG3BL12 060609 AEROSHELL #33

Aero. 33, We[illegible]ered, run 2



Description	Batch Name	Scale Range	Sample Freq.	Eng. Units	01:08:48
	dg3bl16	0.00/0.00	00:00:01		
LOAD	dg3bl16	0.00/1000.00	00:00:01	LB	No Data
SPEED	dg3bl16	0.00/50.00	00:00:01	RPM	No Data

Mobil 2 Run 1

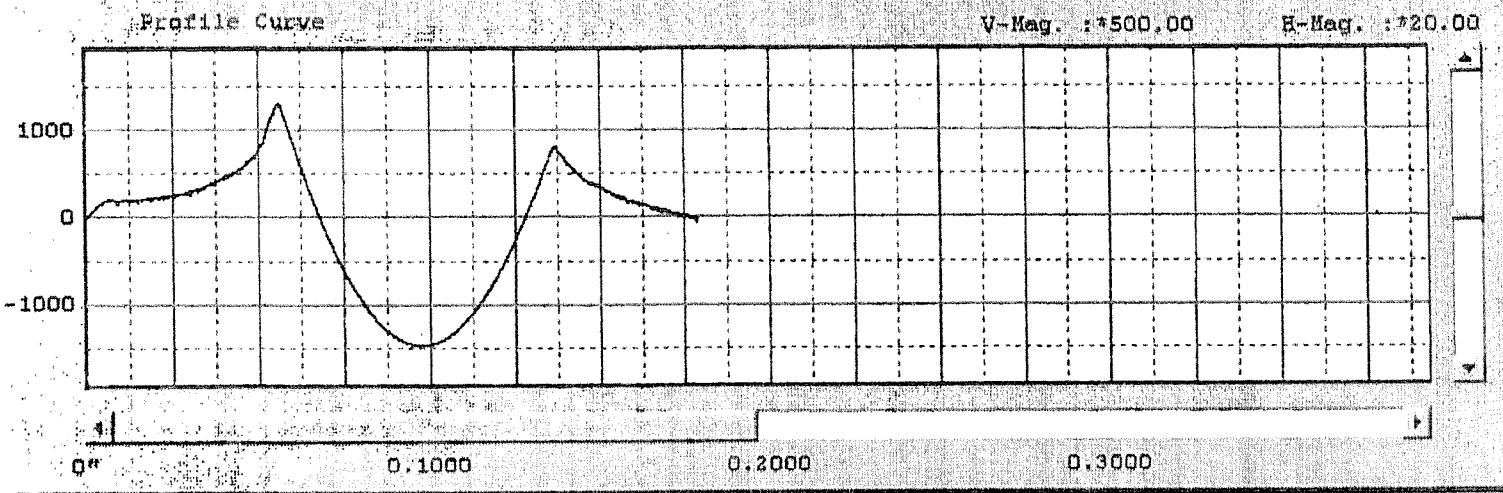


Description	Batch Name	Scale Range	Sample Freq.	Eng. Units	01:12:07
COEF-FRICT	dg3bl18	0.000/0.020	00:00:01		No Data
LOAD	dg3bl18	0.00/1000.00	00:00:01	LB	No Data
SPEED	dg3bl18	0.00/50.00	00:00:01	RPM	No Data

Roughness Analysis

File(F) Condition(C) Parameter(P) Analysis(A) Display(D) Measurement(M) Integrated Analysis(U) Window(W) Others(Q)

V-Mag 500 H-Mag. AUTO ○1 ○2 ○3 ○4 ○5 ○6 ○7 ◉8 ○9 ○10 ○0.1 Ana/Result Meas

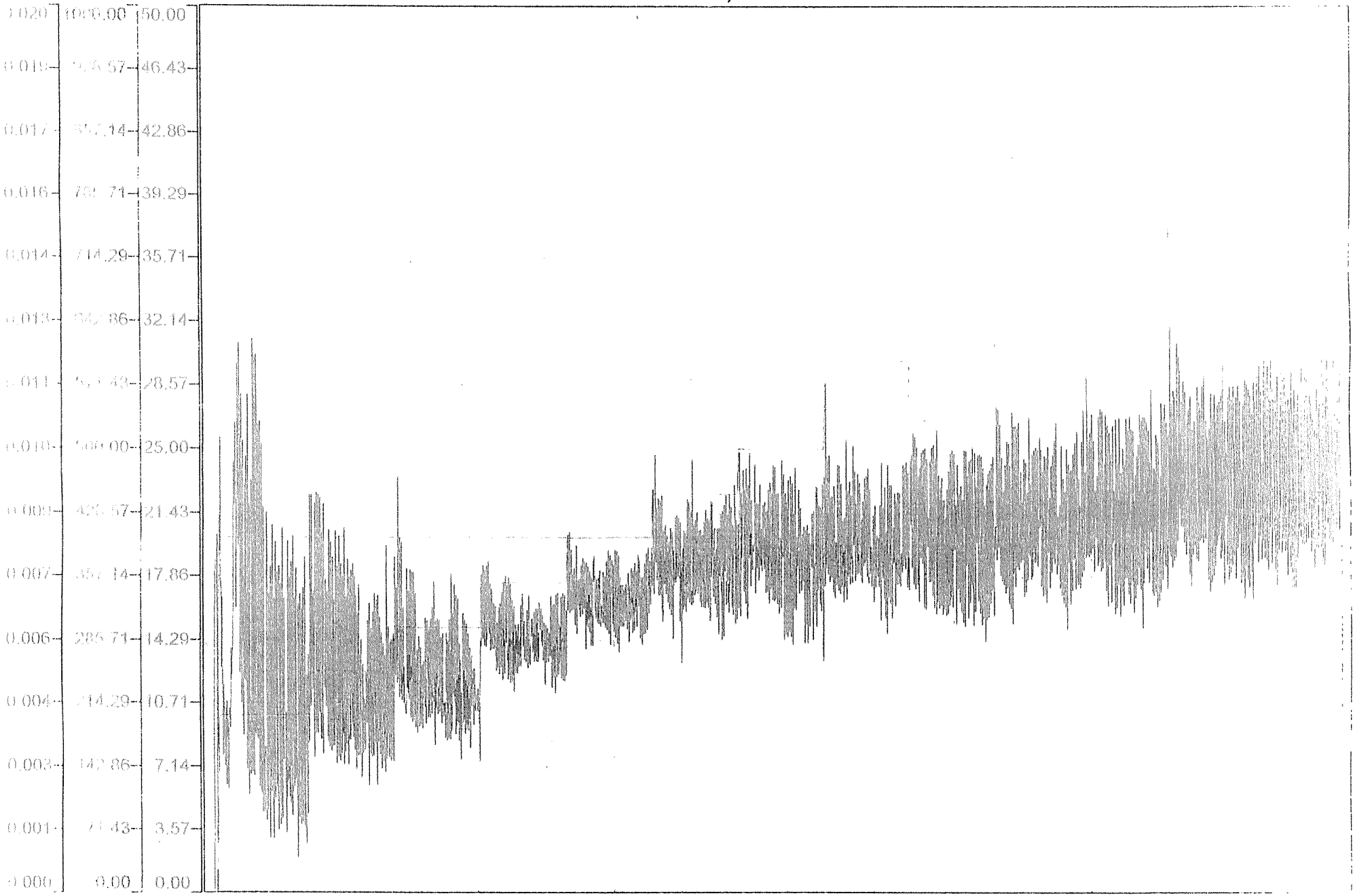


Parameter name	Value	Unit
Pc	2803.065	u"
Rz.J	1232.622	u"
Tilt A	0.440	deg
AVH	411.493	u"
Hmax	1336.612	u"
Hmin	41.417	u"
AREA	4.640E+07	u"2

Item name	Set value 1	Set va...
Company Name	D&G Project	
Purpose	~~kerosun11 33 Weathered~~ MOBIL #28	
Part's Name	3 ball Micro lower	
Material	Al.Bronze/Oxide balls	
Date	01/11/29	
Time	03:53:56	
Orientation	across path, at thermocouple	
Lot No.		
Sample No.	13	
Output Unit	",u"	
Polarity	Positive	
Pickup	Standard Pickup	
Standard	ANSI	
Measurement Type	Profile	
Measurement Length	0.18"	
Cutoff Wavelength		
Measurement Mag.	* 10K	

13 11/29/01 3:54 AM

Aeroshell ; run 1

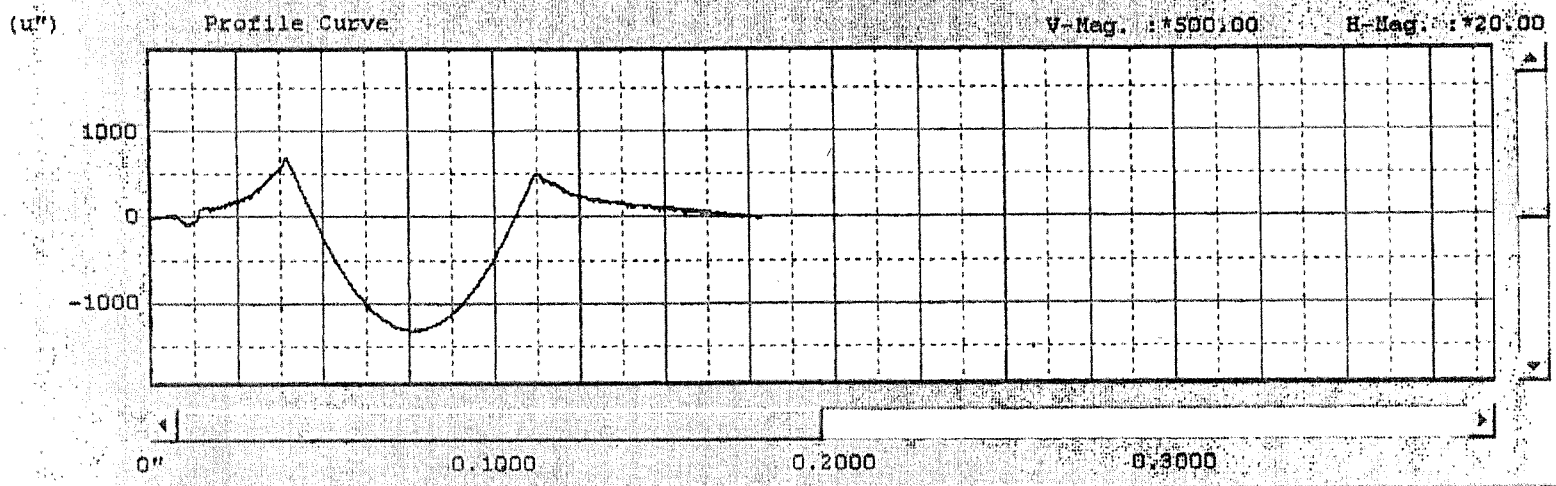


Description	Batch Name	Scale Range	Sample Freq.	Eng. Units	01:07:04
COEF-FRICT	dg3bl22	0.000/0.020	00:00:01		***
[illegible]	dg3bl22	0.00/1000.00	00:00:01	LB	***
SPEED	dg3bl22	0.00/50.00	00:00:01	RPM	***

Roughness Analysis

File(F) Condition(C) Parameter(P) Analysis(A) Display(D) Measurement(M) Integrated Analysis(U) Window(W) Others(O)

V-Mag. AUTO H-Mag. AUTO 1 2 3 4 5 6 7 8 9 10 L Ana/Result Meas

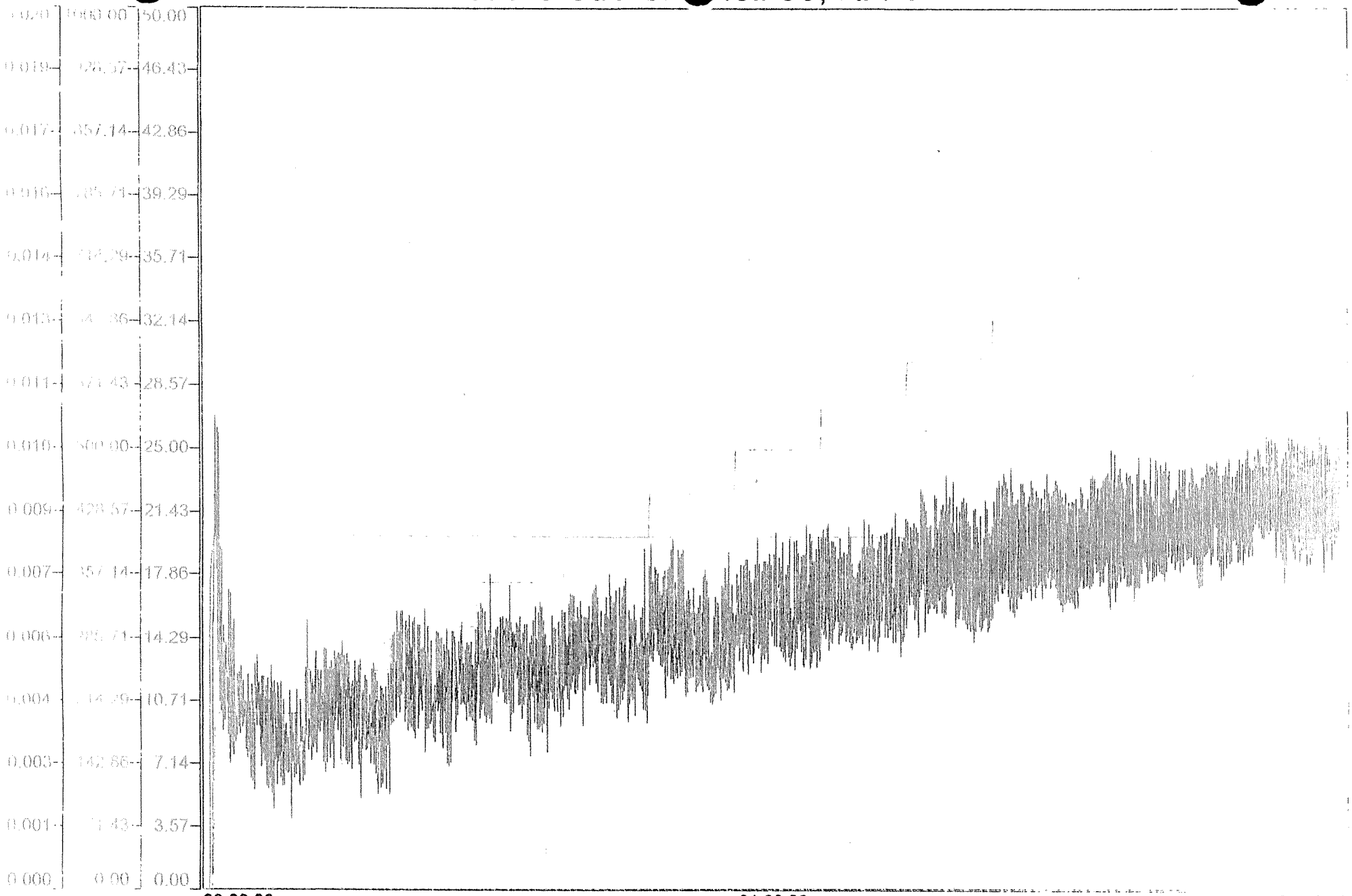


Parameter name	Value	Unit
Pt	2008.185	u"
Rz.J	547.605	u"
Tilt A	0.413	deg
AVH	234.349	u"
Hmax	698.503	u"
Hmin	39.921	u"
AREA	2.262E+07	u"2

Item name	Set value 1	Set va...
Company Name	D&G Project	
Purpose	Aeroshell 33, run 1	
Part's Name	3 ball Micro lower	
Material	Al.Bronze/Oxide balls	
Date	01/11/29	
Time	14:03:59	
Orientation	across path, at thermocouple	
Lot No.		
Sample No.	16	
Output Unit	",u"	
Polarity	Positive	
Pickup	Standard Pickup	
Standard	ANSI	
Measurement Type	Profile	
Measurement Length	0.18"	
Cutoff Wavelength		
Measurement Mag.	* 10K	

16 11/29/01 2:05 PM

Weathered Aer[illegible]ell 33, run 1

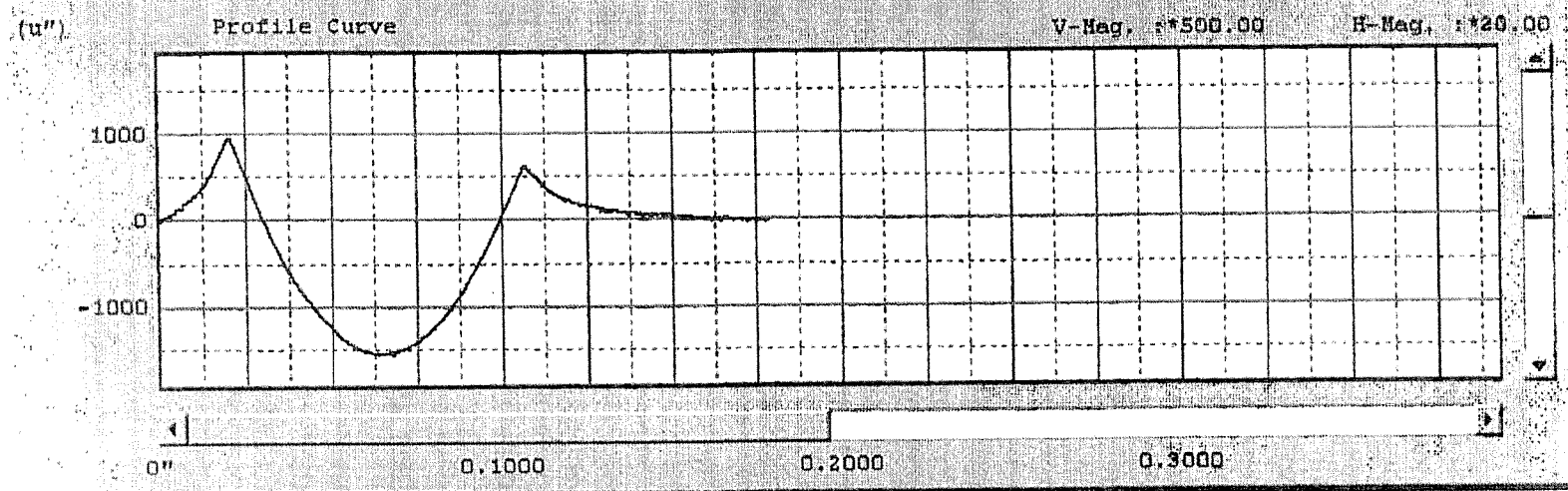


Description	Batch Name	Scale Range	Sample Freq.	Eng. Units	01:06:50
COEF-FRICT	dg3bl21	0.000/0.020	00:00:01		***
[illegible]	dg3bl21	0.00/1000.00	00:00:01	LB	***
[illegible]	dg3bl21	0.00/50.00	00:00:01	RPM	***

Roughness Analysis

File(F) Condition(C) Parameter(P) Analysis(A) Display(D) Measurement(M) Integrated Analysis(U) Window(W) Others(O)

V-Mag. 500 H-Mag. AUTO ○1○2○3○4○5○6○7○8○9●10○0.L Ana/Result Meas



Parameter name	Value	Unit
Pt	2547.869	u"
Rz.J	656.392	u"
Tilt A	0.358	deg
AVH	279.521	u"
Hmax	989.447	u"
Hmin	40.394	u"
AREA	2.437E+07	u"2

Item name	Set value 1	Set va...
Company Name	D&G Project	
Purpose	Weath. Aero. 33, Run 1	
Part's Name	3 ball Micro lower	
Material	Al.Bronze/Oxide balls	
Date	01/11/29	
Time	11:20:55	
Orientation	across path, at thermocouple	
Lot No.		
Sample No.	15	
Output Unit	",u"	
Polarity	Positive	
Pickup	Standard Pickup	
Standard	ANSI	
Measurement Type	Profile	
Measurement Length	0.18"	
Cutoff Wavelength		
Measurement Mag.	* 10K	

15 11/29/01 11:21 AM

M A C H I N E S E T - U P S U M M A R Y

PARAMETER	CURRENT CONFIGURATION
CONFIGURATION LIST NUMBER	006-108-023
SPECIMEN TYPE	3 Ball Micro Film
LOAD RANGE	HIGH 10 to 820 lbs.
TYPE OF MOTION	UNIDIRECTIONAL
UNIDIRECTIONAL SPEED RANGE	0 - 23 RPM
CYCLE/DISTANCE RESOLUTION	1
TORQUE SENSOR RANGE TYPE	LOW 10 LBS
TEMPERATURE CONTROL	SPECIMEN

T E S T L I M I T S S U M M A R Y

PARAMETER	MAXIMUM	ALERT	SHUTDOWN	
SPEED	24	23	24	RPM
SPECIMEN LOAD	864.0	820.0	850.0	LBS
CHAMBER TEMP.	421	200	200	DEG C
SPECIMEN TEMP.	421	120	200	DEG C
[illegible]R	1200	0	0	.0001 IN.
[illegible]LE	30000	0	0	
DISTANCE	30000	0	0	FEET
COEFFRIC.	2.0000	0.0000	0.0000	
TORQUE	10.00	5.00	9.00	LB.IN.
VIBRATION	20.00	0.00	0.00	G
ELAPSED TIME	522:59:59	005:00:00	005:01:00	HHH:MM:SS

S T A R T T E S T S U M M A R Y

PARAMETER	MAXIMUM	VALUE	
STARTING SEQUENCE		9	SPEED-LOAD
INITIAL SPEED SETPOINT	22	20	RPM
INITIAL SPECIMEN LOAD SETPOINT	807.0	200.0	LBS
INITIAL TEMPERATURE SETPOINT	189	15	DEG C
START SPEED HOLD TIME	3600	0	SEC
START LOAD HOLD TIME	3600	0	SEC
INITIAL SPEED RAMP RATE	1000	10	RPM/SEC
INITIAL LOAD RAMP RATE	600	20	LBS/SEC
IS SPECIAL CONFIGURATION REQUIRE		YES	
IGNORE TEMPERATURE OVERSHOOT		YES	

S P E C I A L C O N F I G U R A T I O N S U M M A R Y

POINT	SPEED SETPT	LOAD SETPT	TEMP. SETPT	SPEED RATE	LOAD RATE	DURATION	NEXT STEP	REPS
1	20.0	200	15	10	20	300	2	1

2	20.0	250	15	10	10	300	3	1
3	20.0	300	15	10	20	300	4	1
4	20.0	350	15	10	20	300	5	1
5	20.0	400	15	10	20	300	6	1
6	20.0	450	15	10	20	300	7	1
7	20.0	500	15	10	20	300	8	1
8	20.0	550	15	10	20	300	9	1
9	20.0	600	15	10	20	300	10	1
10	20.0	650	15	10	20	300	11	1
11	20.0	700	15	10	20	300	12	1
12	20.0	750	15	10	20	300	13	1
13	20.0	800	15	10	20	300	40	1
14	0.0	0	0	0	0	0	0	0
15	0.0	0	0	0	0	0	0	0
16	0.0	0	0	0	0	0	0	0
17	0.0	0	0	0	0	0	0	0
18	0.0	0	0	0	0	0	0	0
19	0.0	0	0	0	0	0	0	0
20	0.0	0	0	0	0	0	0	0
21	0.0	0	0	0	0	0	0	0
22	0.0	0	0	0	0	0	0	0
23	0.0	0	0	0	0	0	0	0
24	0.0	0	0	0	0	0	0	0
25	0.0	0	0	0	0	0	0	0
26	0.0	0	0	0	0	0	0	0
27	0.0	0	0	0	0	0	0	0
28	0.0	0	0	0	0	0	0	0
29	0.0	0	0	0	0	0	0	0
30	0.0	0	0	0	0	0	0	0
31	0.0	0	0	0	0	0	0	0
32	0.0	0	0	0	0	0	0	0
33	0.0	0	0	0	0	0	0	0
34	0.0	0	0	0	0	0	0	0
35	0.0	0	0	0	0	0	0	0
36	0.0	0	0	0	0	0	0	0
37	0.0	0	0	0	0	0	0	0
38	0.0	0	0	0	0	0	0	0
39	0.0	0	0	0	0	0	0	0
40	0.0	0	0	0	0	0	0	0

Company:	***Dombroff & Gilmore***	Page:	1
Date:	12/03/01	Project #:	01-111
Technician	N. Pekoc		

Method:	Modified Thrust Washer
Machine:	Falex High Performance Multi-Specimen Test Machine, Computer Controlled Version
Serial #:	809C350011008, 009-091-105

TEST SPECIMENS:

Upper Material:	**C95500 Al Bronze**
Finish (μ in.):	32
Hardness (HRc):	112-123
Falex ID #:	5172
Lower Material:	**AISI 4140 Steel, black oxide coated**
Finish (μ in.):	32
Hardness (HRc):	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5164

TEST CONDITIONS:

Test Speed (rpm):	5
Temperature (°C):	Ambient
Duration (hr):	24
Test Load (lb):	1520
Mean Test Radius (in):	0.531
Contact pressure (psi):	7600

Test Results:

Test Date:	11/26/01	12/03/01	11/27/01	11/29/01
Test Number:	09048	09057	09049	09052
Upper Falex ID #:	5172A	5172J	5172B	5172E
Lower Falex ID #:	5164A	5164J	5164B	5164E
Lubricant:	**Aeroshell 33 weathered**	**Aeroshell 33 weathered**	**Mobil 28**	**Mobil 28**
Lubricant Falex ID #:	4949	4949	4944	4944
SaveFile Name:	DGWEAR01	DGWEAR07	DGWEAR02	DGWEAR04
Test Program Name:	D&GWEARTEST	D&GWEARTEST	D&GWEARTEST	D&GWEARTEST
Mass Loss, Upper (mg):	19.1	22.8	5.7	3.2
Mass Loss, Lower (mg):	1.7	1.3	1.7	1.8
Bronze height change (mm):	N/A	0.031	0.0128	0.009

Comments: See Graphs for Torque, Friction Coefficient, Load, and Specimen Temperature trends.

Coefficient of Friction (CoF)
The dimensionless ratio of the friction force (FF) between the upper rotating material and the lower stationary material to the normal force (N) pressing these bodies together.

TW

Company:	*Dombroff & Gilmore*	Page:	2
Date:	12/03/01	Project #:	01-111
Technician	N. Pekoc		

Method: Modified Thrust Washer
Machine: Falex High Performance Multi-Specimen Test Machine, Computer Controlled Version
Serial #: 809C350011008, 009-091-105

TEST SPECIMENS:

Upper Material: **C95500 Al Bronze**
Finish (μ in.): 32
Hardness (HRc): 112-123
Falex ID #: 5172

Lower Material: **AISI 4140 Steel Black Oxide Coated**
Finish (μ in.): 32
Hardness (HRc): Nitride, case depth .003-.005
Core strength 160-180 KSI
Falex ID #: 5164

TEST CONDITIONS:

Test Speed (rpm):	5
Temperature (°C):	Ambient
Duration (hr):	24
Test Load (lb):	1520
Mean Test Radius (in):	0.531
Contact Pressure (psi):	7600

Pressure

Test Results:

Test Date:	11/28/01	12/03/01	11/29/01	11/30/01
Test Number:	09050	9058	09053*	09054*
Upper Falex ID #:	5172C	5172K	5172F	5172G
Lower Falex ID #:	5164C	5164K	5164F	5164G
Lubricant:	**Aeroshell 33**	**Aeroshell 33**	**Aeroshell 33 Weathered**	**Aeroshell 33 Weathered**
Lubricant Falex ID #:	4948	4948	4949	4949
SaveFile Name:	DGWEAR03	TDAT002-003	TDAT038-039	DGWEAR05
Test Program Name:	D&GWEARTEST	DGTHWRT	DGTHWRT	D&GWEARTEST
Mass Loss, Upper (mg):	41.4	23.7	52.0	98.0
Mass Loss, Lower (mg):	1.9	1.9	0.8	1.6
Bronze height change (mm):	0.082	0.0305	0.077	0.024

Comments: See Graphs for Torque, Friction Coefficient, Load, and Specimen Temperature trends.
*Pin for the upper (rotating) specimen broke.

Coefficient of Friction (CoF)
The dimensionless ratio of the friction force (FF) between the upper rotating material and the lower stationary material to the normal force (N) pressing these bodies together.

TW

Company:	***Dombroff & Gilmore***	Page:	3
Date:	12/03/01	Project #:	01-111
Technician	N. Pekoc / M. Rapp		

Method:	Modified Thrust Washer
Machine:	Falex High Performance Multi-Specimen Test Machine, Computer Controlled Version
Serial #:	809C350011008, 009-091-105

TEST SPECIMENS:

Upper Material:	**C95500 Al Bronze**
Finish (μ in):	32
Hardness (HRc):	112-123
Falex ID #:	5172
Lower Material:	**AISI 4140 Steel, black oxide coated**
Finish (μ in):	32
Hardness (HRc):	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5164

TEST CONDITIONS:

Test Speed (rpm):	5
Temperature (°C):	Ambient
Duration (hr):	24
Test Load (lb):	1520
Mean Test Radius (in):	0.531
Contact Pressure (psi):	7600

Pressure

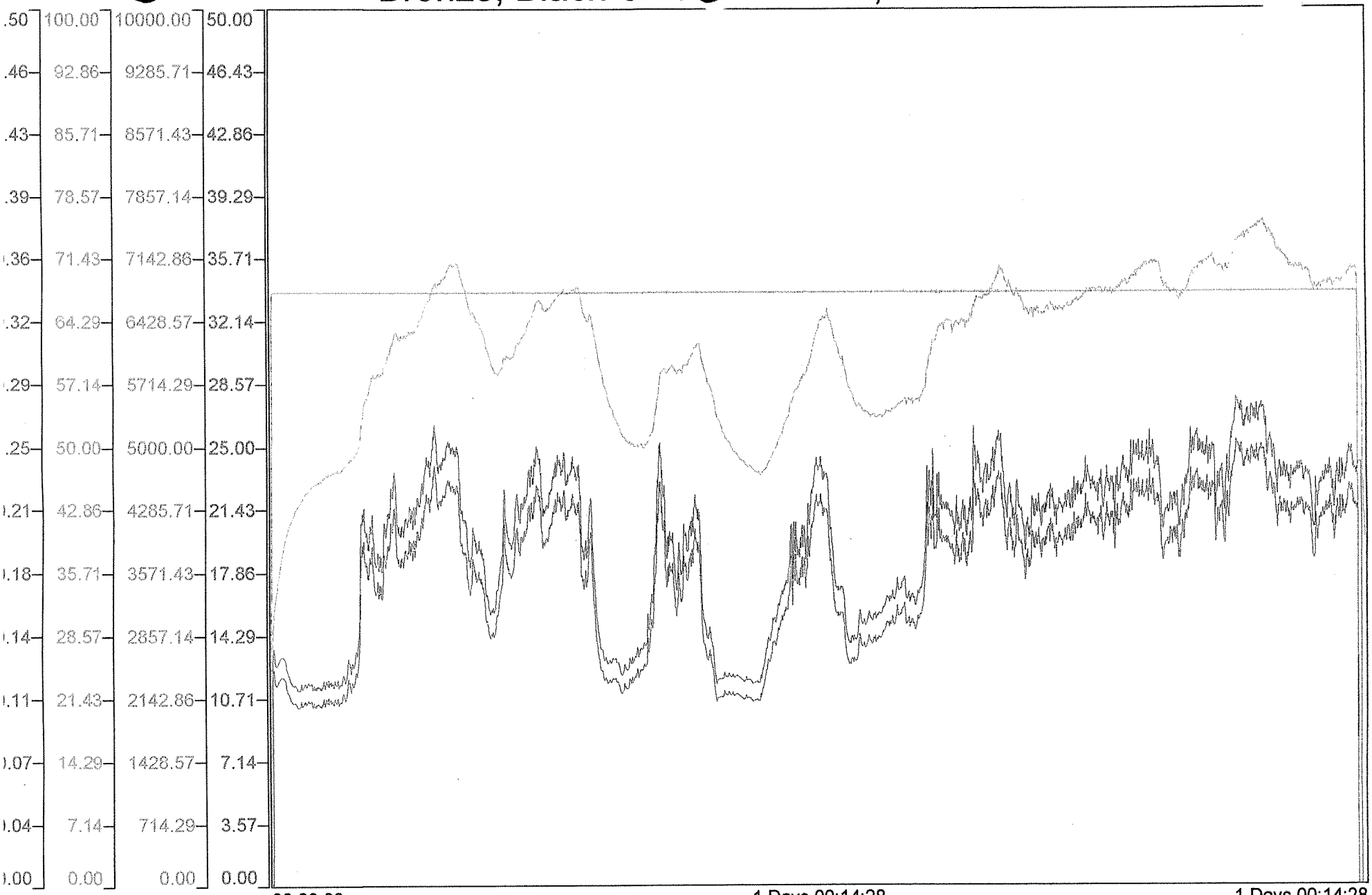
Test Results:

Test Date:	11/28/01	12/1/01
Test Number:	9051*	09056*
Upper Falex ID #:	5172D	5172I
Lower Falex ID #:	5164D	5164I
Lubricant:	**Aeroshell 33 weathered**	**Aeroshell 33**
Lubricant Falex ID #:	4949	4948
SaveFile Name:	TDAT018-037	TDAT000-001
Test Program Name:	DGTHWRT	DGTHWRT
Mass Loss, Upper (mg):	22.4	26.2
Mass Loss, Lower (mg):	1.8	1.0
Bronze height change (mm):	0:025	0.025

Comments: See Graphs for Torque, Friction Coefficient, Load, and Specimen Temperature trends.
*Pin for the upper (rotating) specimen broke.

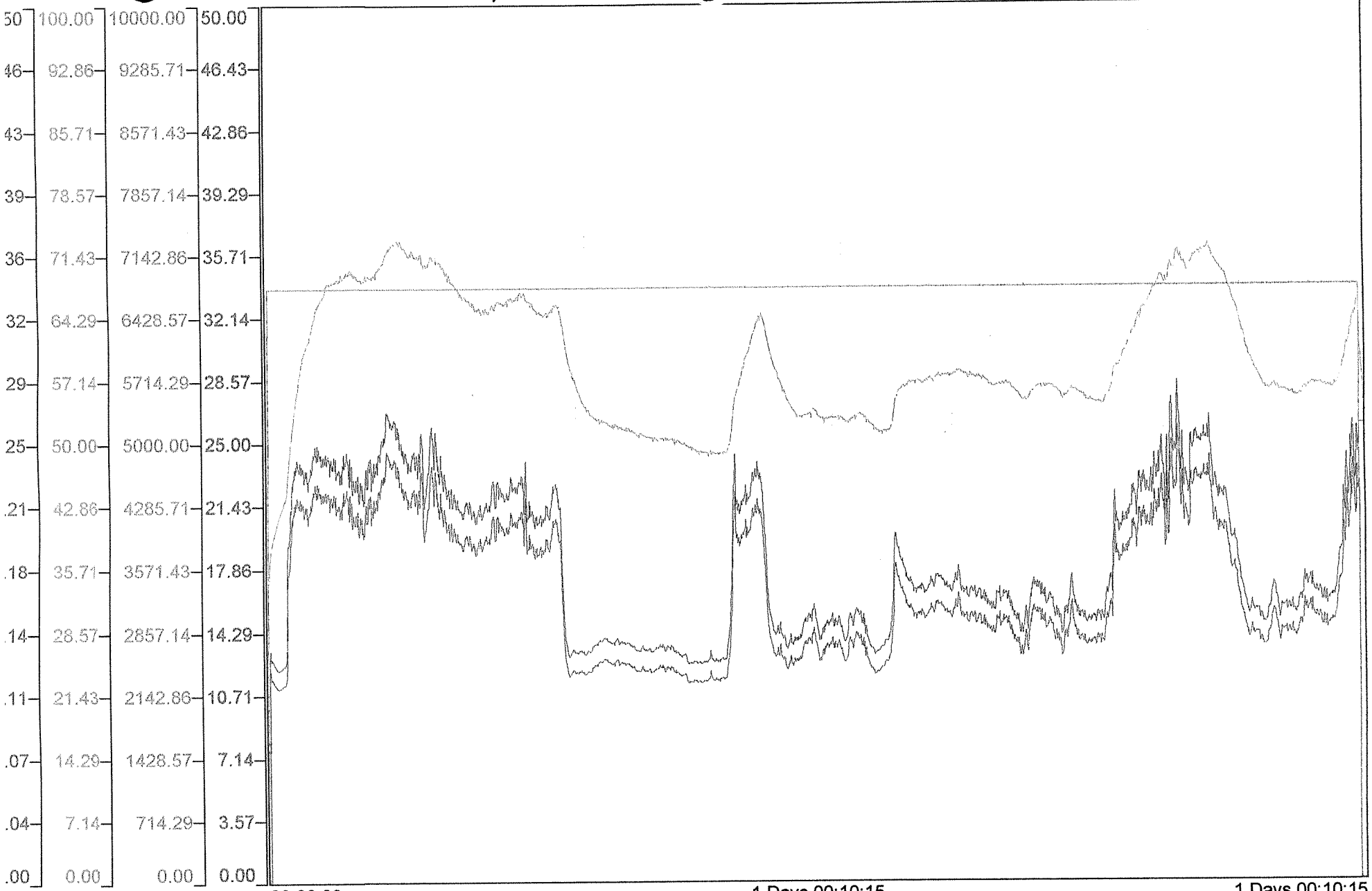
Coefficient of Friction (CoF)
The dimensionless ratio of the friction force (FF) between the upper rotating material and the lower stationary material to the normal force (N) pressing these bodies together.

Bronze, Black Oxid Mobil 28, run 1



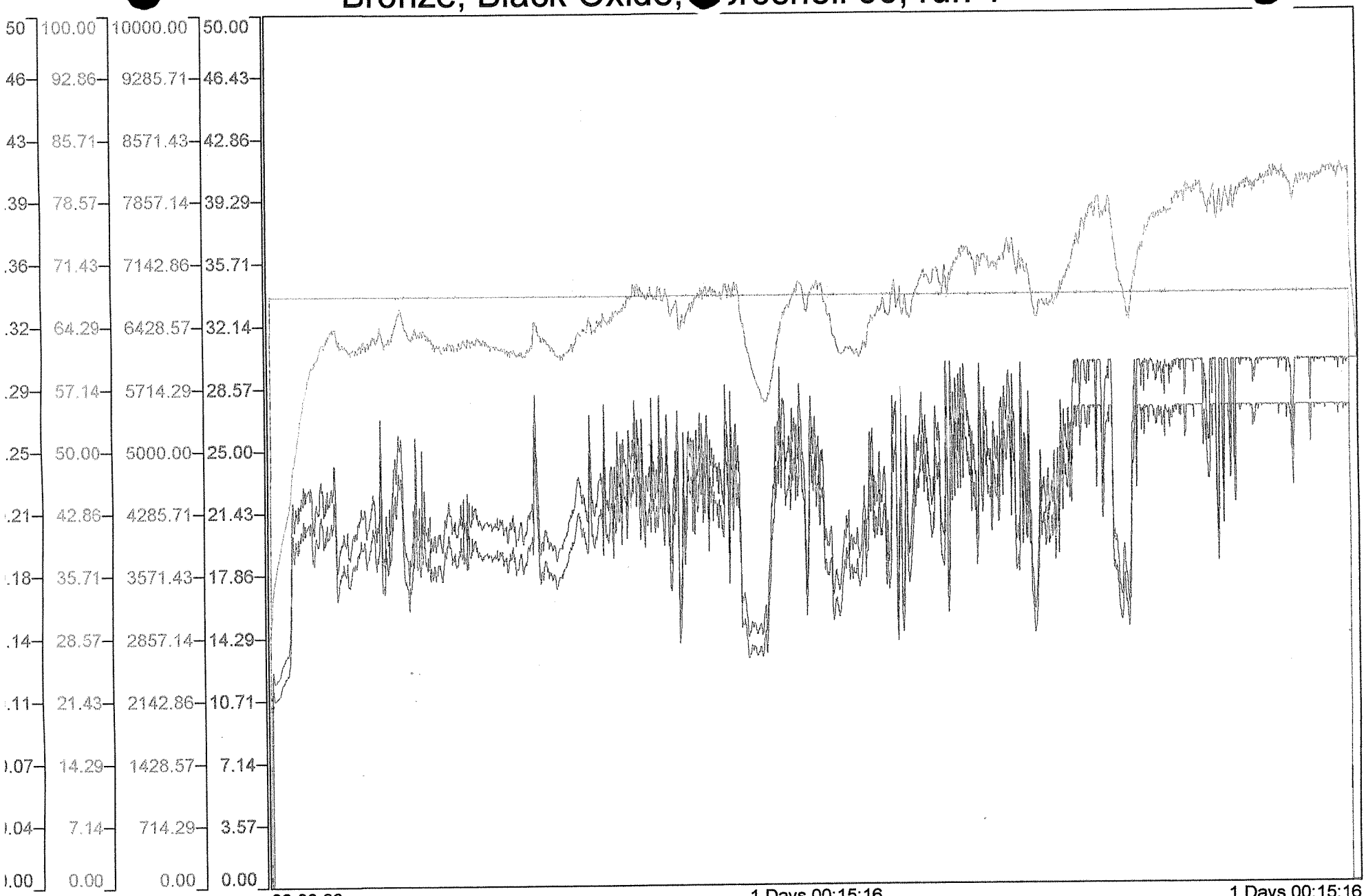
Description	Batch Name	Scale Range	Eng. Units	1 Day 00:14:28
COEFFICIENT OF FRICTION	dgwear02	0.00/0.50	Coef	0.00
NTERFACE TEMP.	dgwear02	0.00/100.00	DEG.C	39.43
SPECIMEN LOAD	dgwear02	0.00/10000.00	N	0.00
TORQUE	dgwear02	0.00/50.00	N-m	-5.42e-03

Bronze, Black Oxid Mobil 28, run 2



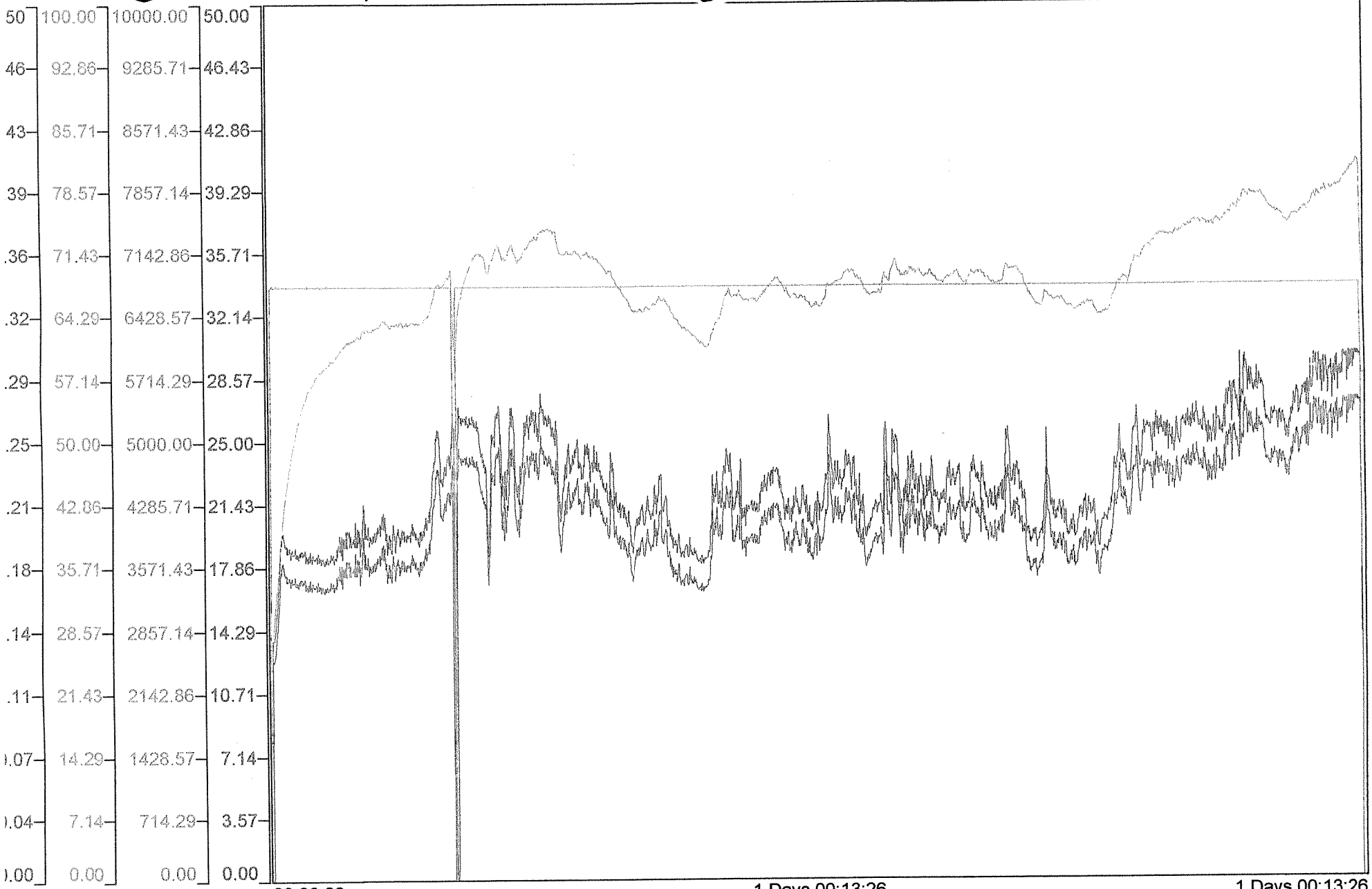
escription	Batch Name	Scale Range	Eng. Units	1 Day 00:10:15
OEFFICIENT OF FRICTION	dgwear04	0.00/0.50	Coef	0.26
NTERFACE TEMP.	dgwear04	0.00/100.00	DEG.C	53.18
PECIMEN LOAD	dgwear04	0.00/10000.00	N	0.00
ORQUE	dgwear04	0.00/50.00	N-m	-5.80e-03

Bronze, Black Oxide, [illegible]eroshell 33, run 1



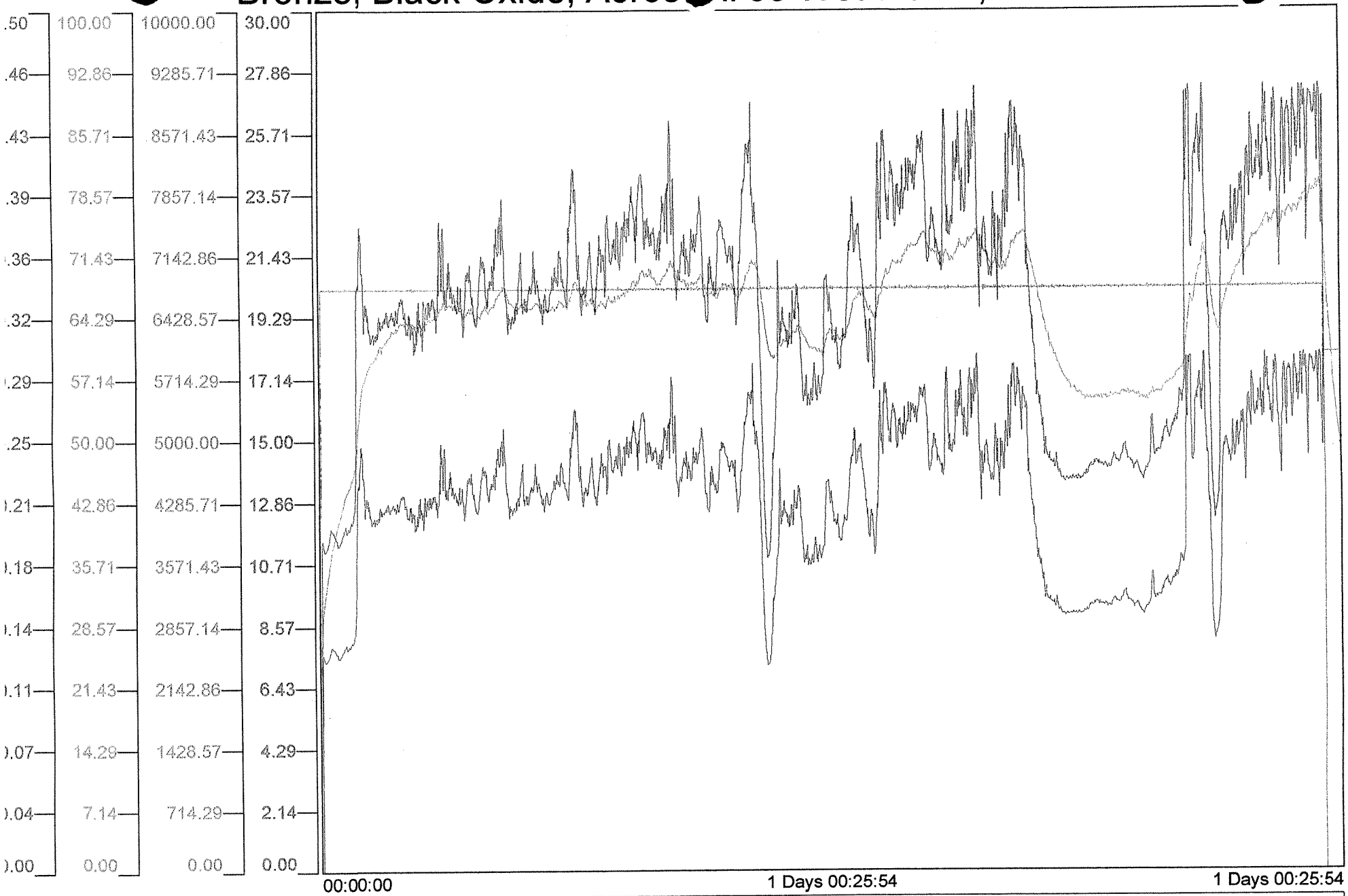
Description	Batch Name	Scale Range	Eng. Units	1 Day 00:15:16
COEFFICIENT OF FRICTION	dgwear03	0.00/0.50	Coef	0.30
NTERFACE TEMP.	dgwear03	0.00/100.00	DEG.C	58.48
SPECIMEN LOAD	dgwear03	0.00/10000.00	N	0.00
TORQUE	dgwear03	0.00/50.00	N-m	-6.88e-03

Bronze, Black Oxide, Aeros[illegible]ll 33 Weathered, run 1



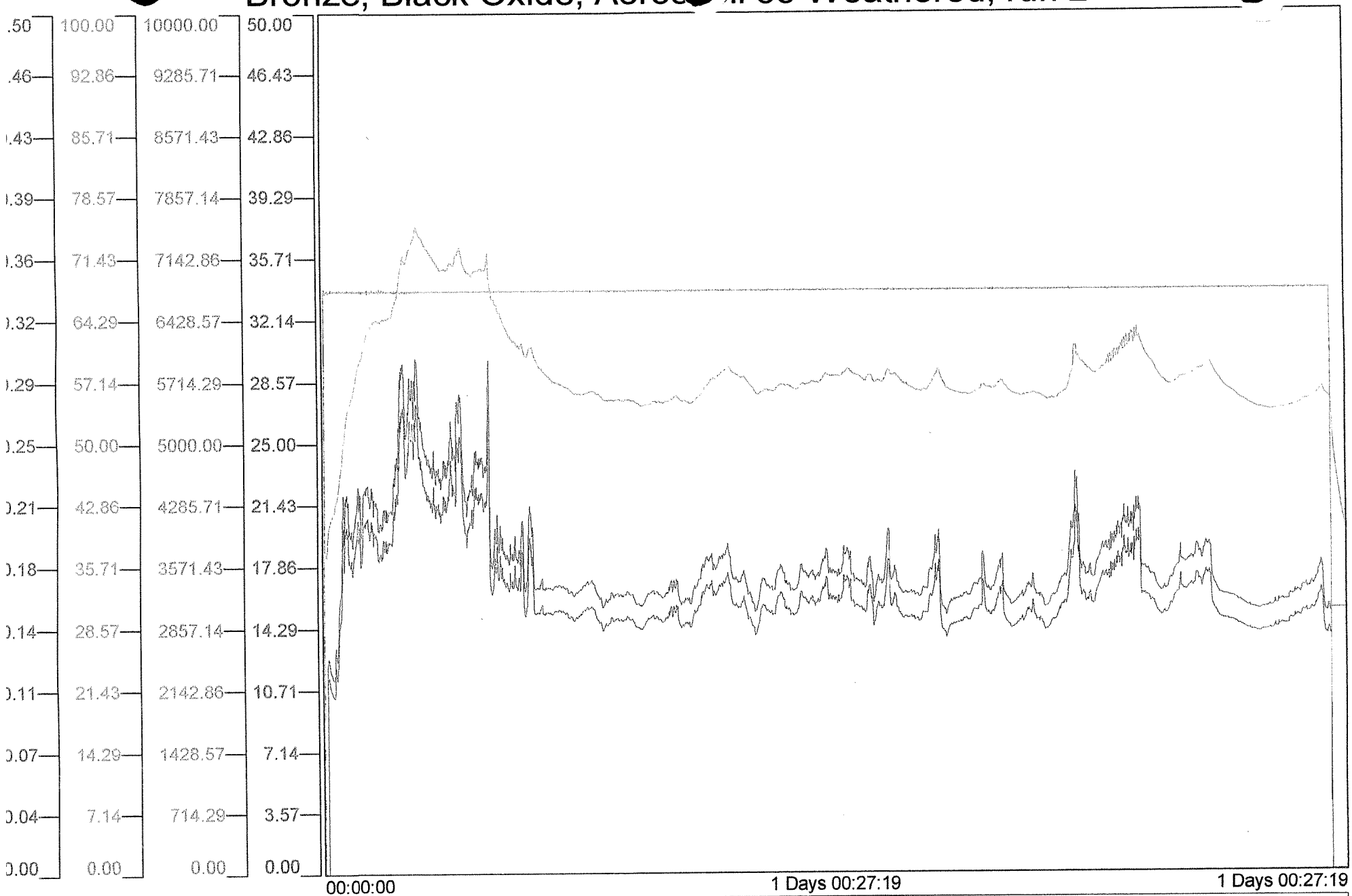
Description	Batch Name	Scale Range	Eng. Units	1 Day 00:13:26
COEFFICIENT OF FRICTION	dgwear01	0.00/0.50	Coef	0.29
NTERFACE TEMP	dgwear01	0.00/100.00	DEG.C	65.61
SPECIMEN LOAD	dgwear01	0.00/10000.00	N	0.00
TORQUE	dgwear01	0.00/50.00	N-m	4.21e-03

Bronze, Black Oxide, Aeros[illegible]ll 33 Weathered, run 3



Description	Batch Name	Scale Range	Eng. Units	1 Day 00:25:54
COEFFICIENT OF FRICTION	dgwear07	0.00/0.50	Coef	***
NTERFACE TEMP.	dgwear07	0.00/100.00	DEG.C	***
SPECIMEN LOAD	dgwear07	0.00/10000.00	N	***
TORQUE	dgwear07	0.00/30.00	N-m	***

Bronze, Black Oxide, Aeros[illegible]ll 33 Weathered, run 2



Description	Batch Name	Scale Range	Eng. Units	1 Day 00:27:19
COEFFICIENT OF FRICTION	dgwear05	0.00/0.50	Coef	***
INTERFACE TEMP.	dgwear05	0.00/100.00	DEG.C	***
SPECIMEN LOAD	dgwear05	0.00/10000.00	N	***
TORQUE	dgwear05	0.00/50.00	N-m	***

Company:	**Dombroff & Gilmore**	Page:	19
Date:	11/21/2001	Project #:	01-111
Technician:	M. Rapp		

Test Method:	ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine:	Falex Computer Controlled Block on Ring Test Machine
Serial #:	800135004198

Testing Specimens:

Sample ID:	**Mobil 28**
Falex ID #:	4944
Block Type:	HP Test Block
Material:	C95500 Al Bronze
Finish (µin):	32
Hardness (BHN):	112-123
Falex ID #:	5060
Ring Type:	Falex test ring w/ black oxide coating
Material:	AISI 4140 steel
Finish (µin):	32
Condition	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	180
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/21/01
Test Number:	0107422

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3972	22.2658
Final	7.3912	22.2652
Loss	0.0060	0.0006

Block Scar Data

Measurement 1 (mm):	3.137
Measurement 2 (mm):	3.119
Measurement 3 (mm):	3.071
Average Scar (mm):	3.109
Standared Deviation:	0.028
Coefficient of Variation (%)	0.896
Volumetric Wear (mm^3):	0.9111
Final Pressure (psi):	5,882

Comments:

Test file: 3704_180.xls
Save file: D&G35

Test block and ring shared with Test #0107423. Single score mark is this test.

Company:	**Dombroff & Gilmore**	Page:	20
Date:	11/21/2001	Project #:	01-111
Technician:	M. Rapp		

Test Method:	ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine:	Falex Computer Controlled Block on Ring Test Machine
Serial #:	800135004198

Testing Specimens:

Sample ID:	**Mobil 28**
Falex ID #:	4944
Block Type:	HP Test Block
Material:	C95500 Al Bronze
Finish (µin):	32
Hardness (BHN):	112-123
Falex ID #:	5060
Ring Type:	Falex test ring w/ black oxide coating
Material:	AISI 4140 steel
Finish (µin):	32
Condition	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	180
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/21/01
Test Number:	0107423

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3915	22.2652
Final	7.3849	22.2653
Loss	0.0066	-0.0001

Block Scar Data

Measurement 1 (mm):	3.267
Measurement 2 (mm):	3.264
Measurement 3 (mm):	3.232
Average Scar (mm):	3.254
Standared Deviation:	0.016
Coefficient of Variation (%)	0.487
Volumetric Wear (mm^3):	1.0452
Final Pressure (psi):	5,620

Comments:

Test file: 3704_180.xls
Save file: D&G36

Test block and ring shared with Test #0107422. Double score mark is this test.

Company:	**Dombroff & Gilmore**	Page:	14
Date:	11/15/2001	Project #:	01-111
Technician:	M. Rapp		

Test Method:	ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine:	Falex Computer Controlled Block on Ring Test Machine
Serial #:	800135004198

Testing Specimens:

Sample ID:	**Aeroshell 33**
Falex ID #:	4948
Block Type:	HP Test Block
Material:	C95500 Al Bronze
Finish (µin):	32
Hardness (BHN):	112-123
Falex ID #:	5060
Ring Type:	Falex test ring w/ black oxide coating
Material:	AISI 4140 steel
Finish (µin):	32
Condition	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	180
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/14/01
Test Number:	0107417

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3989	22.3005
Final	7.3929	22.2993
Loss	0.0060	0.0012

Block Scar Data

Measurement 1 (mm):	2.995
Measurement 2 (mm):	2.931
Measurement 3 (mm):	2.829
Average Scar (mm):	2.918
Standared Deviation:	0.068
Coefficient of Variation (%)	2.342
Volumetric Wear (mm^3):	0.7533
Final Pressure (psi):	6,267

Comments:

Test file: 3704_180.xls
Save file: D&G30

Company:	**Dombroff & Gilmore**	Page:	15
Date:	11/21/2001	Project #:	01-111
Technician:	M. Rapp		

Test Method: ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine: Falex Computer Controlled Block on Ring Test Machine
Serial #: 800135004198

Testing Specimens:

Sample ID: **Aeroshell 33**
Falex ID #: 4948

Block Type: HP Test Block
- Material: C95500 Al Bronze
- Finish (µin): 32
- Hardness (BHN): 112-123

Falex ID #: 5060
Ring Type: Falex test ring w/ black oxide coating
- Material: AISI 4140 steel
- Finish (µin): 32
- Condition: Nitride, case depth .003-.005 Core strength 160-180 KSI

Falex ID #: 5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	180
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/20/01
Test Number:	0107418

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3942	22.3002
Final	7.3877	22.3002
Loss	0.0065	0.0000

Block Scar Data

Measurement 1 (mm):	3.236
Measurement 2 (mm):	3.289
Measurement 3 (mm):	3.202
Average Scar (mm):	3.242
Standared Deviation:	0.036
Coefficient of Variation (%)	1.104
Volumetric Wear (mm^3):	1.0337
Final Pressure (psi):	5,640

Comments:

Test file: 3704_180.xls
Save file: D&G31

Test block and ring shared with Test #0107417. Double score mark is this test.

Company:	**Dombroff & Gilmore**	Page:	32
Date:	12/03/2001	Project #:	01-111
Technician:	M. Rapp		

Test Method: ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine: Falex Computer Controlled Block on Ring Test Machine
Serial #: 800135004198

Testing Specimens:

Sample ID: **Aeroshell 33**
Falex ID #: 4948

Block Type: HP Test Block
Material: C95500 Al Bronze
Finish (µin): 32
Hardness (BHN): 112-123
Falex ID #: 5212
Ring Type: Falex test ring w/ black oxide coating
Material: AISI 4140 steel
Finish (µin): 32
Condition: Nitride, case depth .003-.005
Core strength 160-180 KSI
Falex ID #: 5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	180
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/30/01
Test Number:	0107435

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.4439	22.3125
Final	7.4347	22.3119
Loss	0.0092	0.0006

Block Scar Data

Measurement 1 (mm):	3.472
Measurement 2 (mm):	3.429
Measurement 3 (mm):	3.378
Average Scar (mm):	3.426
Standared Deviation:	0.038
Coefficient of Variation (%)	1.121
Volumetric Wear (mm^3):	1.2202
Final Pressure (psi):	5,337

Comments:

Test file: 3704_180.xls
Save file: D&G48

Company:	**Dombroff & Gilmore**	Page:	16
Date:	11/21/2001	Project #:	01-111
Technician:	M. Rapp		

Test Method: ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine: Falex Computer Controlled Block on Ring Test Machine
Serial #: 800135004198

Testing Specimens:

Sample ID: **Weathered Aeroshell 33**
Falex ID #: 4949

Block Type: HP Test Block
Material: C95500 Al Bronze
Finish (µin): 32
Hardness (BHN): 112-123
Falex ID #: 5060
Ring Type: Falex test ring w/ black oxide coating
Material: AISI 4140 steel
Finish (µin): 32
Condition: Nitride, case depth .003-.005
Core strength 160-180 KSI
Falex ID #: 5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	180
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/20/01
Test Number:	0107419

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3921	22.3134
Final	7.3857	22.3121
Loss	0.0064	0.0013

Block Scar Data

Measurement 1 (mm):	3.287
Measurement 2 (mm):	3.238
Measurement 3 (mm):	3.220
Average Scar (mm):	3.248
Standared Deviation:	0.028
Coefficient of Variation (%)	0.872
Volumetric Wear (mm^3):	1.0394
Final Pressure (psi):	5,630

Comments:

Test file: 3704_180.xls
Save file: D&G32

Test block and ring shared with Test #0107421. Single score mark is this test.

Company:	**Dombroff & Gilmore**	Page:	18
Date:	11/21/2001	Project #:	01-111
Technician:	M. Rapp		

Test Method:	ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine:	Falex Computer Controlled Block on Ring Test Machine
Serial #:	800135004198

Testing Specimens:

Sample ID:	**Weathered Aeroshell 33**
Falex ID #:	4949
Block Type:	HP Test Block
Material:	C95500 Al Bronze
Finish (µin):	32
Hardness (BHN):	112-123
Falex ID #:	5060
Ring Type:	Falex test ring w/ black oxide coating
Material:	AISI 4140 steel
Finish (µin):	32
Condition	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	180
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/20/01
Test Number:	0107421

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3857	22.3130
Final	7.3782	22.3133
Loss	0.0075	-0.0003

Block Scar Data

Measurement 1 (mm):	3.256
Measurement 2 (mm):	3.245
Measurement 3 (mm):	3.225
Average Scar (mm):	3.242
Standared Deviation:	0.013
Coefficient of Variation (%)	0.396
Volumetric Wear (mm^3):	1.0333
Final Pressure (psi):	5,641

Comments:

Test file: 3704_180.xls
Save file: D&G34

Test block and ring shared with Test #0107419. Double score mark is this test.

Company:	**Dombroff & Gilmore**	Page:	31
Date:	12/11/01	Project #:	01-111
Technician:	M. Rapp		

Test Method:	ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine:	Falex Computer Controlled Block on Ring Test Machine
Serial #:	800135004198

Testing Specimens:

Sample ID:	**Aeroshell 33**
Falex ID #:	4948
Block Type:	HP Test Block
Material:	C95500 Al Bronze
Finish (µin):	32
Hardness (BHN):	112-123
Falex ID #:	5060
Ring Type:	Falex test ring w/ black oxide coating
Material:	AISI 4140 steel
Finish (µin):	32
Condition	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5150

Testing Conditions:

Speed (cpm):	2.1
Temperature (°C):	Ambient
Load (lb):	180
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/28/01
Test Number:	0107434

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.4015	22.3328
Final	7.3960	22.3325
Loss	0.0055	0.0003

Block Scar Data

Measurement 1 (mm):	3.097
Measurement 2 (mm):	3.051
Measurement 3 (mm):	3.050
Average Scar (mm):	3.066
Standared Deviation:	0.022
Coefficient of Variation (%)	0.715
Volumetric Wear (mm^3):	0.8738
Final Pressure (psi):	5,965

Comments:

Test file: 3704_180ls.xls
Save file: D&G47

Company: **Dombroff & Gilmore**
Project #: 01-111
Date: 12/11/01
Technician: M. Rapp

Test Method: ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine: Falex Computer Controlled Block on Ring Test Machine
Serial #: 800135004198

Testing Specimens:

Sample ID: **Mobil 28**
Falex ID #: 4944

Block Type: HP Test Block
Material: C95500 Al Bronze
Finish (µin): 32
Hardness (BHN): 112-123
Falex ID #: 5060
Ring Type: Falex test ring w/ black oxide coating
Material: AISI 4140 steel
Finish (µin): 32
Condition: Nitride, case depth .003-.005
Core strength 160-180 KSI
Falex ID #: 5150

Testing Conditions:

Speed (cpm): 2.1
Temperature (°C): Ambient
Load (lb): 180
Duration (cycles): 5000
Oscillation Angle: 90°

Test Date: 11/21/01
Test Number: 0107425

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3837	22.3608
Final	7.3807	22.3606
Loss	0.0030	0.0002

Block Scar Data

Measurement 1 (mm):	3.030
Measurement 2 (mm):	2.974
Measurement 3 (mm):	2.936
Average Scar (mm):	2.980
Standared Deviation:	0.039
Coefficient of Variation (%)	1.296
Volumetric Wear (mm^3):	0.8022

Final Pressure (psi): 6,137

Comments:

Test file: 3704_180ls.xls
Save file: D&G38

Company:	**Dombroff & Gilmore**	Page:	7
Date:	11/12/2001	Project #:	01-111
Technician:	M. Rapp		

Test Method:	ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine:	Falex Computer Controlled Block on Ring Test Machine
Serial #:	800135004198

Testing Specimens:

Sample ID:	**Weathered Aeroshell 33**
Falex ID #:	4949
Block Type:	HP Test Block
Material:	C95500 Al Bronze
Finish (µin):	32
Hardness (BHN):	112-123
Falex ID #:	5060
Ring Type:	Falex test ring w/ black oxide coating
Material:	AISI 4140 steel
Finish (µin):	32
Condition	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/9/01
Test Number:	0107410

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3831	22.3041
Final	7.3694	22.3039
Loss	0.0137	0.0002

Block Scar Data

Measurement 1 (mm):	4.088
Measurement 2 (mm):	4.061
Measurement 3 (mm):	4.033
Average Scar (mm):	4.061
Standared Deviation:	0.022
Coefficient of Variation (%)	0.553
Volumetric Wear (mm^3):	2.0335
Final Pressure (psi):	9,007

Comments:

Test file: 3704_360.xls
Save file: D&G23

2.5ml of Arco deicer (TL# 5063) was applied three times, at start of test, 20 minutes and 40 minutes.

Company:	**Dombroff & Gilmore**	Page:	8
Date:	11/12/2001	Project #:	01-111
Technician:	M. Rapp		

Test Method: ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine: Falex Computer Controlled Block on Ring Test Machine
Serial #: 800135004198

Testing Specimens:

Sample ID: **Mobil 28**
Falex ID #: 4944

Block Type:	HP Test Block
Material:	C95500 Al Bronze
Finish (µin):	32
Hardness (BHN):	112-123
Falex ID #:	5060
Ring Type:	Falex test ring w/ black oxide coating
Material:	AISI 4140 steel
Finish (µin):	32
Condition	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/10/01
Test Number:	0107411

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3974	22.3245
Final	7.3850	22.3236
Loss	0.0124	0.0009

Block Scar Data

Measurement 1 (mm):	3.960
Measurement 2 (mm):	3.928
Measurement 3 (mm):	3.859
Average Scar (mm):	3.916
Standared Deviation:	0.042
Coefficient of Variation (%)	1.076
Volumetric Wear (mm^3):	1.8228
Final Pressure (psi):	9,341

Comments:

Test file: 3704_360.xls
Save file: D&G24

2.5ml of Arco deicer (TL# 5063) was applied three times, at start of test, 20 minutes and 40 minutes.

Company:	**Dombroff & Gilmore**	Page:	10
Date:	11/12/2001	Project #:	01-111
Technician:	M. Rapp		

Test Method:	ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine:	Falex Computer Controlled Block on Ring Test Machine
Serial #:	800135004198

Testing Specimens:

Sample ID:	**Mobil 28**
Falex ID #:	4944
Block Type:	HP Test Block
Material:	C95500 Al Bronze
Finish (µin):	32
Hardness (BHN):	112-123
Falex ID #:	5060
Ring Type:	Falex test ring w/ black oxide coating
Material:	AISI 4140 steel
Finish (µin):	32
Condition	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/10/01
Test Number:	0107413

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.4001	22.3107
Final	7.3907	22.3101
Loss	0.0094	0.0006

Block Scar Data

Measurement 1 (mm):	3.143
Measurement 2 (mm):	3.661
Measurement 3 (mm):	4.092
Average Scar (mm):	3.632
Standared Deviation:	0.388
Coefficient of Variation (%)	**10.682**
Volumetric Wear (mm^3):	1.4539
Final Pressure (psi):	10,070

Comments:

Test file: 3704_360.xls
Save file: D&G26

2.5ml of Arco deicer (TL# 5063) was applied three times, at start of test, 20 minutes and 40 minutes.

Test failed due to exceeding Coefficient of Variation. Test was re-run as Test 0107414
Block side with single score mark is this test, double score mark is Test 0107414

Company:	**Dombroff & Gilmore**	Page:	17
Date:	11/20/2001	Project #:	01-111
Technician:	M. Rapp		

Test Method: ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine: Falex Computer Controlled Block on Ring Test Machine
Serial #: 800135004198

Testing Specimens:

Sample ID: **Weathered Aeroshell 33**
Falex ID #: 4949

Block Type:	HP Test Block
Material:	C95500 Al Bronze
Finish (µin):	32
Hardness (BHN):	112-123
Falex ID #:	5060
Ring Type:	Falex test ring w/ black oxide coating
Material:	AISI 4140 steel
Finish (µin):	32
Condition	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/20/01
Test Number:	0107420

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3875	22.2462
Final	7.3773	22.2454
Loss	0.0102	0.0008

Block Scar Data

Measurement 1 (mm):	3.874
Measurement 2 (mm):	3.852
Measurement 3 (mm):	3.805
Average Scar (mm):	3.844
Standared Deviation:	0.029
Coefficient of Variation (%)	0.749
Volumetric Wear (mm^3):	1.7238
Final Pressure (psi):	9,516

Comments:

Test file: 3704_360.xls
Save file: D&G33

2.5ml of Arco deicer (TL# 5063) was applied three times, at start of test, 20 minutes and 40 minutes.

Test block and ring shared with Test #0107412. Double score mark is this test.

Company:	**Dombroff & Gilmore**	Page:	21
Date:	11/26/2001	Project #:	01-111
Technician:	M. Rapp		

Test Method: ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine: Falex Computer Controlled Block on Ring Test Machine
Serial #: 800135004198

Testing Specimens:

Sample ID: **Weathered Aeroshell 33**
Falex ID #: 4949

Block Type:	HP Test Block
Material:	C95500 Al Bronze
Finish (µin):	32
Hardness (BHN):	112-123
Falex ID #:	5060
Ring Type:	Falex test ring w/ black oxide coating
Material:	AISI 4140 steel
Finish (µin):	32
Condition	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	180
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/21/01
Test Number:	0107424

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.4085	22.3292
Final	7.4021	22.3281
Loss	0.0064	0.0011

Block Scar Data

Measurement 1 (mm):	3.158
Measurement 2 (mm):	3.151
Measurement 3 (mm):	3.149
Average Scar (mm):	3.153
Standared Deviation:	0.004
Coefficient of Variation (%)	0.122
Volumetric Wear (mm^3):	0.9501
Final Pressure (psi):	5,801

Comments:

Test file: 3704_180.xls
Save file: D&G37

2.5ml of deicer was applied three times, at start of test, 20 and 40 minutes

Company:	**Dombroff & Gilmore**	Page:	23
Date:	11/26/2001	Project #:	01-111
Technician:	M. Rapp		

Test Method:	ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine:	Falex Computer Controlled Block on Ring Test Machine
Serial #:	800135004198

Testing Specimens:

Sample ID:	**Weathered Aeroshell 33**
Falex ID #:	4949
Block Type:	HP Test Block
Material:	C95500 Al Bronze
Finish (µin):	32
Hardness (BHN):	112-123
Falex ID #:	5060
Ring Type:	Falex test ring w/ black oxide coating
Material:	AISI 4140 steel
Finish (µin):	32
Condition	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	95
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/26/01
Test Number:	0107426

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.4112	22.3319
Final	7.3979	22.3309
Loss	0.0133	0.0010

Block Scar Data

Measurement 1 (mm):	4.111
Measurement 2 (mm):	4.051
Measurement 3 (mm):	4.003
Average Scar (mm):	4.055
Standared Deviation:	0.044
Coefficient of Variation (%)	1.090
Volumetric Wear (mm^3):	2.0249
Final Pressure (psi):	9,020

Comments:

Test file: 3704_360ht.xls
Save file: D&G39

2.5ml of distilled water was applied at start of test.

Block and ring shared with test #0107427. Single score mark is this test.

Company:	**Dombroff & Gilmore**	Page:	24
Date:	11/28/2001	Project #:	01-111
Technician:	M. Rapp		

Test Method: ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine: Falex Computer Controlled Block on Ring Test Machine
Serial #: 800135004198

Testing Specimens:

Sample ID: **Weathered Aeroshell 33**
Falex ID #: 4949

Block Type: HP Test Block
Material: C95500 Al Bronze
Finish (µin): 32
Hardness (BHN): 112-123
Falex ID #: 5060
Ring Type: Falex test ring w/ black oxide coating
Material: AISI 4140 steel
Finish (µin): 32
Condition: Nitride, case depth .003-.005
Core strength 160-180 KSI
Falex ID #: 5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	95
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/26/01
Test Number:	0107427

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3976	22.2309
Final	7.3841	22.2304
Loss	0.0135	0.0005

Block Scar Data

Measurement 1 (mm):	4.004
Measurement 2 (mm):	3.998
Measurement 3 (mm):	3.998
Average Scar (mm):	4.000
Standared Deviation:	0.003
Coefficient of Variation (%)	0.071
Volumetric Wear (mm^3):	1.9434
Final Pressure (psi):	9,144

Comments:

Test file: 3704_360ht.xls
Save file: D&G40

2.5ml of distilled water was applied at start of test.

Block and ring shared with test #0107426. Double score mark is this test.

Company:	**Dombroff & Gilmore**	Page:	25
Date:	11/28/2001	Project #:	01-111
Technician:	M. Rapp		

Test Method:	ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine:	Falex Computer Controlled Block on Ring Test Machine
Serial #:	800135004198

Testing Specimens:

Sample ID:	**Weathered Aeroshell 33**
Falex ID #:	4949
Block Type:	HP Test Block
Material:	C95500 Al Bronze
Finish (µin):	32
Hardness (BHN):	112-123
Falex ID #:	5060
Ring Type:	Falex test ring w/ black oxide coating
Material:	AISI 4140 steel
Finish (µin):	32
Condition	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	95
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/27/01
Test Number:	0107428

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3988	22.2643
Final	7.3845	22.2633
Loss	0.0143	0.0010

Block Scar Data

Measurement 1 (mm):	4.089
Measurement 2 (mm):	4.034
Measurement 3 (mm):	4.023
Average Scar (mm):	4.049
Standared Deviation:	0.029
Coefficient of Variation (%)	0.713
Volumetric Wear (mm^3):	2.0154
Final Pressure (psi):	9,034

Comments:

Test file: 3704_360ht.xls
Save file: D&G41

Block and ring shared with test #0107429. Single score mark is this test.

Company:	**Dombroff & Gilmore**	Page:	26
Date:	11/28/2001	Project #:	01-111
Technician:	M. Rapp		

Test Method: ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine: Falex Computer Controlled Block on Ring Test Machine
Serial #: 800135004198

Testing Specimens:

Sample ID: **Weathered Aeroshell 33**
Falex ID #: 4949

Block Type:	HP Test Block
Material:	C95500 Al Bronze
Finish (µin):	32
Hardness (BHN):	112-123
Falex ID #:	5060
Ring Type:	Falex test ring w/ black oxide coating
Material:	AISI 4140 steel
Finish (µin):	32
Condition	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	95
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/27/01
Test Number:	0107429

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3838	22.2634
Final	7.3709	22.2634
Loss	0.0129	0.0000

Block Scar Data

Measurement 1 (mm):	4.050
Measurement 2 (mm):	3.982
Measurement 3 (mm):	3.978
Average Scar (mm):	4.003
Standared Deviation:	0.033
Coefficient of Variation (%)	0.825
Volumetric Wear (mm^3):	1.9483
Final Pressure (psi):	9,136

Comments:

Test file: 3704_360ht.xls
Save file: D&G42

Block and ring shared with test #0107428. Double score mark is this test.

Company:	**Dombroff & Gilmore**	Page:	27
Date:	11/28/2001	Project #:	01-111
Technician:	M. Rapp		

Test Method:	ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine:	Falex Computer Controlled Block on Ring Test Machine
Serial #:	800135004198

Testing Specimens:

Sample ID:	**Mobil 28**
Falex ID #:	4944
Block Type:	HP Test Block
Material:	C95500 Al Bronze
Finish (µin):	32
Hardness (BHN):	112-123
Falex ID #:	5060
Ring Type:	Falex test ring w/ black oxide coating
Material:	AISI 4140 steel
Finish (µin):	32
Condition	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	95
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/27/01
Test Number:	0107430

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3935	22.3219
Final	7.3877	22.3217
Loss	0.0058	0.0002

Block Scar Data

Measurement 1 (mm):	3.262
Measurement 2 (mm):	3.183
Measurement 3 (mm):	3.139
Average Scar (mm):	3.195
Standared Deviation:	0.051
Coefficient of Variation (%)	1.593
Volumetric Wear (mm^3):	0.9887
Final Pressure (psi):	11,449

Comments:

Test file: 3704_360ht.xls
Save file: D&G43

2.5 ml of water was applied at start of test.

Block and ring shared with test #0107431. Single score mark is this test.

Company:	**Dombroff & Gilmore**	Page:	28
Date:	11/28/2001	Project #:	01-111
Technician:	M. Rapp		

Test Method: ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine: Falex Computer Controlled Block on Ring Test Machine
Serial #: 800135004198

Testing Specimens:

Sample ID: **Mobil 28**
Falex ID #: 4944

Block Type: HP Test Block
Material: C95500 Al Bronze
Finish (µin): 32
Hardness (BHN): 112-123
Falex ID #: 5060
Ring Type: Falex test ring w/ black oxide coating
Material: AISI 4140 steel
Finish (µin): 32
Condition: Nitride, case depth .003-.005
Core strength 160-180 KSI
Falex ID #: 5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	95
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/28/01
Test Number:	0107431

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3869	22.3210
Final	7.3801	22.3207
Loss	0.0068	0.0003

Block Scar Data

Measurement 1 (mm):	3.396
Measurement 2 (mm):	3.383
Measurement 3 (mm):	3.357
Average Scar (mm):	3.379
Standared Deviation:	0.016
Coefficient of Variation (%)	0.480
Volumetric Wear (mm^3):	1.1699
Final Pressure (psi):	10,826

Comments:

Test file: 3704_360ht.xls
Save file: D&G44

2.5 ml of water was applied at start of test.

Block and ring shared with test #0107430. Double score mark is this test.

Company:	**Dombroff & Gilmore**	Page:	29
Date:	11/28/2001	Project #:	01-111
Technician:	M. Rapp		

Test Method: ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine: Falex Computer Controlled Block on Ring Test Machine
Serial #: 800135004198

Testing Specimens:

Sample ID: **Aeroshell 33**
Falex ID #: 4948

Block Type: HP Test Block
Material: C95500 Al Bronze
Finish (µin): 32
Hardness (BHN): 112-123
Falex ID #: 5060
Ring Type: Falex test ring w/ black oxide coating
Material: AISI 4140 steel
Finish (µin): 32
Condition: Nitride, case depth .003-.005
Core strength 160-180 KSI
Falex ID #: 5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	95
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/28/01
Test Number:	0107432

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.4010	22.3483
Final	7.3880	22.3477
Loss	0.0130	0.0006

Block Scar Data

Measurement 1 (mm):	4.062
Measurement 2 (mm):	4.039
Measurement 3 (mm):	3.991
Average Scar (mm):	4.031
Standared Deviation:	0.030
Coefficient of Variation (%)	0.734
Volumetric Wear (mm^3):	1.9886
Final Pressure (psi):	9,074

Comments:

Test file: 3704_360ht.xls
Save file: D&G45

2.5 ml of water was applied at start of test.

Block and ring shared with test #0107433. Single score mark is this test.

Company:	**Dombroff & Gilmore**	Page:	30
Date:	11/28/2001	Project #:	01-111
Technician:	M. Rapp		

Test Method: ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine: Falex Computer Controlled Block on Ring Test Machine
Serial #: 800135004198

Testing Specimens:

Sample ID: **Aeroshell 33**
Falex ID #: 4948

Block Type: HP Test Block
Material: C95500 Al Bronze
Finish (µin): 32
Hardness (BHN): 112-123
Falex ID #: 5060
Ring Type: Falex test ring w/ black oxide coating
Material: AISI 4140 steel
Finish (µin): 32
Condition: Nitride, case depth .003-.005
Core strength 160-180 KSI
Falex ID #: 5150

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	95
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	11/28/01
Test Number:	0107433

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3879	22.3481
Final	7.3770	22.3481
Loss	0.0109	0.0000

Block Scar Data

Measurement 1 (mm):	3.798
Measurement 2 (mm):	3.795
Measurement 3 (mm):	3.782
Average Scar (mm):	3.792
Standared Deviation:	0.007
Coefficient of Variation (%)	0.183
Volumetric Wear (mm^3):	1.6546
Final Pressure (psi):	9,646

Comments:

Test file: 3704_360ht.xls
Save file: D&G46

2.5 ml of water was applied at start of test.

Block and ring shared with test #0107432. Double score mark is this test.

2	20.0	250	95	10	10	300	3	1
3	20.0	300	95	10	20	300	4	1
4	20.0	350	95	10	20	300	5	1
5	20.0	400	95	10	20	300	6	1
6	20.0	450	95	10	20	300	7	1
7	20.0	500	95	10	20	300	8	1
8	20.0	550	95	10	20	300	9	1
9	20.0	600	95	10	20	300	10	1
10	20.0	650	95	10	20	300	11	1
11	20.0	700	95	10	20	300	12	1
12	20.0	750	95	10	20	300	13	1
13	20.0	800	95	10	20	300	40	1
14	0.0	0	95	10	20	300	0	1
15	0.0	0	95	10	20	300	0	0
16	0.0	0	95	10	20	300	0	0
17	0.0	0	95	10	20	300	0	0
18	0.0	0	95	10	20	300	0	0
19	0.0	0	95	10	20	300	0	0
20	0.0	0	95	10	20	300	0	0
21	0.0	0	95	10	20	300	0	0
22	0.0	0	95	10	20	300	0	0
23	0.0	0	95	10	20	300	0	0
24	0.0	0	95	10	20	300	0	0
25	0.0	0	95	10	20	300	0	0
26	0.0	0	95	10	20	300	0	0
27	0.0	0	95	10	20	300	0	0
28	0.0	0	95	10	20	300	0	0
29	0.0	0	95	10	20	300	0	0
30	0.0	0	95	10	20	300	0	0
31	0.0	0	95	10	20	300	0	0
32	0.0	0	95	10	20	300	0	0
33	0.0	0	95	10	20	300	0	0
34	0.0	0	95	10	20	300	0	0
35	0.0	0	95	10	20	300	0	0
36	0.0	0	95	10	20	300	0	0
37	0.0	0	95	10	20	300	0	0
38	0.0	0	95	10	20	300	0	0
39	0.0	0	95	10	20	300	0	0
40	0.0	0	95	10	20	300	0	0

Company: ***Dombroff & Gilmore***
Date: 12/07/01
Technician M. Rapp

Page: 1
Project #: 01-111

Method: Modified Thrust Washer
Machine: Falex High Performance Multi-Specimen Test Machine, Computer Controlled Version
Serial #: 809C350011008, 009-091-105

TEST SPECIMENS:

Upper Material:	**C95500 Al Bronze**	
Finish (μ in):	32	
Hardness (HRc):	112-123	
Falex ID #:	5172	
Lower Material:	**AISI 4140 steel, black oxide coated**	
Finish (μ in):	32	
Hardness (HRc):	Nitride, case depth .003-.005	
	Core strength 160-180 KSI	
Falex ID #:	5164	

TEST CONDITIONS:

Test Speed (rpm):	5
Temperature (°C):	Various
Duration (hr):	24
Test Load (lb):	1520
Mean Test Radius (in):	0.531
Contact Pressure (psi):	7600

Test Results:

Test Date:	12/04/01	12/05/01	12/04/01	12/06/01
Test Number:	09060	09062	09059	09064
Test Temperature (°C):	**23**	**23**	**95**	**95**
Upper Falex ID #:			5172L	5172Q
Lower Falex ID #:	5172	5172	5164L	5164Q
Lubricant:	5164	5164	**Aeroshell 33**	**Aeroshell 33**
	Aeroshell 33	**Aeroshell 33**	**Weathered, w/ H_2O**	**Weathered, w/ H_2O**
Lubricant Falex ID #:	**Weathered, w/ H_2O**	**Weathered, w/ H_2O**	4949	4949
SaveFile Name:	4949	4949	DGWEAR08	TDAT008-009
Test Program Name:	TDAT004-005	TDAT006-007	D&GWEARTESTHT	DGTHWHT
	DGTHWRT	DGTHWRT		
Mass Loss, Upper (mg):	19.6	13.5	47.9	16.1
Mass Loss, Lower (mg):	1.0	0.3	1.0	2.3
Bronze Height change (mm):	0.028	0.027	0.067	0.024

Comments: See Graphs for Torque, Friction Coefficient, Load, Speed, and Specimen Temperature trends.

Coefficient of Friction (CoF)
The dimensionless ratio of the friction force (FF) between the upper rotating material and the lower stationary material to the normal force (N) pressing these bodies together.

Company:	***Dombroff & Gilmore***	Page:	2
Date:	12/03/01	Project #:	01-111
Technician	N. Pekoc / M. Rapp		

Method: Modified Thrust Washer
Machine: Falex High Performance Multi-Specimen Test Machine, Computer Controlled Version
Serial #: 809C350011008, 009-091-105

TEST SPECIMENS:

Upper Material: **C95500 Al Bronze**
Finish (µ in.): 32
Hardness (HRc): 112-123
Falex ID #: 5172

Lower Material: **AISI 4140 Steel, black oxide coated**
Finish (µ in.): 32
Hardness: Nitride, case depth .003-.005
Core strength 160-180 KSI
Falex ID #: 5164

TEST CONDITIONS:

Test Speed (rpm):	5
Temperature (°C):	95
Duration (hr):	24
Test Load (lb):	1520
Mean Test Radius (in):	0.531
Contact Pressure(psi):	7600

Test Results:

Test Date:	12/5/01	12/8/01	12/06/01	12/07/01
Test Number:	09065	09068	09063	09066
Test Temperature (C):	**95**	**95**	**95**	**95**
Upper Falex ID #:	5172	5172	5172	5172
Lower Falex ID #:	5164	5164	5164	5164
Lubricant:	**Mobil 28 w/ H_2O**	**Mobil 28 w/ H_2O**	**Aeroshell 33 w/ H_2O**	**Aeroshell 33 w/ H_2O**
Lubricant Falex ID #:	4944	4944	4948	4948
SaveFile Name:	DGWEAR11	TDAT012-013	DGWEAR10	TDAT010-011
Test Program Name:	D&GWEARTESTHT	DGTHWHT	D&GWEARTESTHT	DGTHWHT
Mass Loss, Upper (mg):	15.3	9.3	47.4	23.6
Mass Loss, Lower (mg):	1.5	1.5	1.1	1.8
Bronze Height Change (mm):	0.025	0.013	0.071	0.030

Comments: See Graphs for Torque, Friction Coefficient, Load, and Specimen Temperature trends.

Coefficient of Friction (CoF)
The dimensionless ratio of the friction force (FF) between the upper rotating material and the lower stationary material to the normal force (N) pressing these bodies together.

Company:	***Dombroff & Gilmore***	Page:	3
Date:	12/10/01	Project #:	01-111
Technician	N. Pekoc / M. Rapp		

Method:	Modified Thrust Washer
Machine:	Falex High Performance Multi-Specimen Test Machine, Computer Controlled Version
Serial #:	809C350011008, 009-091-105

TEST SPECIMENS:

Upper Material:	**C95500 Al Bronze**
Finish (μ in.):	32
Hardness (HRc):	112-123
Falex ID #:	5172
Lower Material:	**AISI 4140 Steel, black oxide coated**
Finish (μ in):	32
Hardness (HRc):	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5164

TEST CONDITIONS:

Test Speed (rpm):	5
Temperature (°C):	95
Duration (hr):	24
Test Load (lb):	1520
Mean Test Radius (in):	0.531
Contact Pressure (psi):	7600

Test Results:

Test Date:	12/5/01	12/8/01	12/1/01
Test Number:	09061*	09067*	09055*
Test Temperature (C):	**95**	**95**	**95**
Upper Falex ID #:	5172N	5172T	5172H
Lower Falex ID #:	5164N	5164T	5164H
Lubricant:	**Mobil 28 w/ H_2O**	**Aeroshell 33 weathered, w/ H_2O**	**Mobil 28 w/ H_2O**
Lubricant Falex ID #:	4944	4949	4944
SaveFile Name:	DGWEAR09	DGWEAR12	DGWEAR06
Test Program Name:	D&GWEARTESTHT	D&GWEARTESTHT	D&GWEARTESTHT
Mass Loss, Upper (mg):	43.3	96.4	28.8
Mass Loss, Lower (mg):	2.3	2.1	1.8
Bronze Height Change (mm):	0.029	0.086	0.031

Comments: See Graphs for Torque, Friction Coefficient, Load, and Specimen Temperature trends.
*Pin for the upper (rotating) specimen broke.

Coefficient of Friction (CoF)
The dimensionless ratio of the friction force (FF) between the upper rotating material and the lower stationary material to the normal force (N) pressing these bodies together.

Company:	***Dombroff & Gilmore***	Page:	5
Date:	01/28/02	Project #:	02-8
Technician	N. Pekoc		

Method:	Modified Thrust Washer
Machine:	Falex High Performance Multi-Specimen Test Machine, Computer Controlled Version
Serial #:	809C350011008, 009-091-105

TEST SPECIMENS:

Upper Material:	**C95500 Al Bronze**
Finish (μ in.):	32
Hardness (HRc):	112-123
Falex ID #:	5030
Lower Material:	**AISI 4140 Steel, black oxide coated**
Finish (μ in.):	32
Hardness (HRc):	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5306

TEST CONDITIONS:

Test Speed (rpm):	5
Temperature (°C):	Ambient
Duration (hr):	24
Test Load (lb):	Varies
Mean Test Radius (in):	0.531
Contact pressure (psi):	Varies

Test Results:

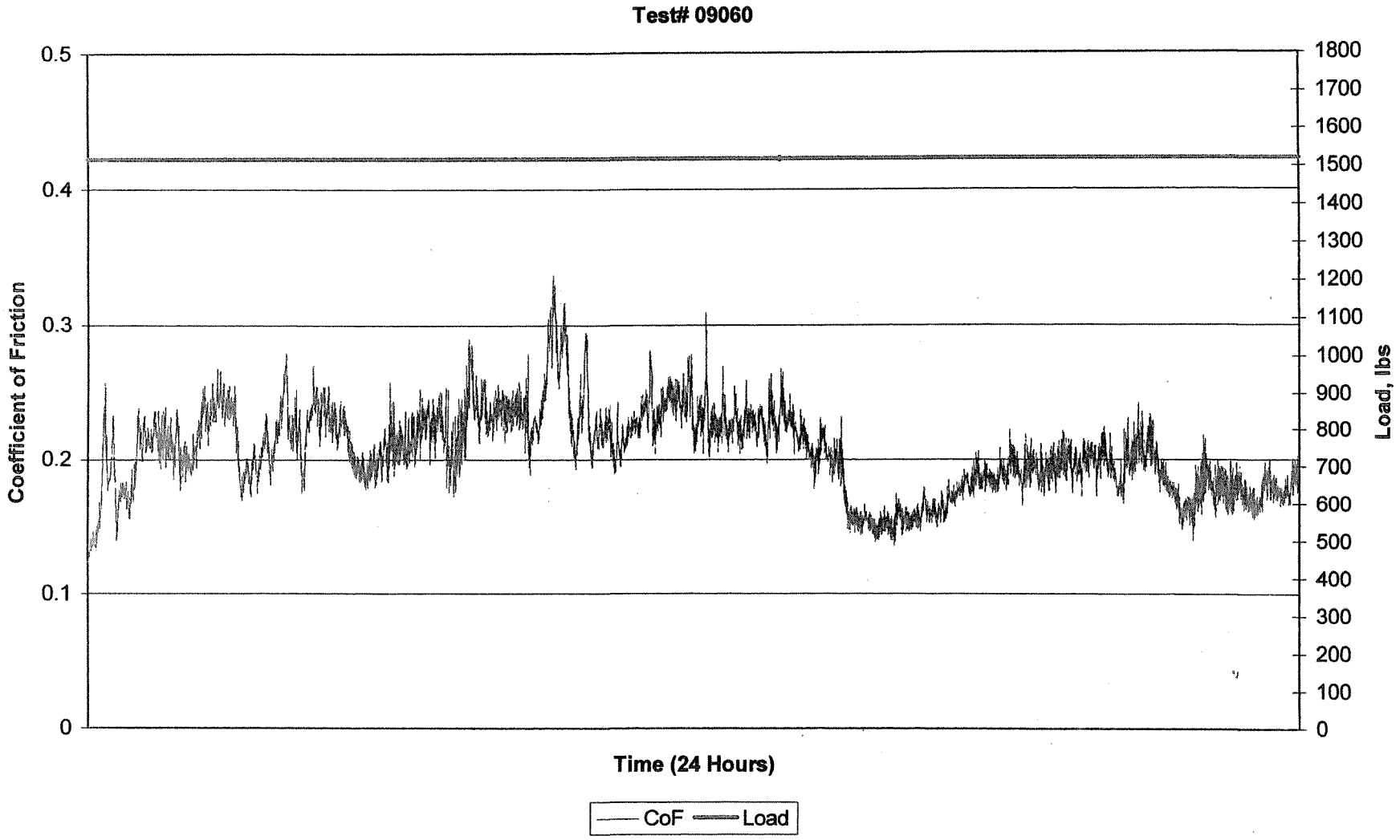
Test Date:	01/15/02
Test Number:	09071
Upper Falex ID #:	5030
Lower Falex ID #:	5306
Lubricant:	**Aeroshell 33 w/ H20**
Lubricant Falex ID #:	4948
SaveFile Name:	DGWEAR13
Test Program Name:	D&GWEARTESTHT
Load(Lb):	1520
Mass Loss, Upper (mg):	14.4
Mass Loss, Lower (mg):	1.1
Bronze height change (mm):	0.0315

Comments: See Graphs for Torque, Friction Coefficient, Load, and Specimen Temperature trends.

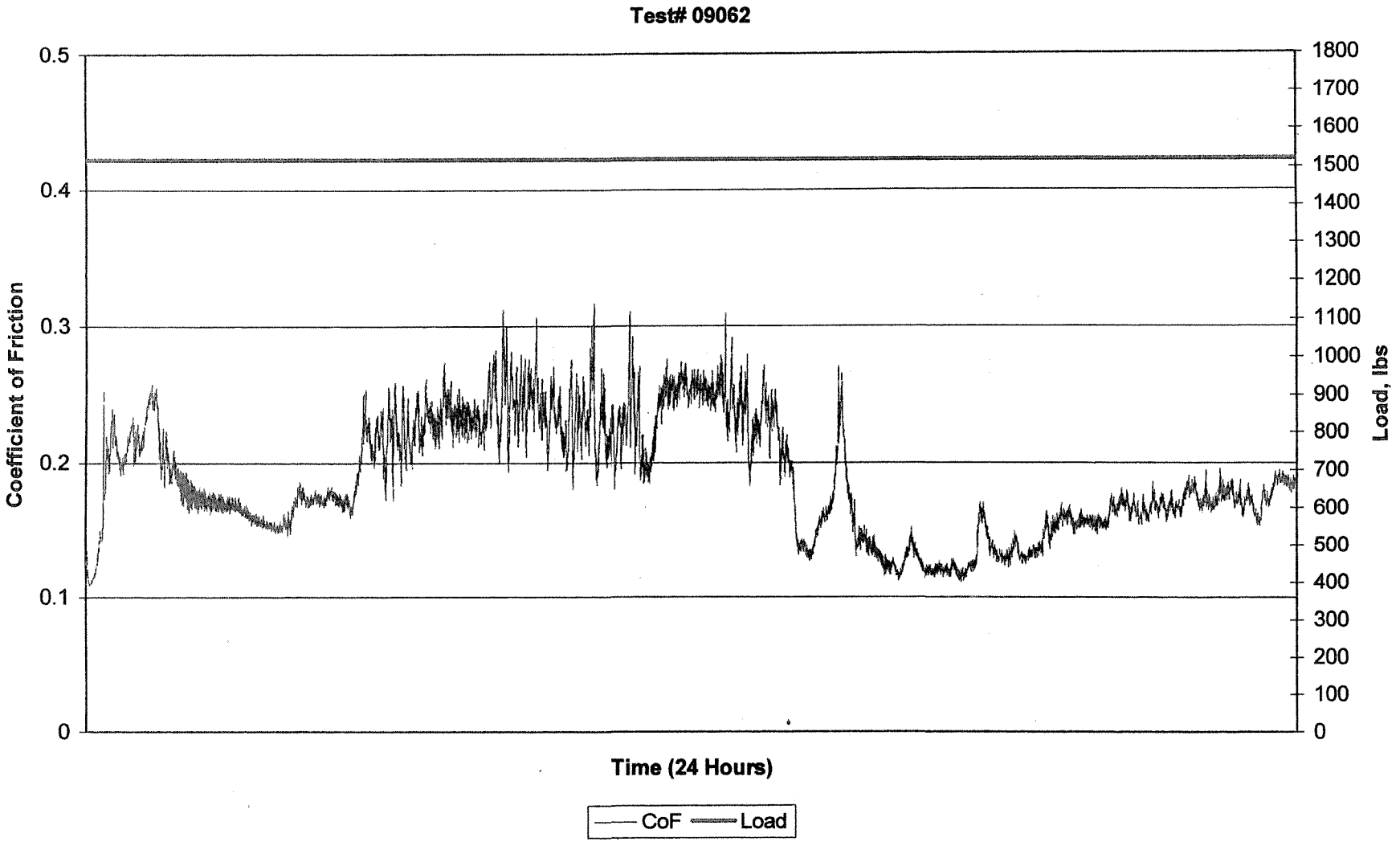
Coefficient of Friction (CoF)

The dimensionless ratio of the friction force (FF) between the upper rotating material and the lower stationary material to the normal force (N) pressing these bodies together.

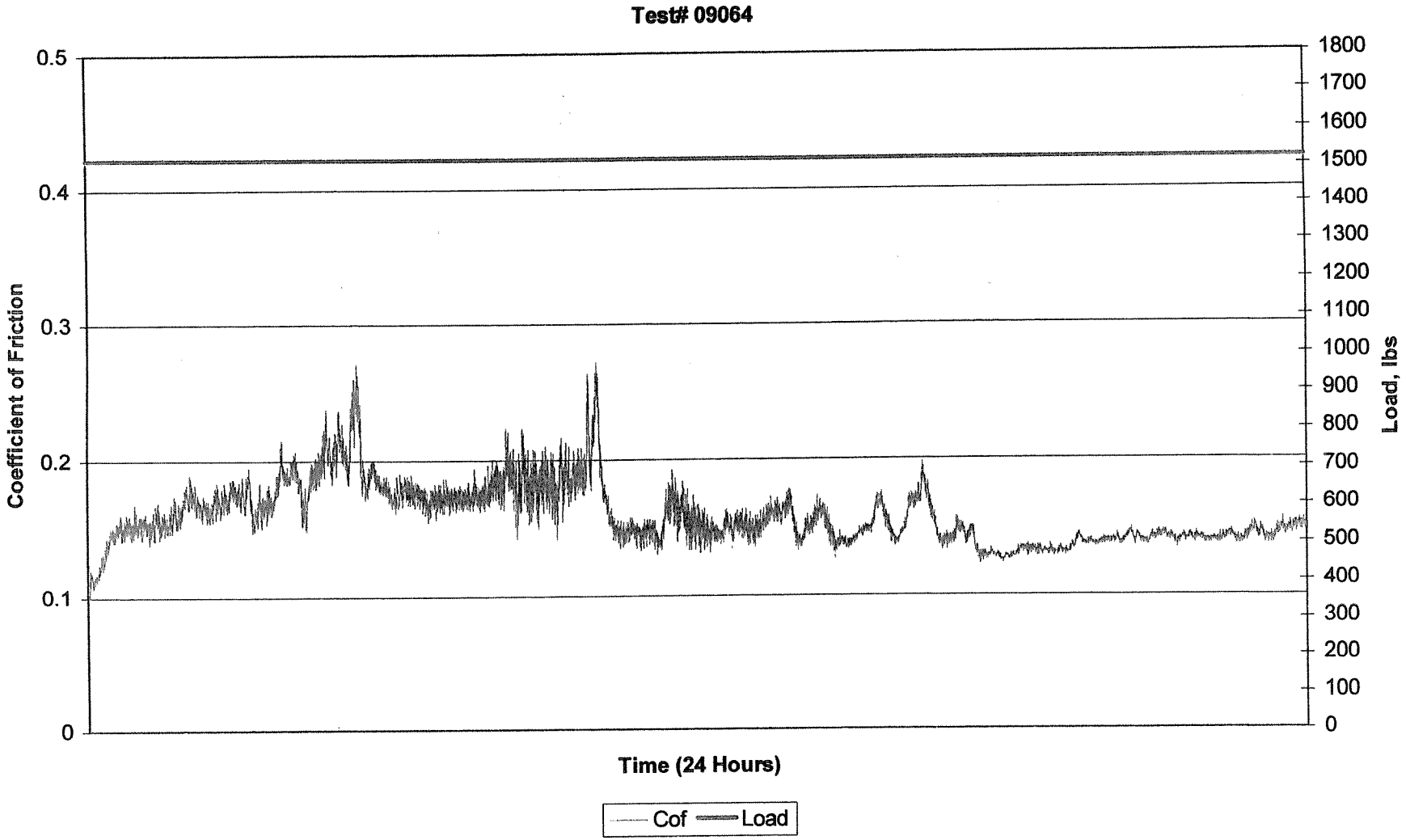
Aeroshell 33 Weathered, w/ H_2o
Thrust Washer Geometry



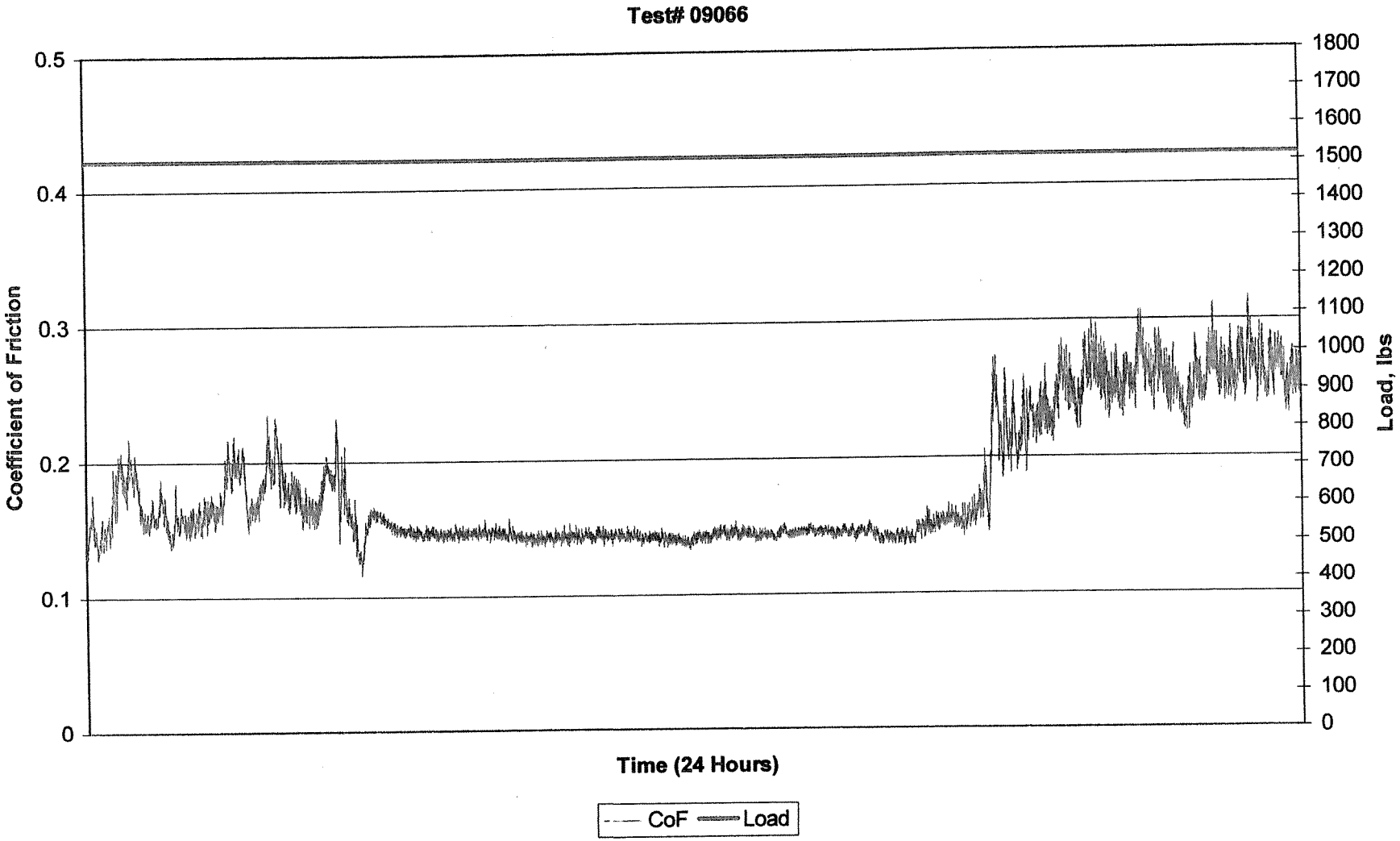
Aeroshell 33 Weathered, w/ H_2o
Thrust Washer Geometry



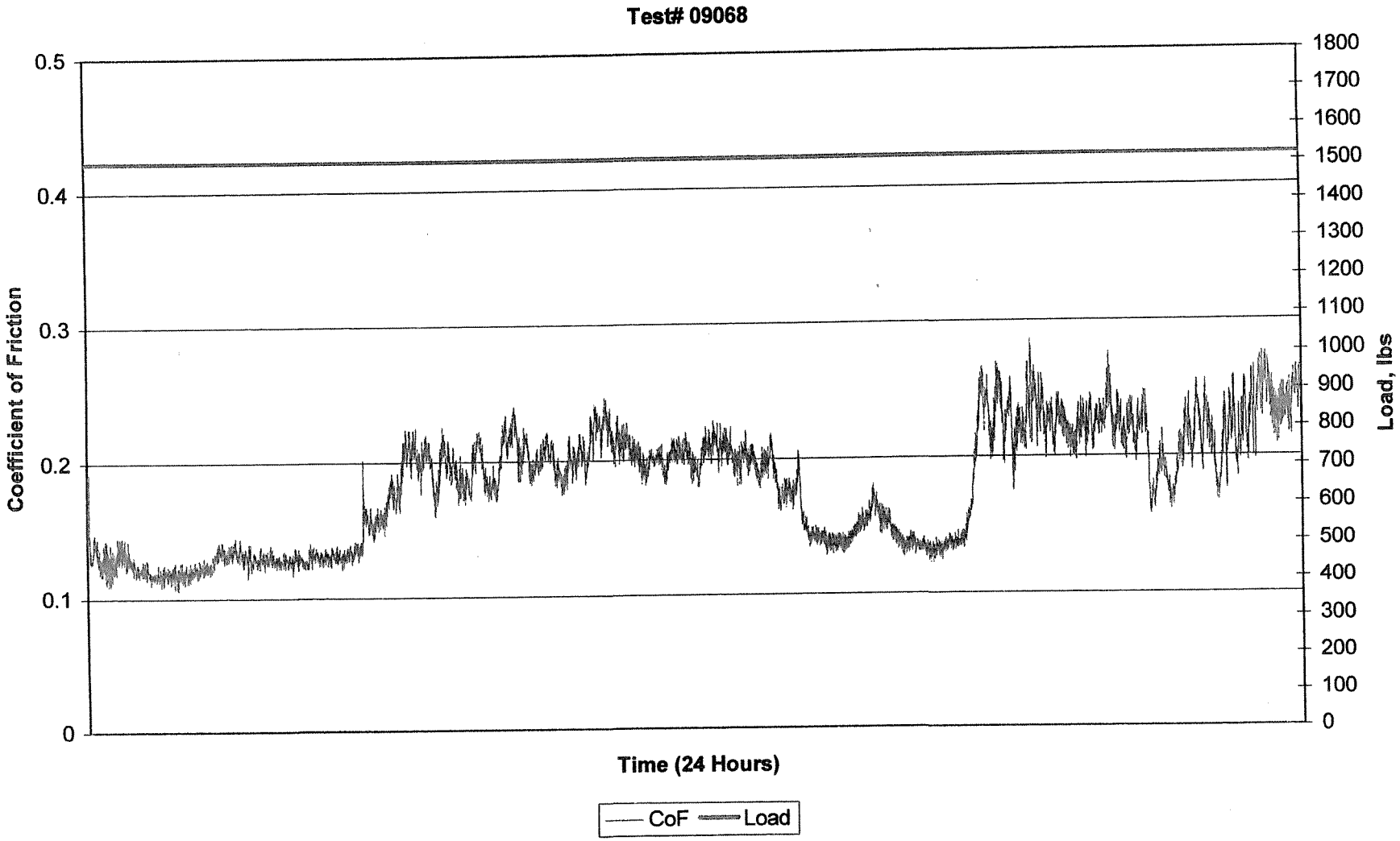
Aeroshell 33 Weathered, w/ H_2o @ 95° C
Thrust Washer Geometry



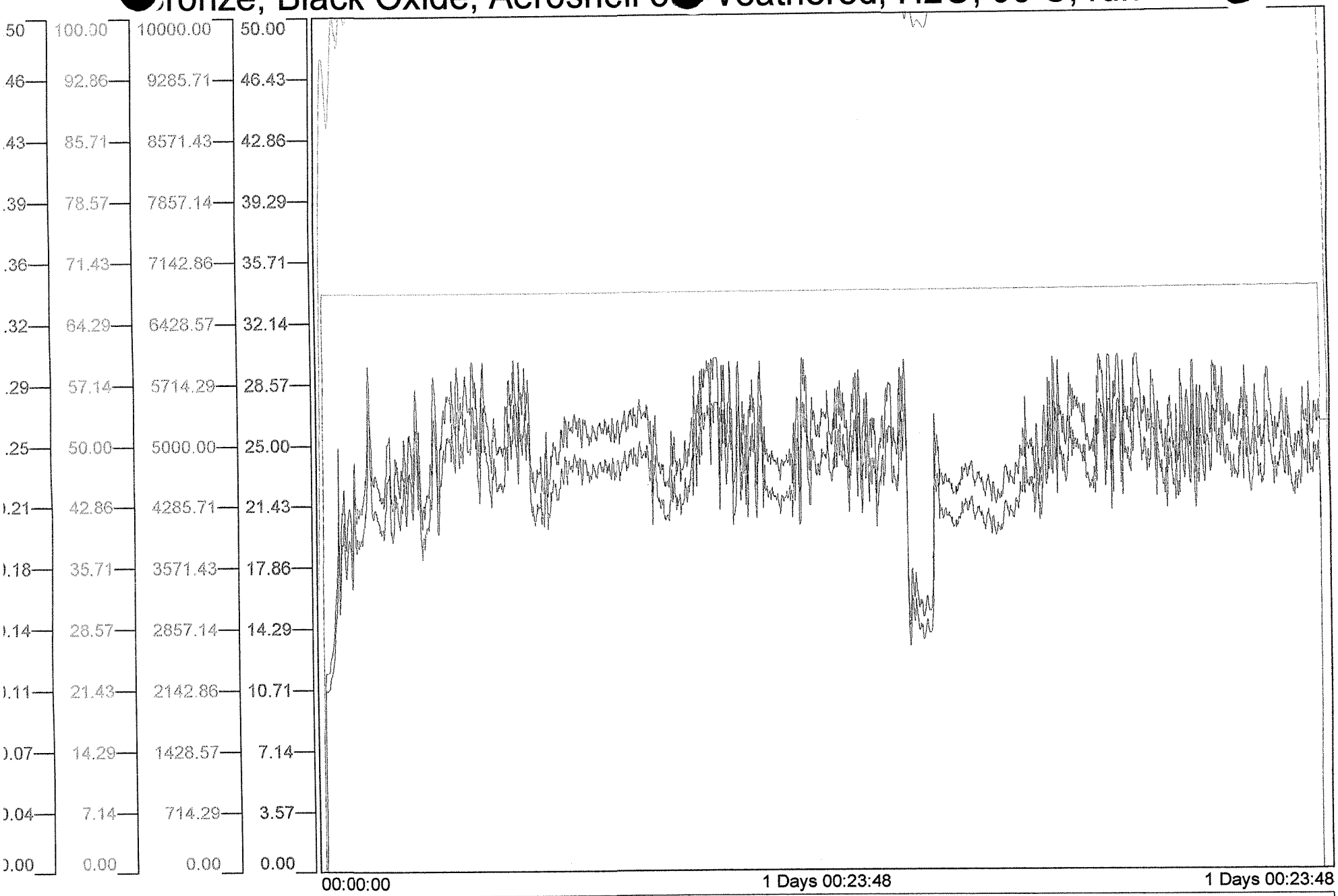
Aeroshell 33, w/ H_2o @ 95° C
Thrust Washer Geometry



Mobil 28, w/ H_2o @ 95° C
Thrust Washer Geometry

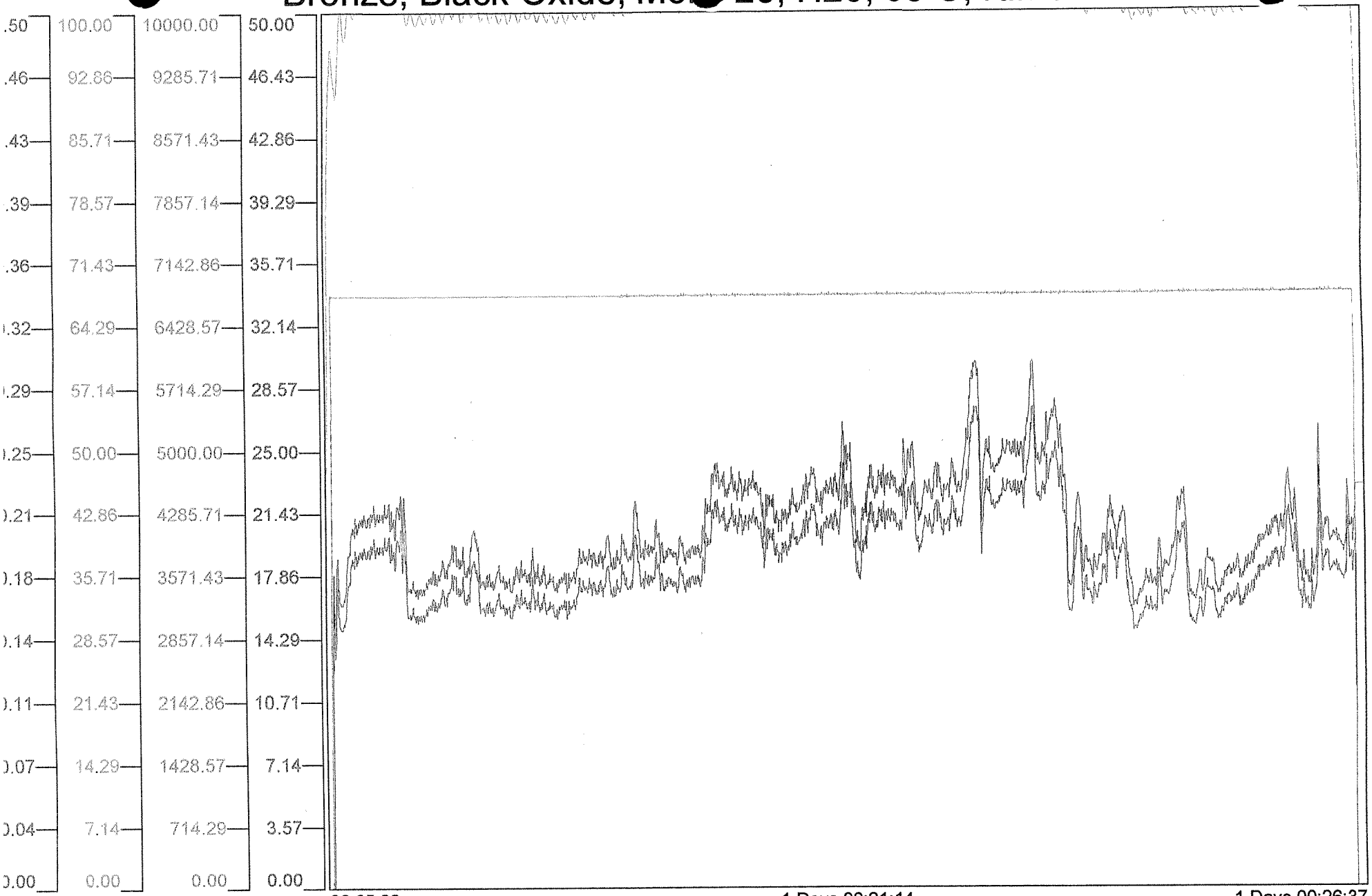


ronze, Black Oxide, Aeroshell 3 Weathered, H2O, 95 C, run 1



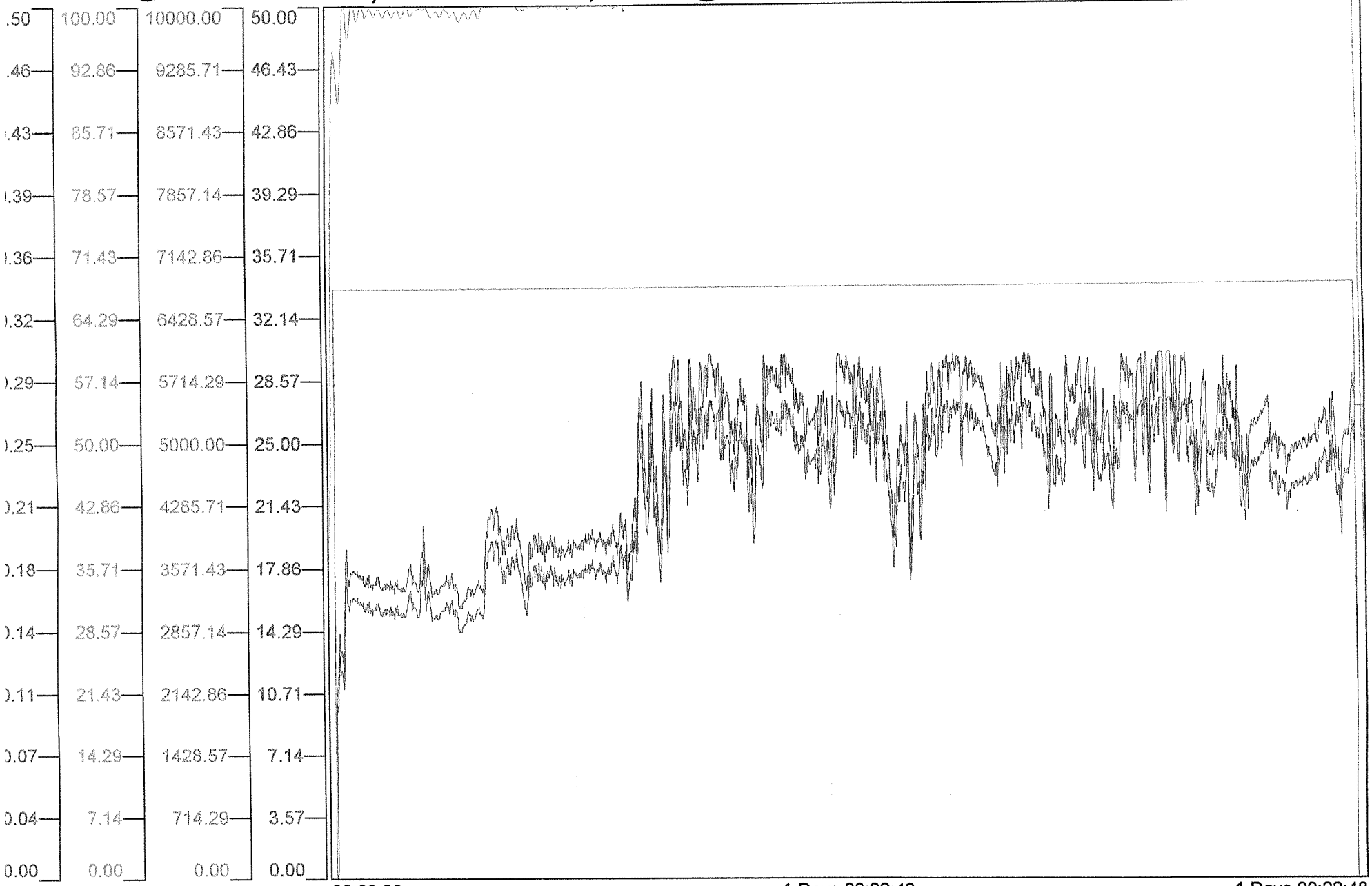
Description	Batch Name	Scale Range	Eng. Units	1 Day 00:23:48
COEFFICIENT OF FRICTION	dgwear08	0.00/0.50	Coef	***
NTERFACE TEMP.	dgwear08	0.00/100.00	DEG.C	***
SPECIMEN LOAD	dgwear08	0.00/10000.00	N	***
TORQUE	dgwear08	0.00/50.00	N-m	***

Bronze, Black Oxide, Mo 28, H20, 95 C, run 3



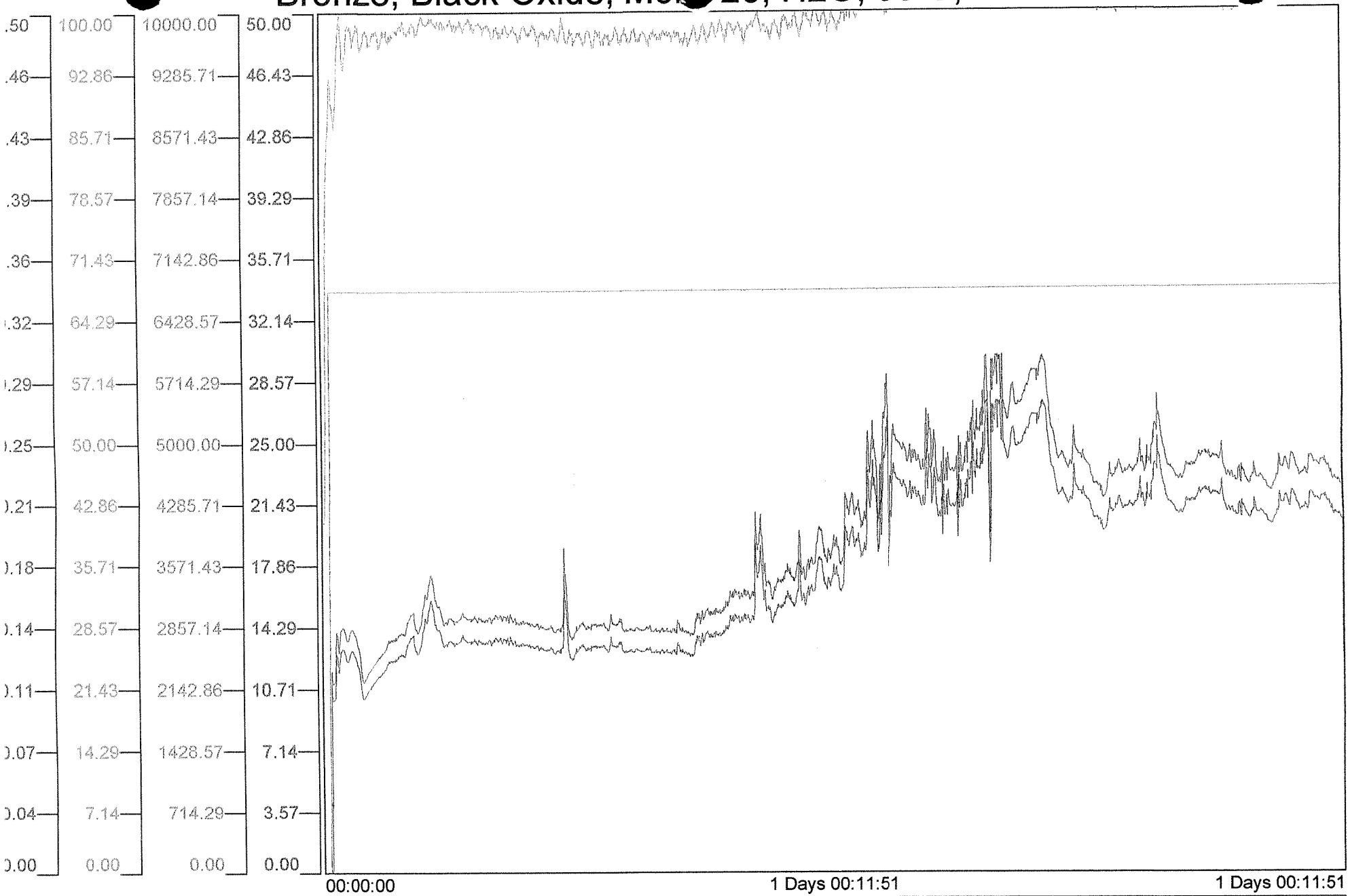
Description	Batch Name	Scale Range	Eng. Units	1 Day 00:26:37
COEFFICIENT OF FRICTION	dgwear11	0.00/0.50	Coef	***
INTERFACE TEMP	dgwear11	0.00/100.00	DEG.C	***
SPECIMEN LOAD	dgwear11	0.00/10000.00	N	***
TORQUE	dgwear11	0.00/50.00	N-m	***

Bronze, Black Oxide, Aeroshell 33, H2O, 95C, run 1



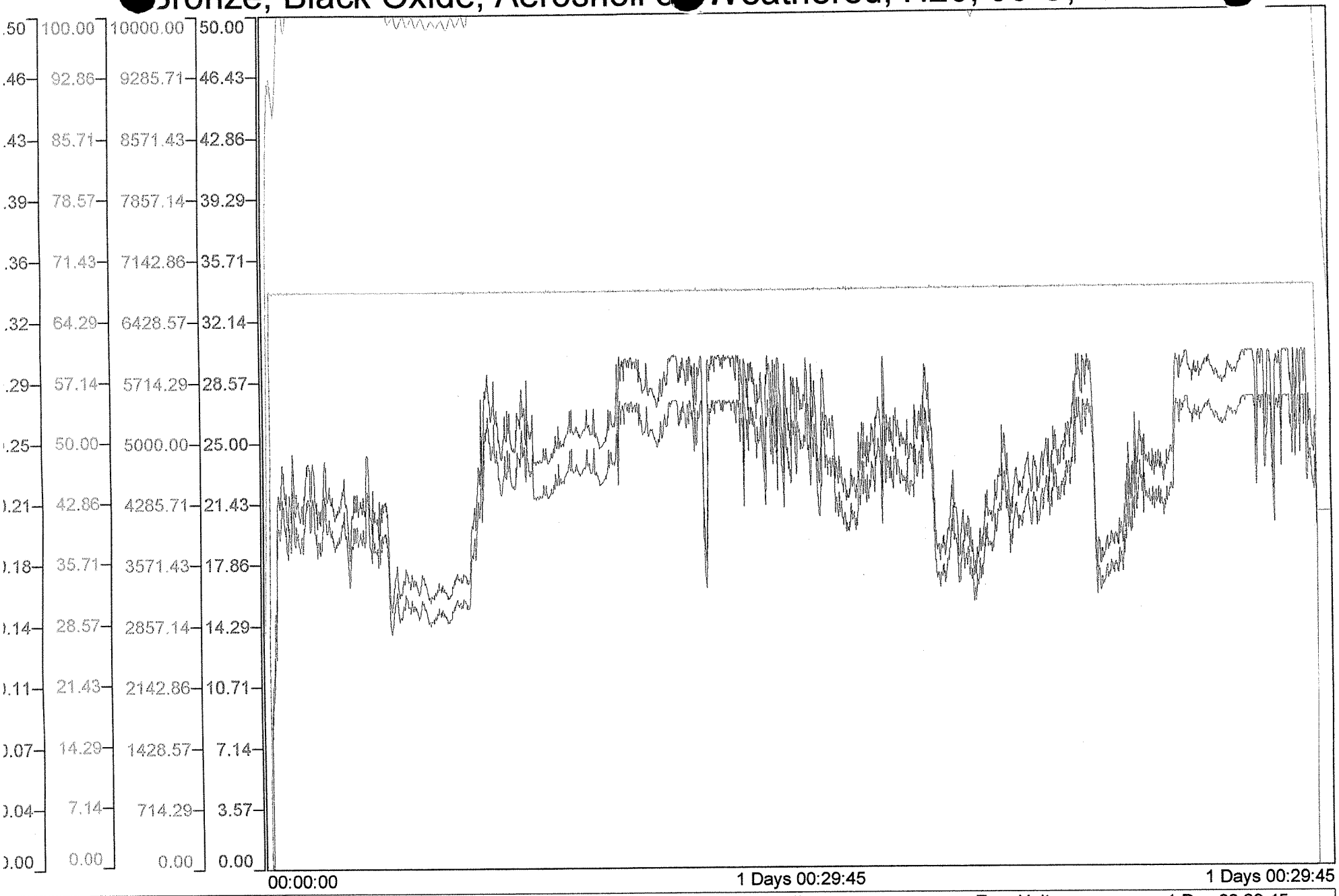
Description	Batch Name	Scale Range	Eng. Units	1 Day 00:22:48
COEFFICIENT OF FRICTION	dgwear10	0.00/0.50	Coef	***
INTERFACE TEMP.	dgwear10	0.00/100.00	DEG.C	***
SPECIMEN LOAD	dgwear10	0.00/10000.00	N	***
TORQUE	dgwear10	0.00/50.00	N-m	***

Bronze, Black Oxide, Mo[illegible]28, H2O, 95 C, run 2



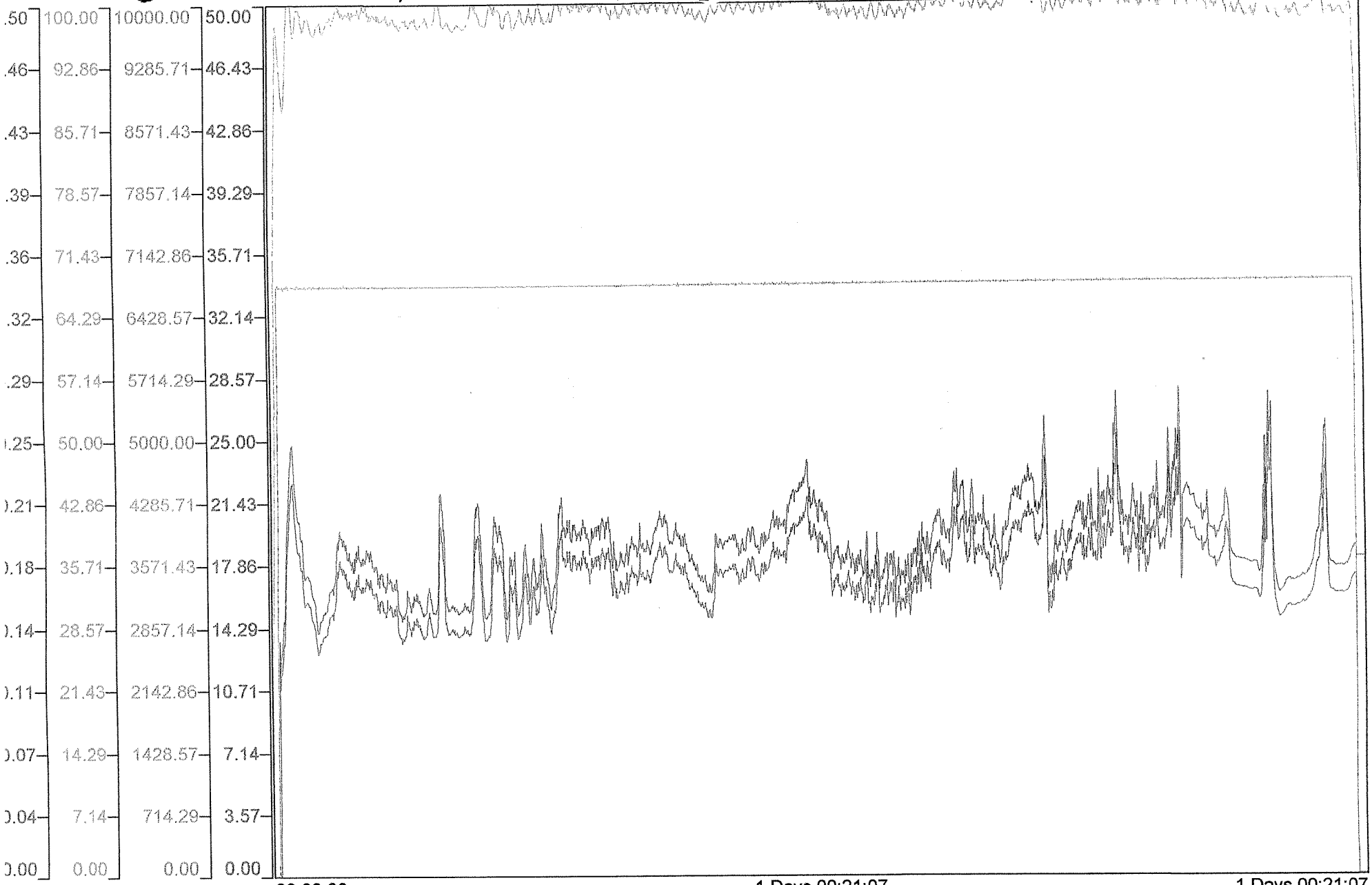
Description	Batch Name	Scale Range	Eng. Units	1 Day 00:11:51
COEFFICIENT OF FRICTION	dgwear09	0.00/0.50	Coef	***
NTERFACE TEMP.	dgwear09	0.00/100.00	DEG.C	***
SPECIMEN LOAD	dgwear09	0.00/10000.00	N	***
TORQUE	dgwear09	0.00/50.00	N-m	***

Bronze, Black Oxide, Aeroshell 3 Weathered, H20, 95 C, run 2



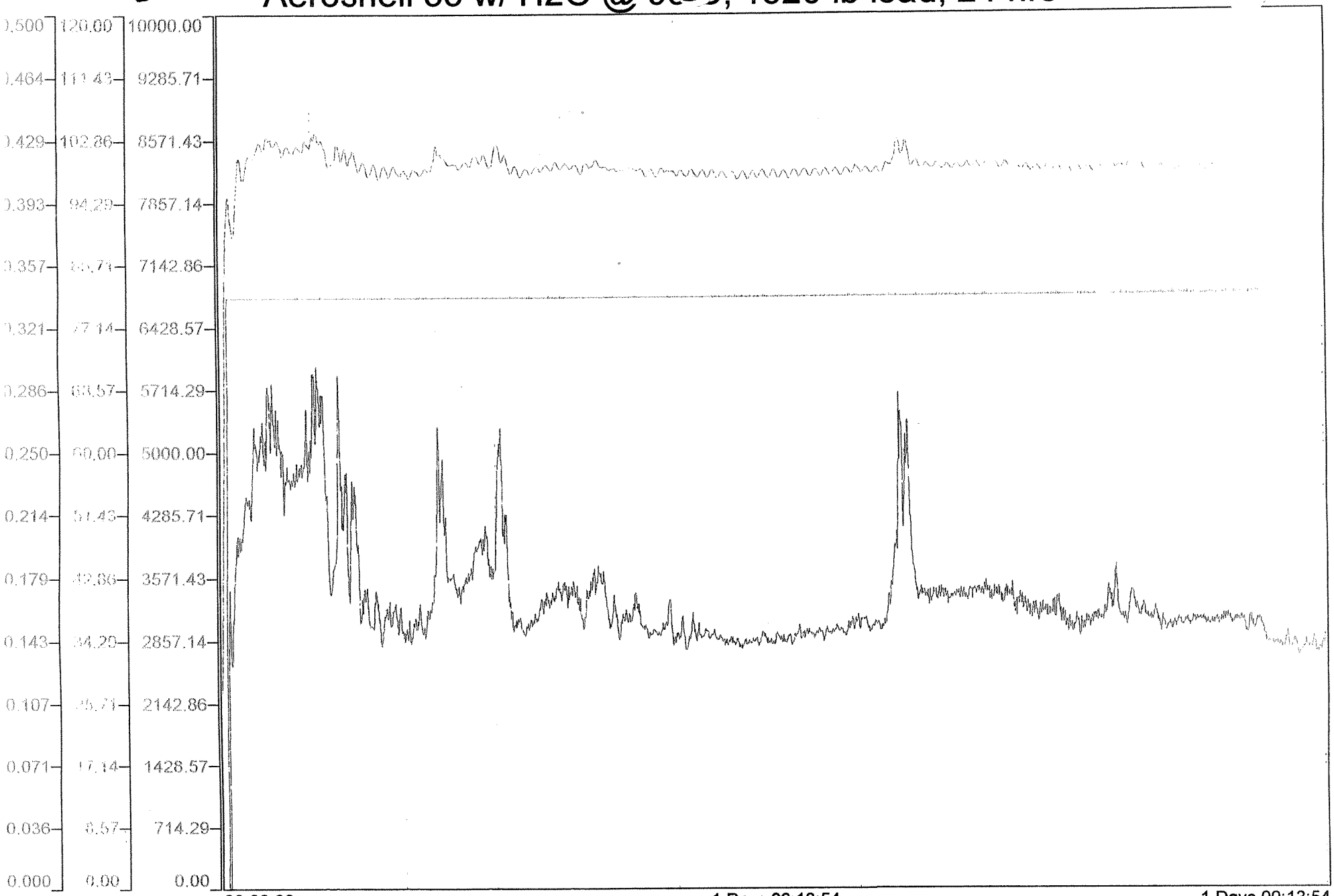
Description	Batch Name	Scale Range	Eng. Units	1 Day 00:29:45
COEFFICIENT OF FRICTION	dgwear12	0.00/0.50	Coef	0.21
INTERFACE TEMP.	dgwear12	0.00/100.00	DEG.C	63.76
SPECIMEN LOAD	dgwear12	0.00/10000.00	N	0.00
TORQUE	dgwear12	0.00/50.00	N-m	0.01

Bronze, Black Oxide, Mo[illegible]28, H2O, 95 C, run 1



Description	Batch Name	Scale Range	Eng. Units	1 Day 00:21:07
COEFFICIENT OF FRICTION	dgwear06	0.00/0.50	Coef	0.18
NTERFACE TEMP.	dgwear06	0.00/100.00	DEG.C	73.90
SPECIMEN LOAD	dgwear06	0.00/10000.00	N	0.00
TORQUE	dgwear06	0.00/50.00	N-m	0.02

Aeroshell 33 w/ H2O @ 9[illegible], 1520 lb load, 24 hrs



Description	Batch Name	Scale Range	Eng. Units	1 Day 00:13:54
COEFFICIENT OF FRICTION	dgwear13	0.000/0.500	Coef	No Data
INTERFACE TEMP.	dgwear13	0.00/120.00	DEG.C	No Data
SPECIMEN LOAD	dgwear13	0.00/10000.00	N	No Data

M A C H I N E S E T - U P S U M M A R Y

PARAMETER	CONFIGURATION
CONFIGURATION LIST NUMBER	006-108-007
SPECIMEN TYPE	Small Thurst Washer
LOAD RANGE	HIGH 10 to 2000 lbs.
TYPE OF MOTION	UNIDIRECTIONAL
UNIDIRECTIONAL SPEED RANGE - MAIN	0 - 1800 RPM
UNIDIRECTIONAL SPEED RANGE - SECONDARY	NOT ACTIVE
CYCLE/DISTANCE RESOLUTION	1
TORQUE SENSOR RANGE TYPE	HIGH 500 LBS.
HIGH/LOW TEMP. ADAPTER	0 - 400 DEG C (MODEL6 ADAPTER)
TEMPERATURE CONTROL	SPECIMEN

T E S T L I M I T S S U M M A R Y

PARAMETER	UNITS	MAXIMUM	ALERT	SHUTDOWN
SPEED - MAIN	RPM	1895	500	600
SPEED - SECONDARY	RPM	0	0	0
SPECIMEN LOAD	LBS	2106	1700	1800
CHAMBER TEMPERATURE	DEG C	422	100	150
SPECIMEN TEMPERATURE	DEG C	422	120	150
WEAR	.0001 IN.	1250	0	0
CYCLE		30000	0	0
DISTANCE	FEET	30000	0	0
COEFFICIENT OF FRICTION		2	0	0
TORQUE	LB.IN.	500	400	450
VIBRATION	G	20	0	0
ELAPSED TIME	HHH:MM:SS	522:59:59	020:00:00	024:00:00

S T A R T T E S T S U M M A R Y

PARAMETER	MAXIMUM	VALUE	
STARTING SEQUENCE		1	LOAD-TEMP.-SPEED
INITIAL SPEED SETPOINT - MAIN	569	375	RPM
INITIAL SPEED SETPOINT - SECONDARY	0	0	RPM
INITIAL SPECIMEN LOAD SETPOINT	1709	1520	LBS
INITIAL TEMPERATURE SETPOINT	142	95	DEG C
START SPEED HOLD TIME - MAIN & SEC.	3600	0	SEC
START LOAD HOLD TIME	3600	0	SEC
INITIAL SPEED RAMP RATE - MAIN	1000	100	RPM/SEC
INITIAL SPEED RAMP RATE - SECONDARY	0	0	RPM/SEC
INITIAL LOAD RAMP RATE	600	200	LBS/SEC
SPECIAL CONFIGURATION REQUIRED		NO	

D A T A S T O R A G E S E T - U P S U M M A R Y

DATA COLLECTION RATE	10	SECS
NUMBER OF RECORDS PER FILE	4325	RECORDS
MAXIMUM NUMBER OF DATA FILES	3	FILES
DATA COLLECTION RATE	0	SECS
NUMBER OF RECORDS PER FILE	0	RECORDS
MAXIMUM NUMBER OF DATA FILES	0	FILES
TRIGGER SIGNAL METHOD	NONE	

Company:	***Dombroff & Gilmore***	Page:	1
Date:	12/07/01	Project #:	01-111
Technician	D. Hlavacek		

Method:	Three-Ball Microfilm
Machine:	Falex Multi-Specimen Test Machine, Computer Controlled Version
Serial #:	835000600496

TEST SPECIMENS:

Upper Material:	**C95500 Al Bronze**
Finish ($_u$ in.):	32
Hardness (BHN):	112-123
Falex ID #:	AA-5174
Lower Material:	**C95500 Al Bronze**
Finish ($_u$ in.):	32
Hardness (BHN):	112-123
Falex ID #:	AA-5173
Ball Material:	E-52100 Steel, black oxide coated
Hardness (HRc):	64-66
Grade:	5
Falex ID #:	Lot 99

TEST CONDITIONS:

Test Speed (rpm):	20
Temperature (°C):	Ambient
Test Load (lb):	200-800 (50 lb steps)
Mean Test Radius (in):	0.672

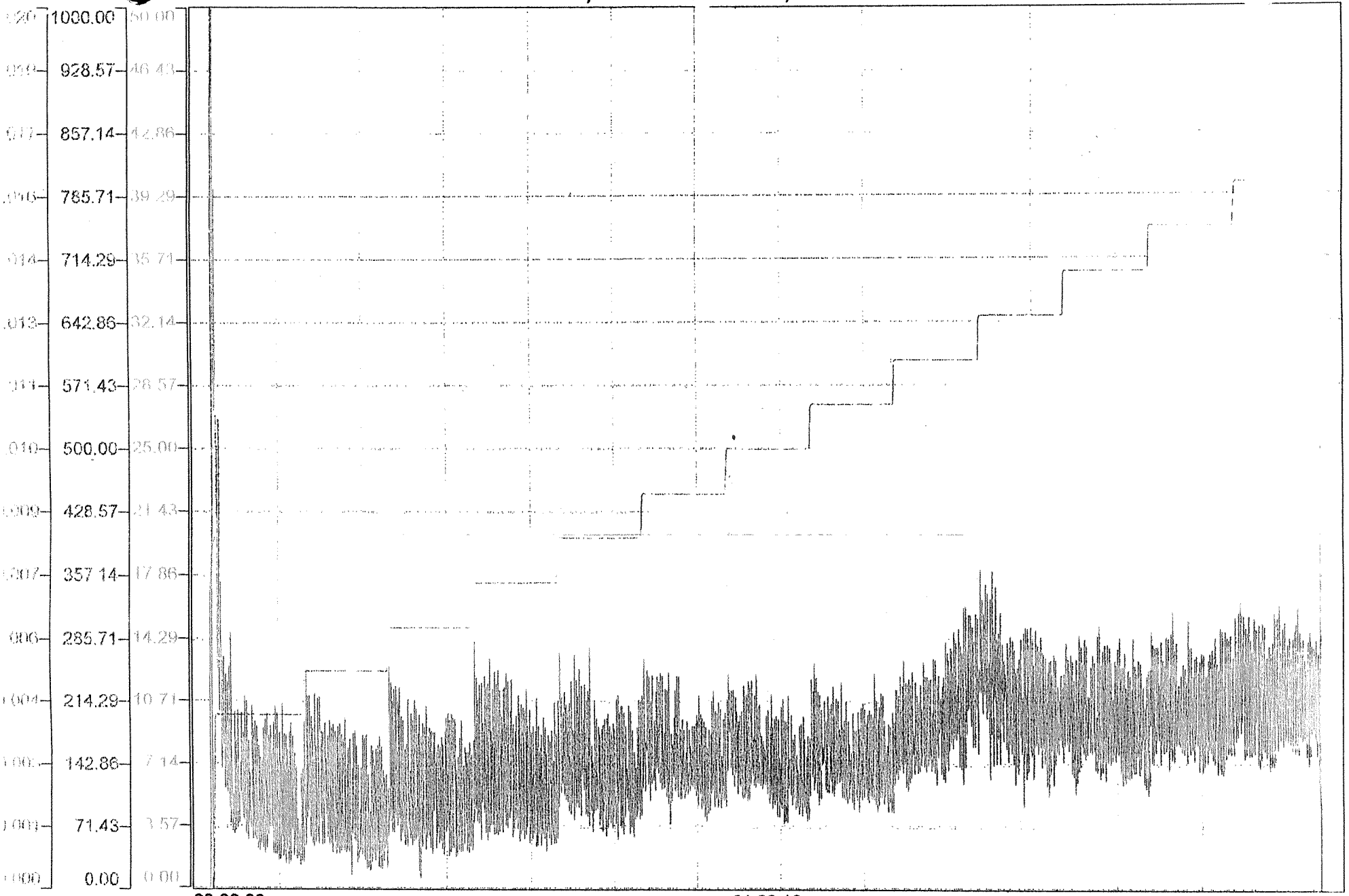
Test Results:

Test Date:	11/20/01	11/21/01	11/29/01	11/29/01
Test Number:	0606411	0606414	0606416	0606417
Upper Falex ID #:	AA-5174	AA-5174	AA-5174	AA-5174
Lower Falex ID #:	AA-5173	AA-5173	AA-5173	AA-5173
Lubricant:	**Aeroshell 33 weathered with de-icer**	**Aeroshell 33 weathered with de-icer**	**Mobil 28 with de-icer**	**Aeroshell 33 weathered at 95C**
Lubricant Falex ID #:	AA 4949	AA 4949	AA 4944	AA 4949
Test Program Name:	DNG3BL2	DNG3BL2	DNG3BL2	DNG3BLHT
SaveFile Name:	dg3bl14*	dg3bl17	dg3bl19	dg3blht20

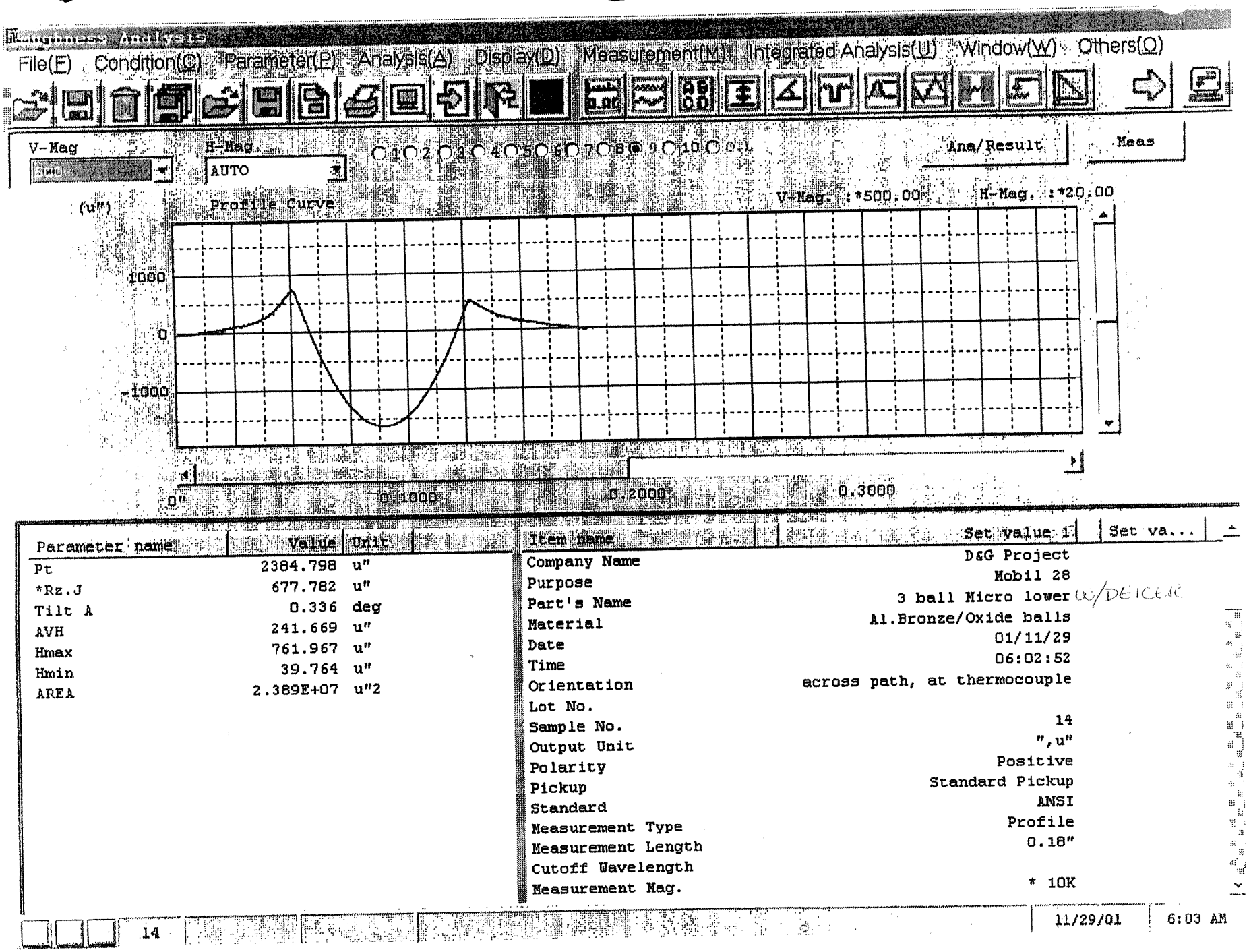
Comments: See Graphs for Friction and additional data.
De-icer applied to assembled test pieces at start of test, after 20 minutes and at 40 minutes. 2.5 ml applied each application.
*No data saved.

Coefficient of Friction (CoF)
The dimensionless ratio of the friction force (FF) between the upper rotating material and the lower stationary material to the normal force (N) pressing these bodies together.

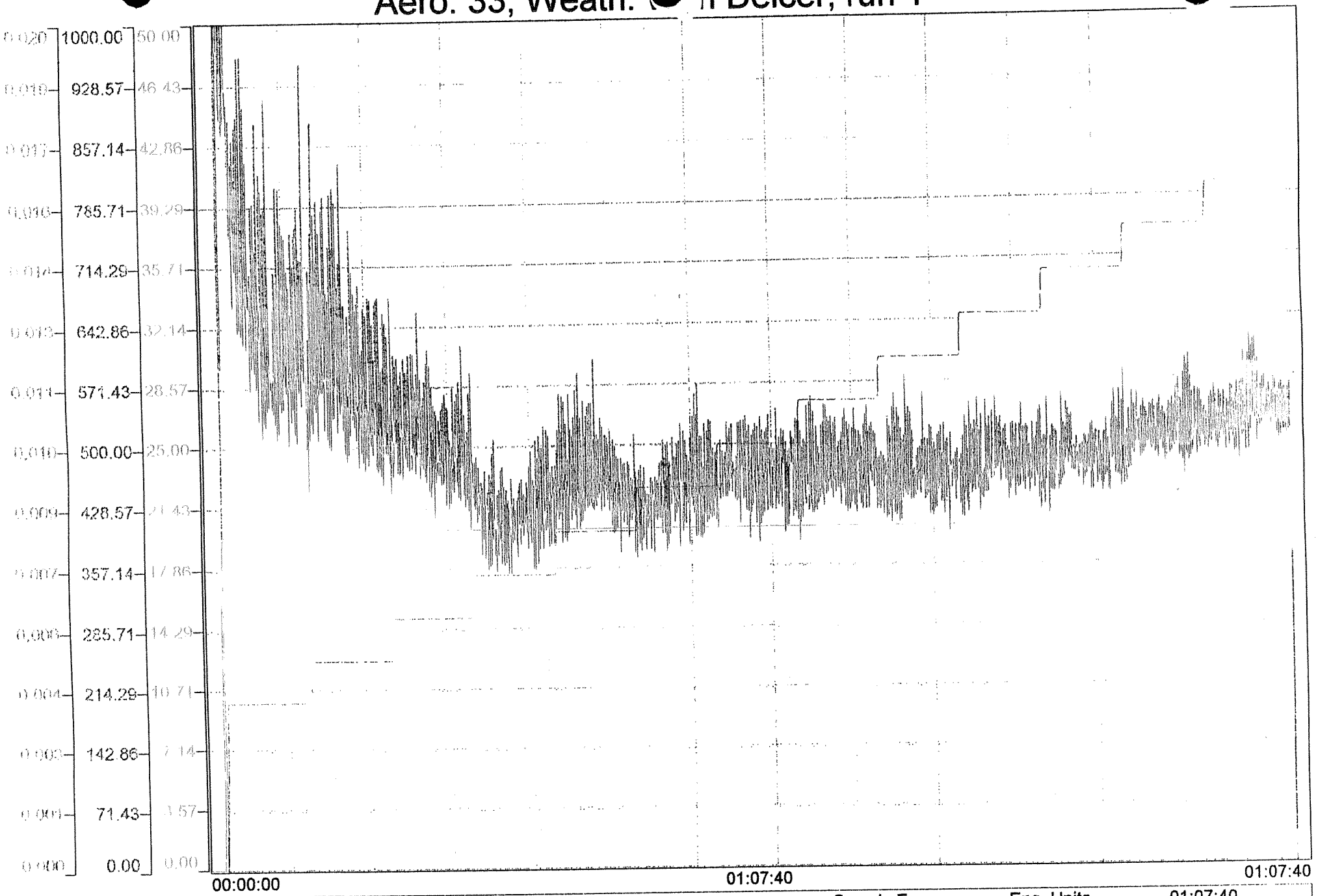
Mobil 28, with [illegible]icer, run 1



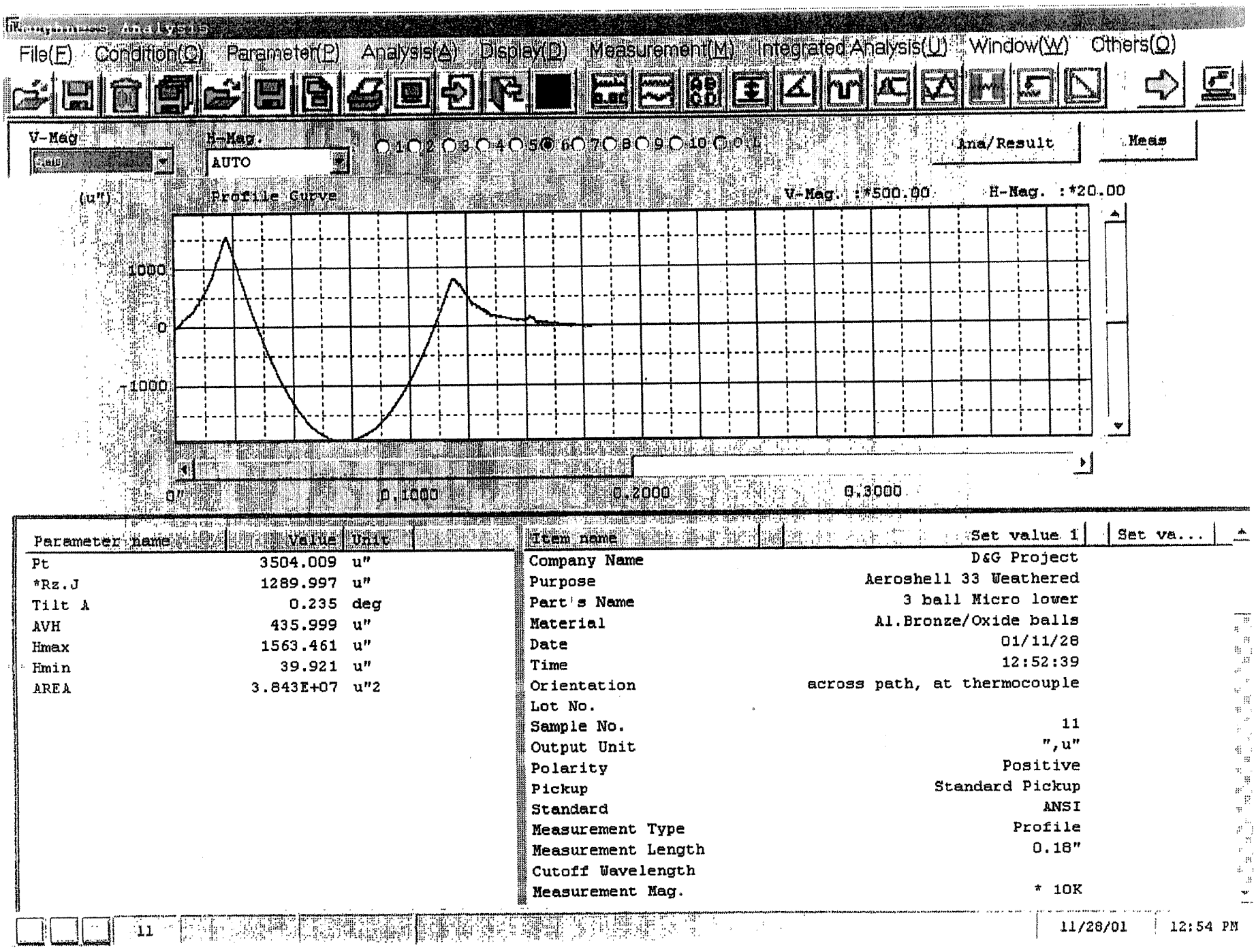
Description	Batch Name	Scale Range	Sample Freq.	Eng. Units	01:08:18
[illegible]FRICT	dg3bl19	0.000/0.020	00:00:01		***
LOAD	dg3bl19	0.00/1000.00	00:00:01	LB	***
[illegible]	dg3bl19	0.00/50.00	00:00:01	RPM	***


File(F) Condition(C) Parameter(P) Analysis(A) Display(D) Measurement(M) Integrated Analysis(U) Window(W) Others(Q)
V-Mag
H-Mag.
AUTO
Ana/Result
Meas
Profile Curve
V-Mag. :*500.00
H-Mag. :*20.00
(u")
1000
0
-1000
0"
0.1000
0.2000
0.3000
Parameter name
Value
Unit
Pt 2384.798 u"
*Rz.J 677.782 u"
Tilt A 0.336 deg
AVH 241.669 u"
Hmax 761.967 u"
Hmin 39.764 u"
AREA 2.389E+07 u"2
Item name
Set value 1
Set va...
Company Name D&G Project
Purpose Mobil 28
Part's Name 3 ball Micro lower w/DEICER
Material Al.Bronze/Oxide balls
Date 01/11/29
Time 06:02:52
Orientation across path, at thermocouple
Lot No.
Sample No. 14
Output Unit ",u"
Polarity Positive
Pickup Standard Pickup
Standard ANSI
Measurement Type Profile
Measurement Length 0.18"
Cutoff Wavelength
Measurement Mag. * 10K
14
11/29/01
6:03 AM

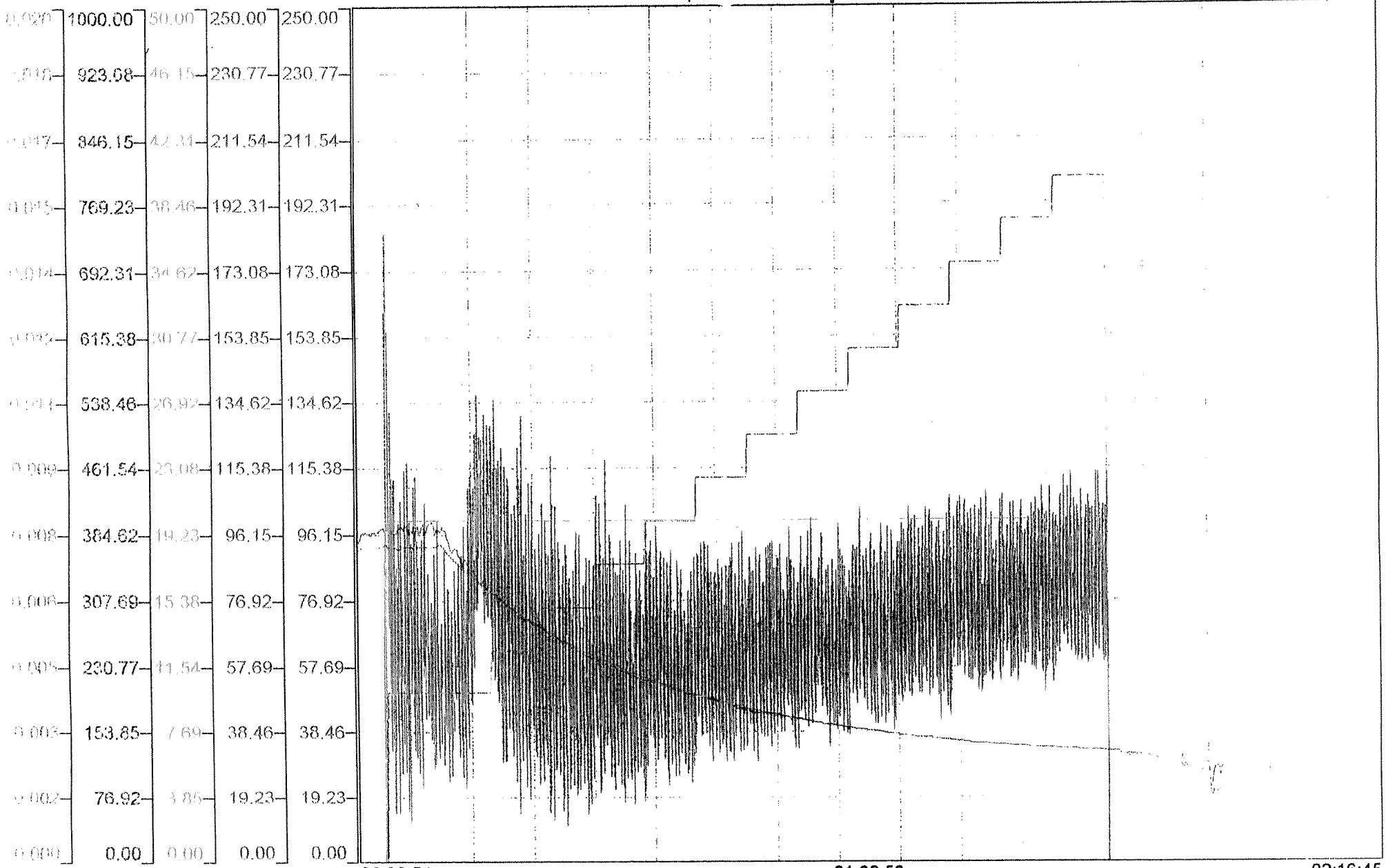
Aero. 33, Weath. [illegible]h Deicer, run 1



Description	Batch Name	Scale Range	Sample Freq.	Eng. Units	01:07:40
[illegible]OSE STRICT	dg3bl17	0.000/0.020	00:00:01		***
LOAD	dg3bl17	0.00/1000.00	00:00:01	LB	***
[illegible]	dg3bl17	0.00/50.00	00:00:01	RPM	---


File(F) Condition(C) Parameter(P) Analysis(A) Display(D) Measurement(M) Integrated Analysis(U) Window(W) Others(O)
V-Mag.
H-Mag.
AUTO
Ana/Result
Meas
(u") Profile Curve
V-Mag. :*500.00
H-Mag. :*20.00
1000
0
-1000
0"
0.1000
0.2000
0.3000
Parameter name
Value
Unit
Pt 3504.009 u"
*Rz.J 1289.997 u"
Tilt A 0.235 deg
AVH 435.999 u"
Hmax 1563.461 u"
Hmin 39.921 u"
AREA 3.843E+07 u"2
Item name
Set value 1
Set va...
Company Name D&G Project
Purpose Aeroshell 33 Weathered
Part's Name 3 ball Micro lower
Material Al.Bronze/Oxide balls
Date 01/11/28
Time 12:52:39
Orientation across path, at thermocouple
Lot No.
Sample No. 11
Output Unit ",u"
Polarity Positive
Pickup Standard Pickup
Standard ANSI
Measurement Type Profile
Measurement Length 0.18"
Cutoff Wavelength
Measurement Mag. * 10K
11
11/28/01
12:54 PM

Weath. Aero. 33, -Temp., run 1



Description	Batch Name	Scale Range	Sample Freq.	Eng. Units	02:16:45
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LOAD	dg3blht20	0.00/1000.00	00:00:01	LB	No Data
[illegible]	dg3blht20	0.00/50.00	00:00:01	RPM	No Data
TEMP C	dg3blht20	0.00/250.00	00:00:01	DEG. C	No Data
TEMP S	dg3blht20	0.00/250.00	00:00:01	DEG. C	No Data

M A C H I N E S E T - U P S U M M A R Y

PARAMETER	CURRENT CONFIGURATION
CONFIGURATION LIST NUMBER	006-108-023
SPECIMEN TYPE	3 Ball Micro Film
LOAD RANGE	HIGH 10 to 820 lbs.
TYPE OF MOTION	UNIDIRECTIONAL
UNIDIRECTIONAL SPEED RANGE	0 - 23 RPM
CYCLE/DISTANCE RESOLUTION	1
TORQUE SENSOR RANGE TYPE	LOW 10 LBS
TEMPERATURE CONTROL	SPECIMEN

T E S T L I M I T S S U M M A R Y

PARAMETER	MAXIMUM	ALERT	SHUTDOWN	
SPEED	24	23	24	RPM
SPECIMEN LOAD	864.0	820.0	850.0	LBS
CHAMBER TEMP.	421	200	250	DEG C
SPECIMEN TEMP.	421	150	250	DEG C
[illegible]R	1200	0	0	.0001 IN.
[illegible]LE	30000	0	0	
DISTANCE	30000	0	0	FEET
COEFFRIC.	2.0000	0.0000	0.0000	
TORQUE	10.00	5.00	9.00	LB.IN.
VIBRATION	20.00	0.00	0.00	G
ELAPSED TIME	522:59:59	005:00:00	005:01:00	HHH:MM:SS

S T A R T T E S T S U M M A R Y

PARAMETER	MAXIMUM	VALUE	
STARTING SEQUENCE		5	TEMP.-SPEED-LOA
INITIAL SPEED SETPOINT	22	20	RPM
INITIAL SPECIMEN LOAD SETPOINT	807.0	200.0	LBS
INITIAL TEMPERATURE SETPOINT	237	95	DEG C
START SPEED HOLD TIME	3600	0	SEC
START LOAD HOLD TIME	3600	0	SEC
INITIAL SPEED RAMP RATE	1000	10	RPM/SEC
INITIAL LOAD RAMP RATE	600	20	LBS/SEC
IS SPECIAL CONFIGURATION REQUIRE		YES	
IGNORE TEMPERATURE OVERSHOOT		YES	

S P E C I A L C O N F I G U R A T I O N S U M M A R Y

POINT	SPEED SETPT	LOAD SETPT	TEMP. SETPT	SPEED RATE	LOAD RATE	DURATION	NEXT STEP	REPS
1	20.0	200	95	10	20	300	2	1

2	20.0	250	95	10	10	300	3	1
3	20.0	300	95	10	20	300	4	1
4	20.0	350	95	10	20	300	5	1
5	20.0	400	95	10	20	300	6	1
6	20.0	450	95	10	20	300	7	1
7	20.0	500	95	10	20	300	8	1
8	20.0	550	95	10	20	300	9	1
9	20.0	600	95	10	20	300	10	1
10	20.0	650	95	10	20	300	11	1
11	20.0	700	95	10	20	300	12	1
12	20.0	750	95	10	20	300	13	1
13	20.0	800	95	10	20	300	40	1
14	0.0	0	0	0	0	0	0	0
15	0.0	0	0	0	0	0	0	0
16	0.0	0	0	0	0	0	0	0
17	0.0	0	0	0	0	0	0	0
18	0.0	0	0	0	0	0	0	0
19	0.0	0	0	0	0	0	0	0
20	0.0	0	0	0	0	0	0	0
21	0.0	0	0	0	0	0	0	0
22	0.0	0	0	0	0	0	0	0
23	0.0	0	0	0	0	0	0	0
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25	0.0	0	0	0	0	0	0	0
26	0.0	0	0	0	0	0	0	0
27	0.0	0	0	0	0	0	0	0
28	0.0	0	0	0	0	0	0	0
29	0.0	0	0	0	0	0	0	0
30	0.0	0	0	0	0	0	0	0
31	0.0	0	0	0	0	0	0	0
32	0.0	0	0	0	0	0	0	0
33	0.0	0	0	0	0	0	0	0
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35	0.0	0	0	0	0	0	0	0
36	0.0	0	0	0	0	0	0	0
37	0.0	0	0	0	0	0	0	0
38	0.0	0	0	0	0	0	0	0
39	0.0	0	0	0	0	0	0	0
40	0.0	0	0	0	0	0	0	0

Scanning Electron Microscope Examination of Wear Surfaces on Falex Test Specimens

Prepared for:

Mr. Brian Holtkamp
Falex Corporation
1020 Airpark Drive
Sugar Grove, IL 60554-9585

December 10, 2001

Ref. MMR 1650

MicroMaterials Research, Inc. • Suite 200 • 136 Shore Drive • Burr Ridge, IL 60521
phone (630) 325-8170 • fax (630) 325-8178 • lab@micromaterialsresearch.com

Introduction

We received a total of nine (9) wear test specimens from Falex Corporation on November 29, December 6 and December 7, 2001. We were asked to characterize the wear surfaces on the test specimens using scanning electron microscopy (SEM) and x-ray microanalysis.

Wear Test Specimens

The nine test specimens are:

Wear Test	Falex Test Number
Pin-on-disk	8002551
Pin-on-disk	8002552
Pin-on-disk	8002559
Block-on-ring	0107406
Block-on-ring	0107407
Block-on-ring	0107426
Thrust washer	09052
Thrust washer	09058
Thrust washer	09059

Each test contains a bronze and black iron part. We examined the wear surfaces on both parts for each test.

Pin-on-disk

This test uses a bronze pin with a rounded tip in contact with the flat surface of a black iron disk.

Block-on-ring

This test uses a bronze block in contact with the curved surface of a black iron ring.

Thrust washer

This test uses a bronze disk with a rim around the edge in contact with the flat surface of a black iron washer.

SEM Examination

All of the test parts were cleaned with isopropyl alcohol before SEM examination. We obtained eight SEM photomicrographs of the wear surface on each part except for the bronze pins from the pin-on-disk tests. Four SEM photomicrographs were obtained for the bronze pins. Photos were obtained at magnifications of 100X, 250X, 500X and 1000X. In addition, we obtained a

photo at 20X showing the complete wear scar for the bronze blocks from the block-on-ring tests. Specimens were tilted to 30°, 45° or 60° for SEM photography.

The photographs are appended to this report. Each photo contains the following information:

Falex test number and part description (top left)
Unique 6-digit photo number (bottom left)
Magnification (bottom middle, e.g., X20, X100, X250, X500 or X1.00\K)
Electron beam accelerating voltage (bottom middle, all at 20 KV)
Distance legend (bottom right, mm = millimeter; μm = micrometer)

The tilt axis for the specimens is parallel to the width (short axis) of the photomicrographs. Negatives are available for each photo.

X-ray Microanalysis

We collected x-ray spectra from two areas of the wear surface for each part, except for the bronze pins from the pin-on-disk tests. Only one spectrum was collected from the wear surface on the pins. X-ray spectra were also obtained for a non-wear black iron surface and a non-wear bronze surface. The x-ray spectra are included in Appendix I. The label below each spectrum includes the Falex test number, part description, magnification and area number (either 1 or 2). The peaks in the spectra indicate the chemical elements in the specimens and are identified by chemical symbols. The chemical symbols include:

iron (Fe)
copper (Cu)
nickel (Ni)
manganese (Mn)
chromium (Cr)
aluminum (Al)
silicon (Si)
calcium (Ca)
oxygen (O)

A peak's intensity in the x-ray spectrum is proportional to the concentration of that element in the specimen.

Table 1 lists semi-quantitative elemental concentrations (weight percent) for the spectra shown in Appendix I. Table 1 includes data for copper, aluminum, iron and nickel. In addition, we have included the ratio of iron to nickel concentrations. The presence of copper on the black iron surface indicates transfer of material from the bronze part. An iron to nickel ration greater than 0.6 indicates transfer of black iron to bronze.

Wear Surface Characteristics

Pin-on-disk tests

The wear surfaces on the bronze pins are flat, round, polished areas that include a few scratches. The diameter of the wear spots on the pins are:

Falex Test Number	Wear Spot Diameter (mm)
8002551	0.4
8002552	0.45
8002559	0.6

The wear track (scar) is barely visible in the SEM photos of the black iron disk from Test 8002551 (see Photo 96; Appendix I, page 3). The wear track is more visible on the disks from Tests 8002552 and 8002559. The wear tests have done little damage to the surfaces of the black iron disks. A minor amount of polishing can be seen on the disk for Test 8002551. The disk from Test 8002552 shows more polishing. The disk from Test 8002559 shows even more polishing with some scratches. In all three cases the original machine marks are still evident in the wear tracks.

Small amounts of copper (less than one weight percent) are detected on the black iron disks. Iron to nickel ratios are greater than 0.6 indicating transfer of black iron to the bronze pins.

Block-on-ring tests

The full widths of the wear scars on the bronze blocks can be seen in Appendix I, pages 16, 23 and 30). The widths of the scars are:

Falex Test Number	Wear Scar Width (mm)
0107406	2.3
0107407	3.3
0107426	3.6

The wear scars on the bronze blocks show scratching. The wear surfaces of the rings show scratching.

Copper is found on the black iron surfaces indicating transfer of bronze. The largest amount of copper is found on the black iron ring from Test 0107406. The smallest amount of copper is found on the black iron ring from Test 0107426.

The iron to nickel ratios are greater than 0.6 indicating transfer of black iron to the bronze surfaces.

Thrust washer tests

The wear surfaces on the bronze parts show areas of polishing, scratching and deep pitting.

The wear surfaces on the black iron washers show polishing and scratching.

Copper is found on all of the black iron wear surfaces indicating transfer of bronze. The highest amount of copper is found on the black iron washer for Test 09058. The lowest amount of copper is found on the black iron washer from Test 09052.

Only the bronze wear surface from Test 09052 shows a significant iron to nickel ratio indicating transfer of black iron to bronze.

Summary

Pin-on-disk tests

Bronze wear surfaces show polishing and a few scratches.

Back iron wear surfaces show very little damage; some polishing and scratches. Machine marks are still clearly visible on the black iron wear surfaces.

Least amount of bronze transfer of the three types of tests. Evidence of black iron transfer.

Block-on-ring tests

Both the bronze and black iron surfaces show scratching.

Evidence of bronze and black iron transfer.

Thrust washer tests

The bronze wear surfaces show polishing, scratching and deep pitting.

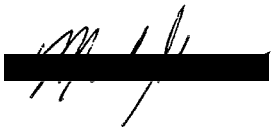
The black iron wear surfaces show scratching and polishing.

Bronze material has transferred to the black iron wear surfaces. The highest amount of copper for all nine tests is found on the black iron surface from Test 09058. There is evidence of black iron transfer to the bronze wear surface from

Test 09052. Test 09052 has the highest amount of black iron found on the bronze surfaces for all nine wear tests.

Sincerely,

MICROMATERIALS RESEARCH, INC.



Mark Germani, Ph.D.
Laboratory Director

Table 1. Semi-quantitative Elemental Compositions of Wear Surfaces
(weight percent)

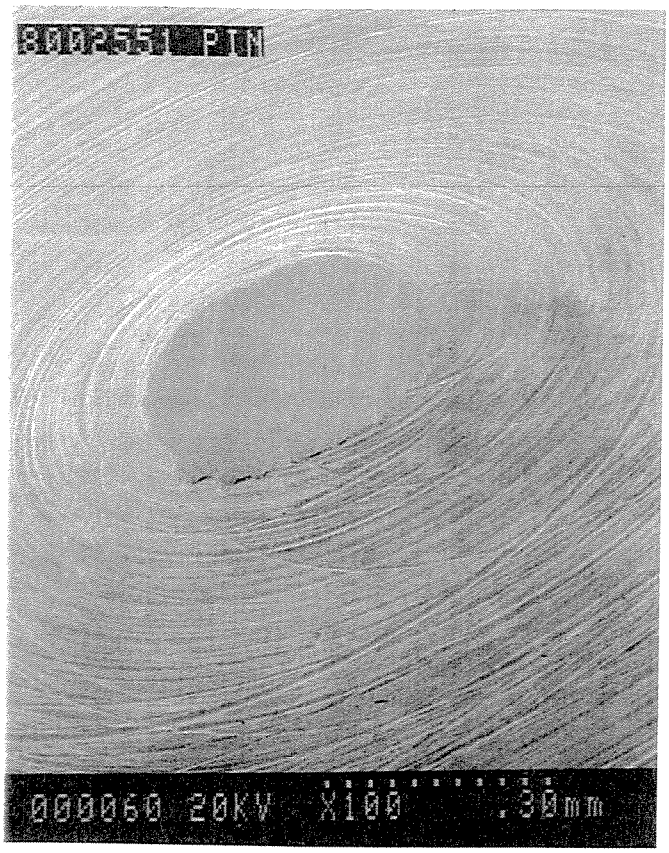
Falex Test Number and Part Description	Cu	Al	Fe	Ni	Fe/Ni
Pin-on-disk					
8002551 bronze pin area 1	78.1	9.6	5.8	6.5	0.9
8002551 black iron disk area 1	0.7	1.5	79.9	nd	
8002551 black iron disk area 2	0.9	1.5	80.2	nd	
8002552 bronze pin area 1	77.2	10.6	5.7	6.5	0.9
8002552 black iron disk area 1	0.6	1.6	81.2	nd	
8002552 black iron disk area 2	0.8	1.6	80	nd	
8002559 bronze pin area 1	76.1	11.4	5.4	7.2	0.8
8002559 black iron disk area 1	0.7	1.9	84.4	nd	
8002559 black iron disk area 2	0.3	1.9	82.8	nd	
Block-on-ring					
0107406 bronze block area 1	82.5	3.2	4.3	6	0.7
0107406 bronze block area 2	81.1	4.2	4.2	5.4	0.8
0107406 black iron ring area 1	6	2.3	76.8	0.6	
0107406 black iron ring area 2	5.7	2.1	78.7	0.6	
0107407 bronze block area 1	83.5	2.9	4.4	4.9	0.9
0107407 bronze block area 2	83.2	2.9	4.2	4.5	0.9
0107407 black iron ring area 1	4.5	3	75.7	0.6	
0107407 black iron ring area 2	5.4	3.7	74	0.7	
0107426 bronze block area 1	82.9	2.8	5.2	6.4	0.8
0107426 bronze block area 2	82.3	2.9	5.4	6.4	0.8
0107426 black iron ring area 1	0.7	1.5	80.4	0.3	
0107426 black iron ring area 2	0.5	0.9	83.1	0.3	
Thrust washer					
09052 bronze rim area 1	80.1	4.4	6.7	5.8	1.2
09052 bronze rim area 2	78	5.5	5.6	5.8	1.0
09052 black iron washer 0 degree position	1.1	2.8	84.3	0.3	
09052 black iron washer 90 degree position	1	2.4	84.2	0.2	
09052 black iron washer 180 degree position	1.1	2.1	84	0.3	
09052 black iron washer 270 degree position	1.4	3	84.5	0.2	
09058 bronze rim area 1	78	6.3	3.3	5.8	0.6
09058 bronze rim area 2	79.3	6.4	3.7	5.8	0.6
09058 black iron washer 0 degree position	5,4	1.6	82.2	0.9	
09058 black iron washer 90 degree position	6.5	1.9	82.9	0.5	
09058 black iron washer 180 degree position	5.5	1.9	81.4	0.7	
09058 black iron washer 270 degree position	5	2	84.5	0.5	
09059 bronze rim area 1	77	6.6	3.2	5.5	0.6
09059 bronze rim area 2	78.5	7	3.9	5.9	0.7
09059 black iron washer 0 degree position	3.2	2.7	83.2	0.9	
09059 black iron washer 90 degree position	2.2	2.9	83.9	0.6	
09059 black iron washer 180 degree position	3.7	3.2	82.1	0.8	
09059 black iron washer 270 degree position	3.2	3.4	83.4	0.6	
09063 black iron washer 0 degree position	5	1.6	80.7	0.7	
09063 black iron washer 90 degree position	3.4	1.5	82.4	0.4	
09063 black iron washer 180 degree position	4.9	1.6	81.5	0.7	
09063 black iron washer 270 degree position	5.3	2	82.2	0.7	
09059 non-wear bronze surface	79.7	10.4	3.8	6.1	0.6
09059 non-wear black iron surface	nd	nd	78.8	nd	

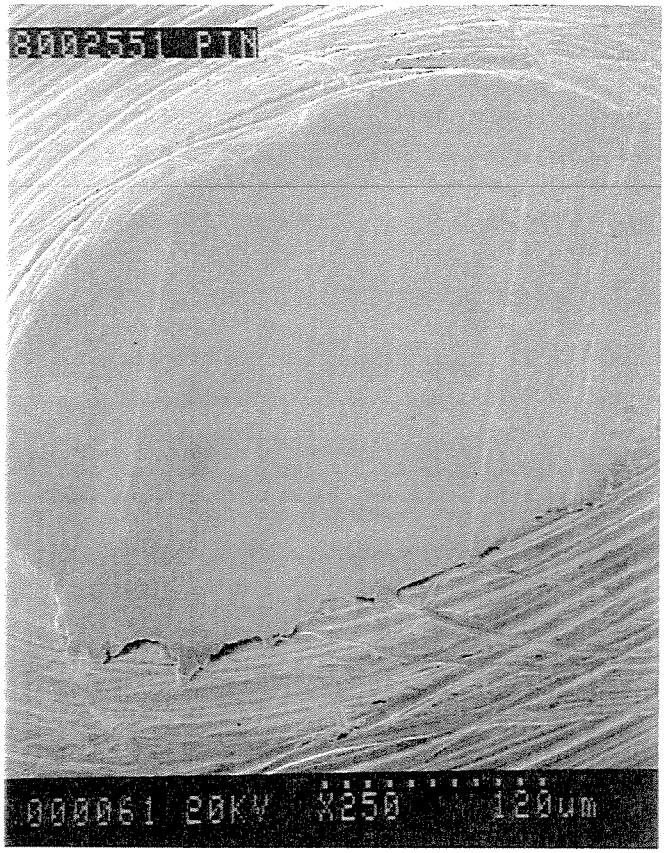
nd = not detected

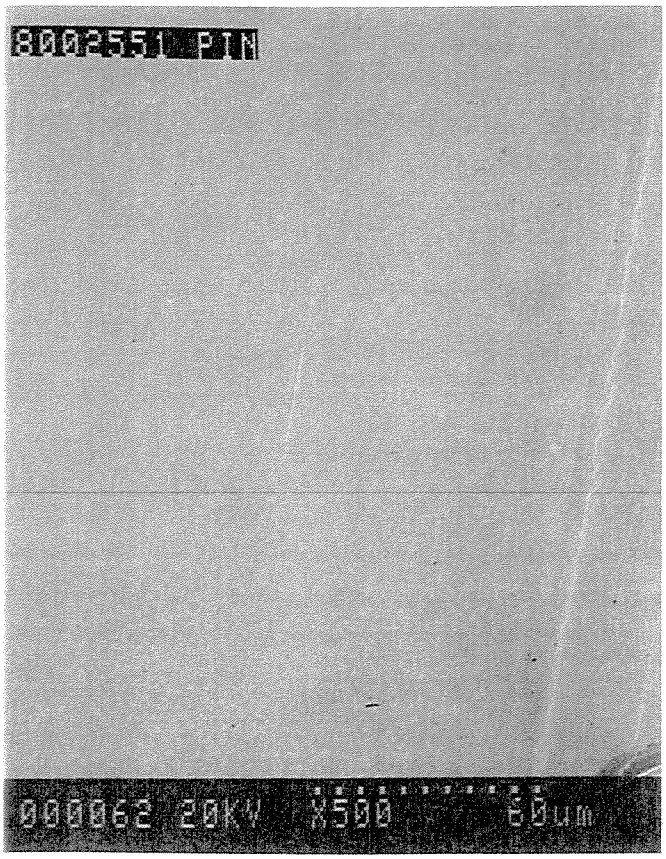
APPENDIX I

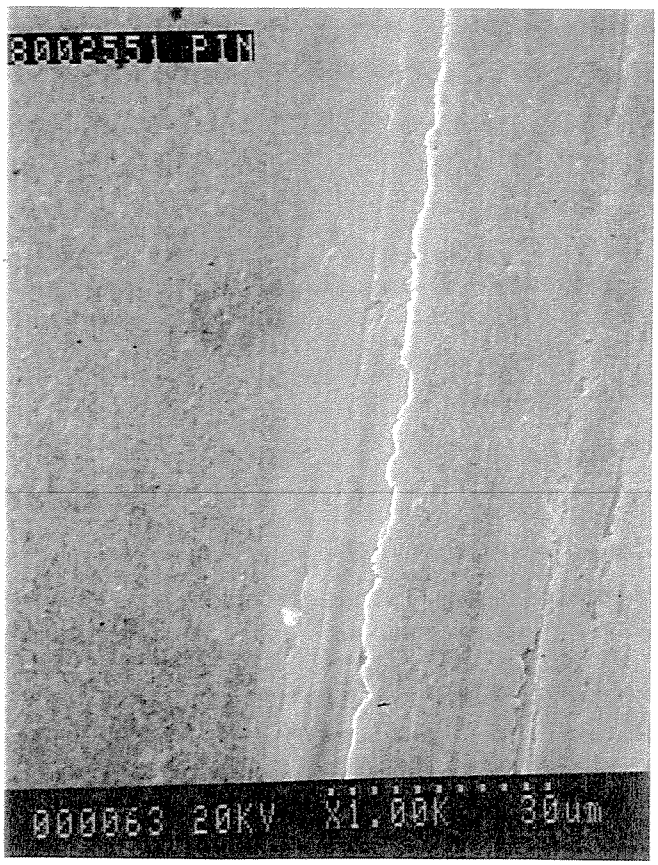
List of Figures

Falex Test 8002551 Pin-on-disk
Bronze pin

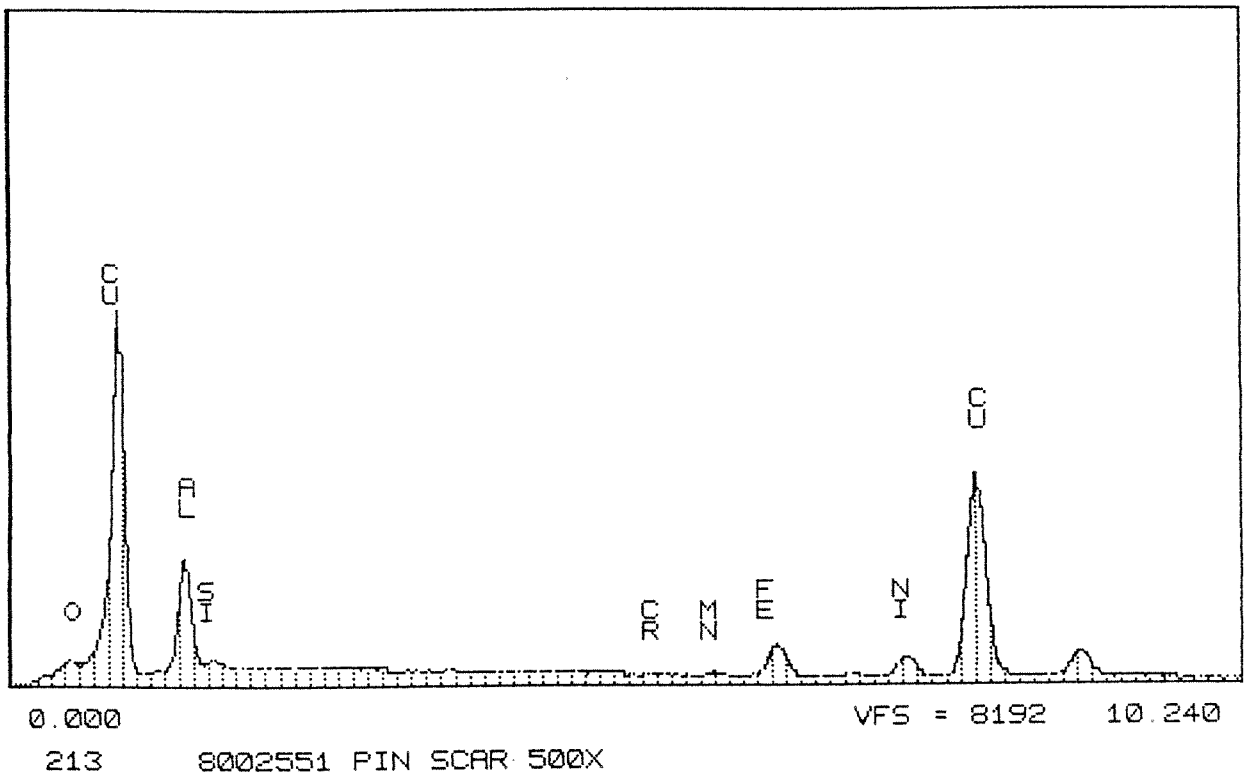




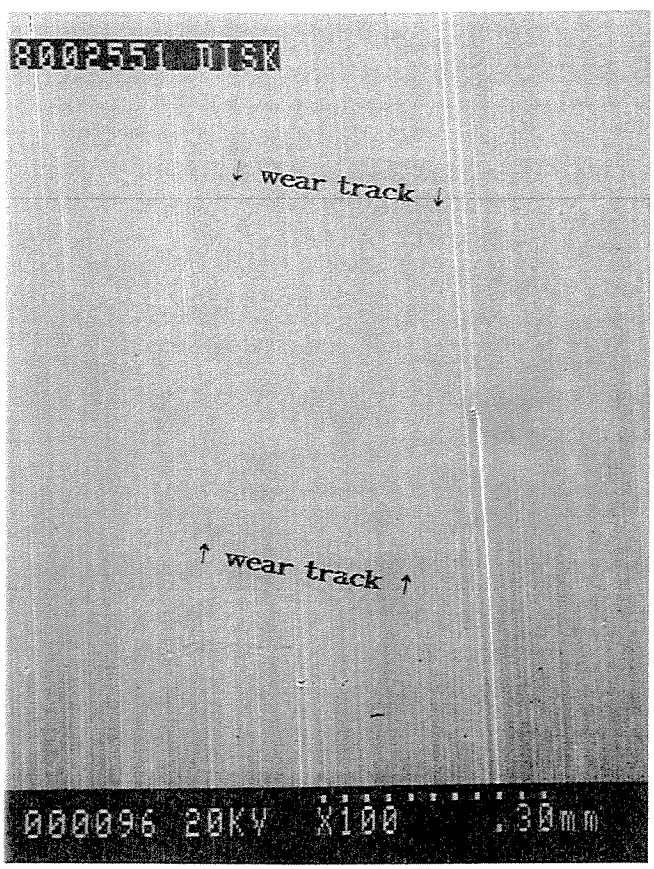


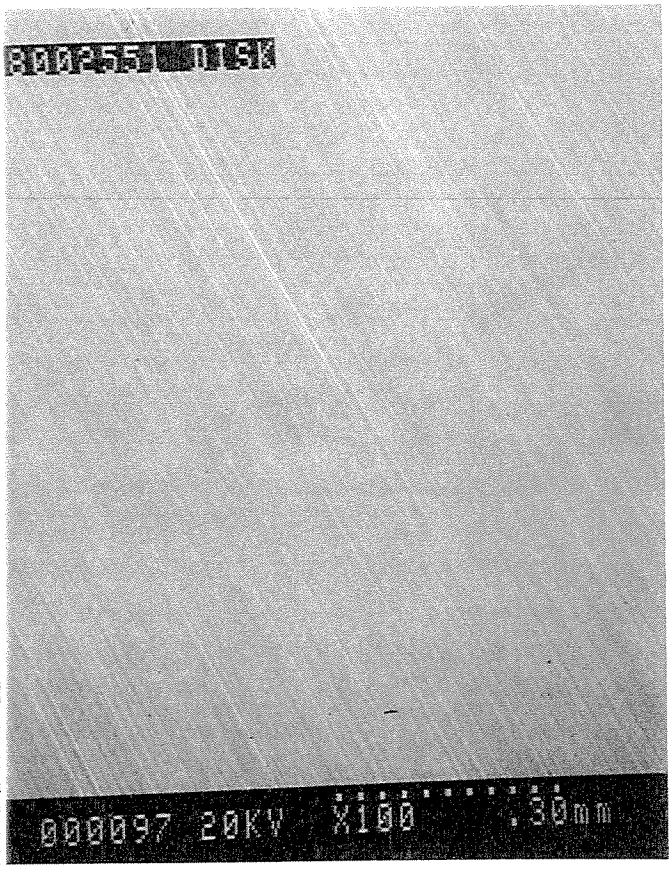


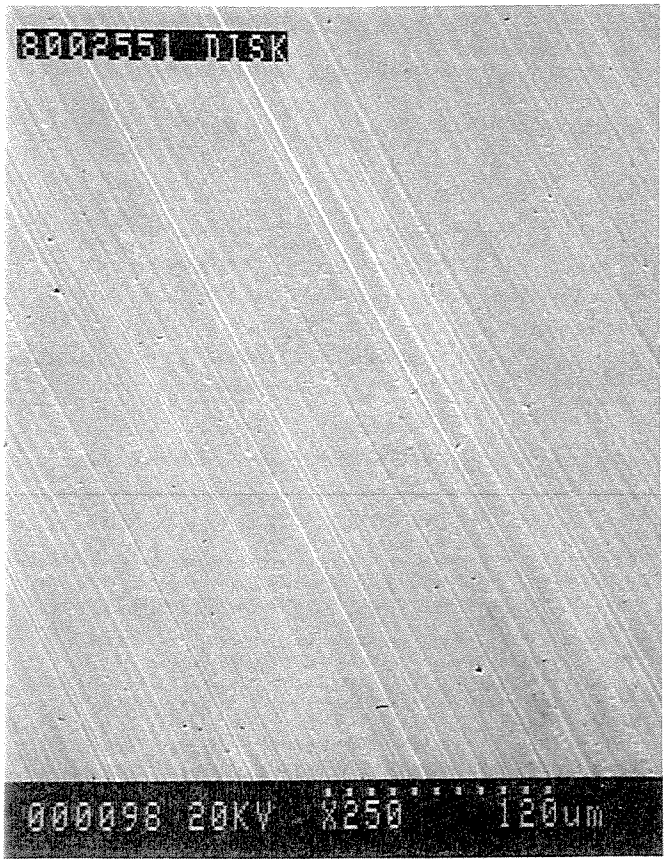
Falex Test 8002551 Pin-on-disk
Bronze pin

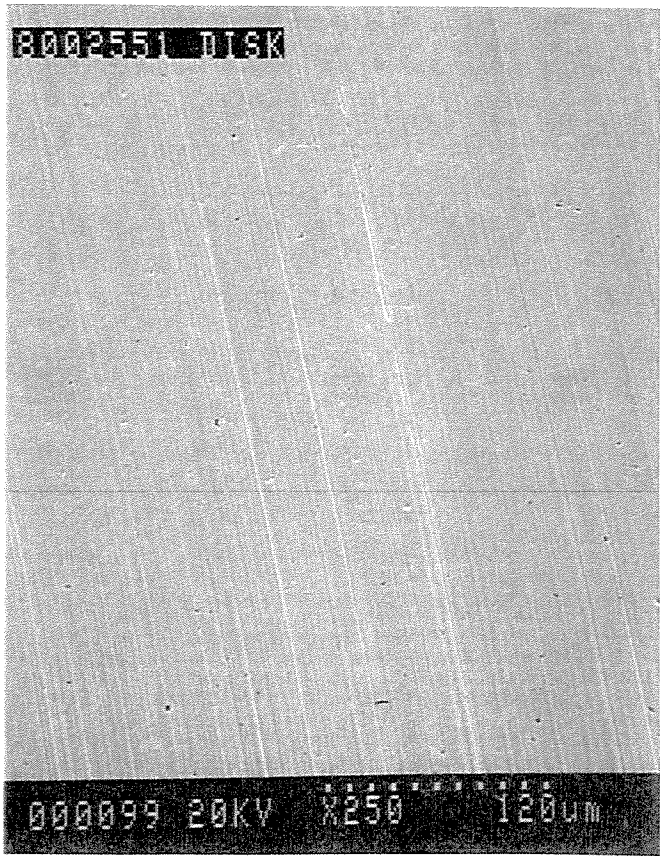


Falex Test 8002551 Pin-on-disk
Black iron disk

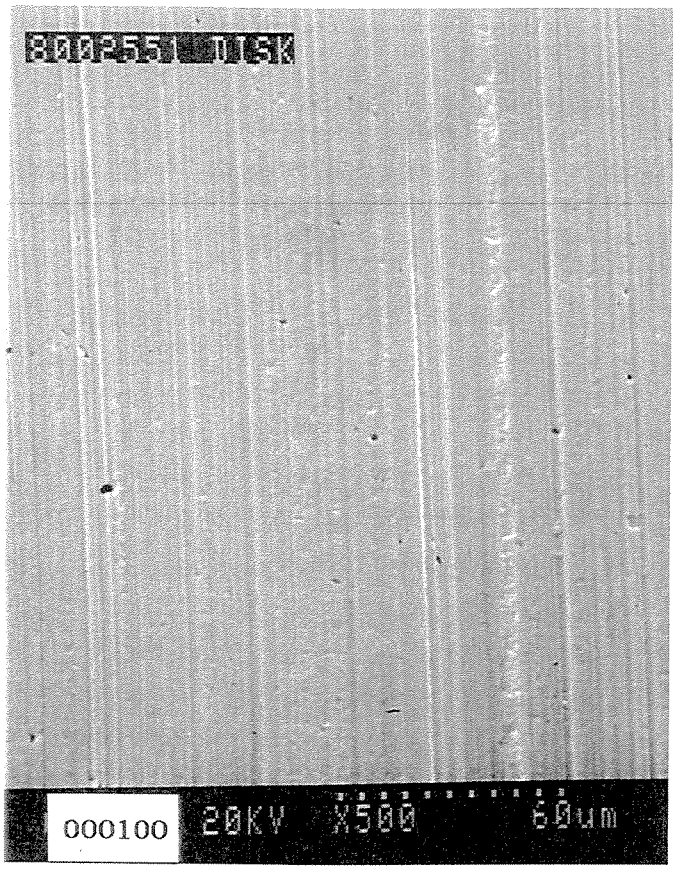


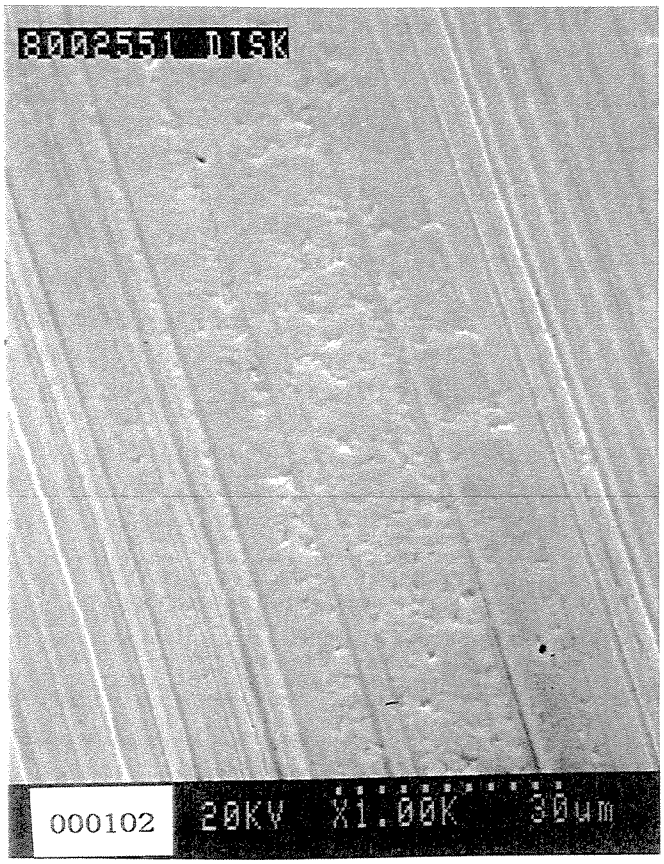


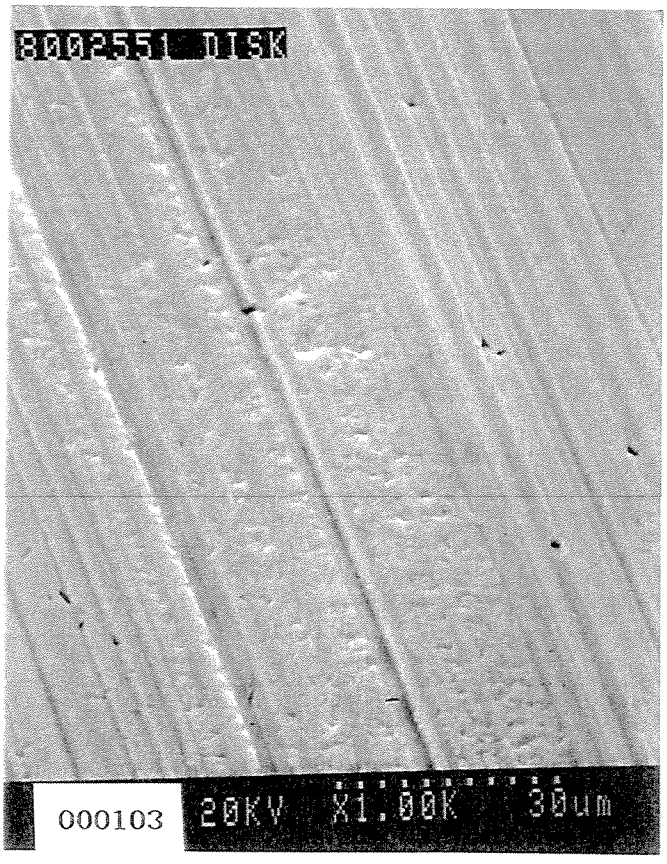




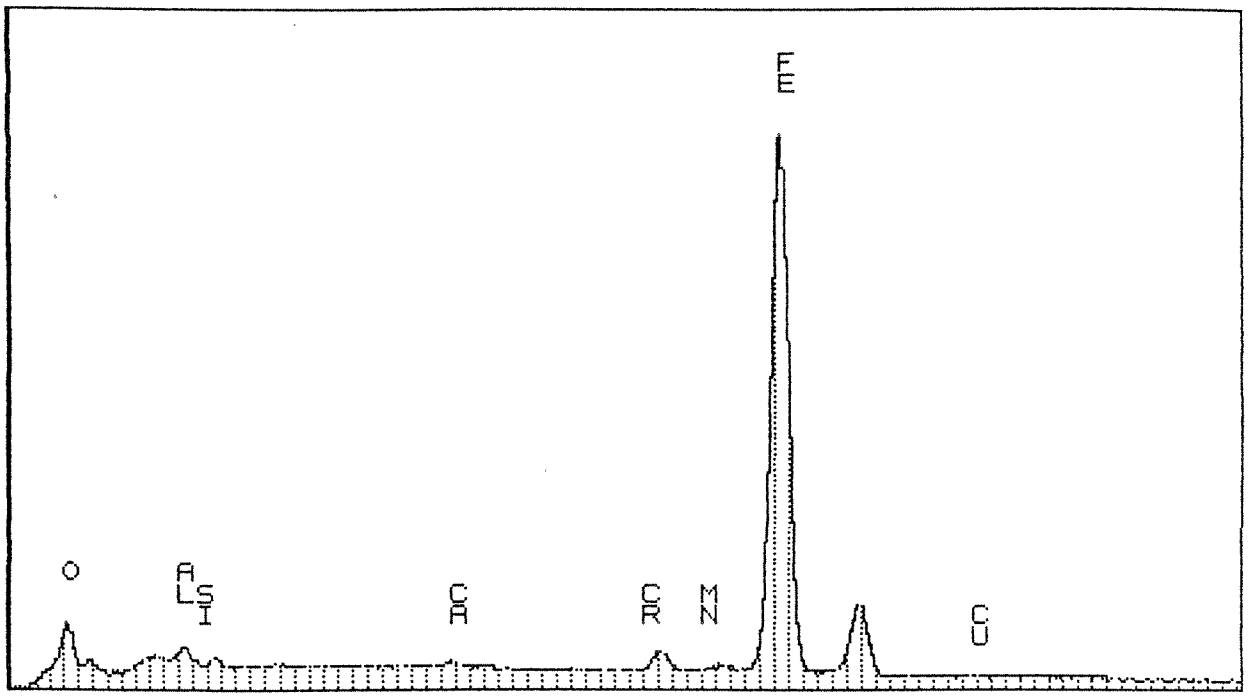
Falex Test 8002551 Pin-on-disk
Black iron disk

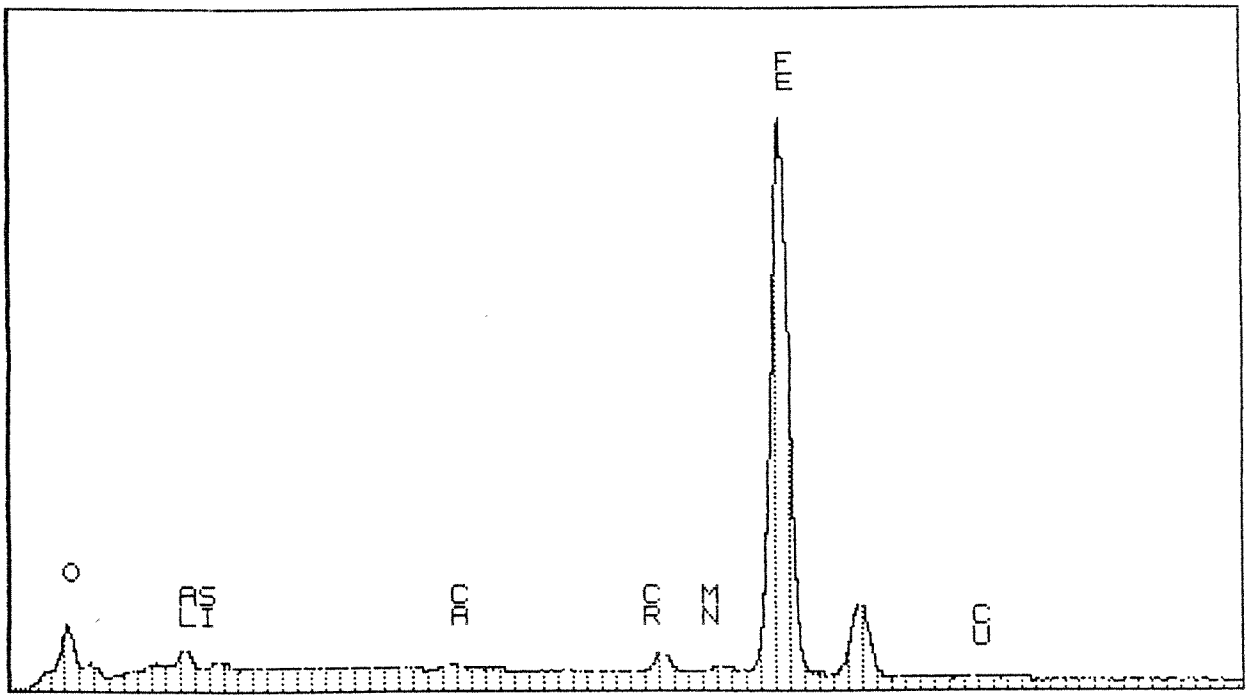




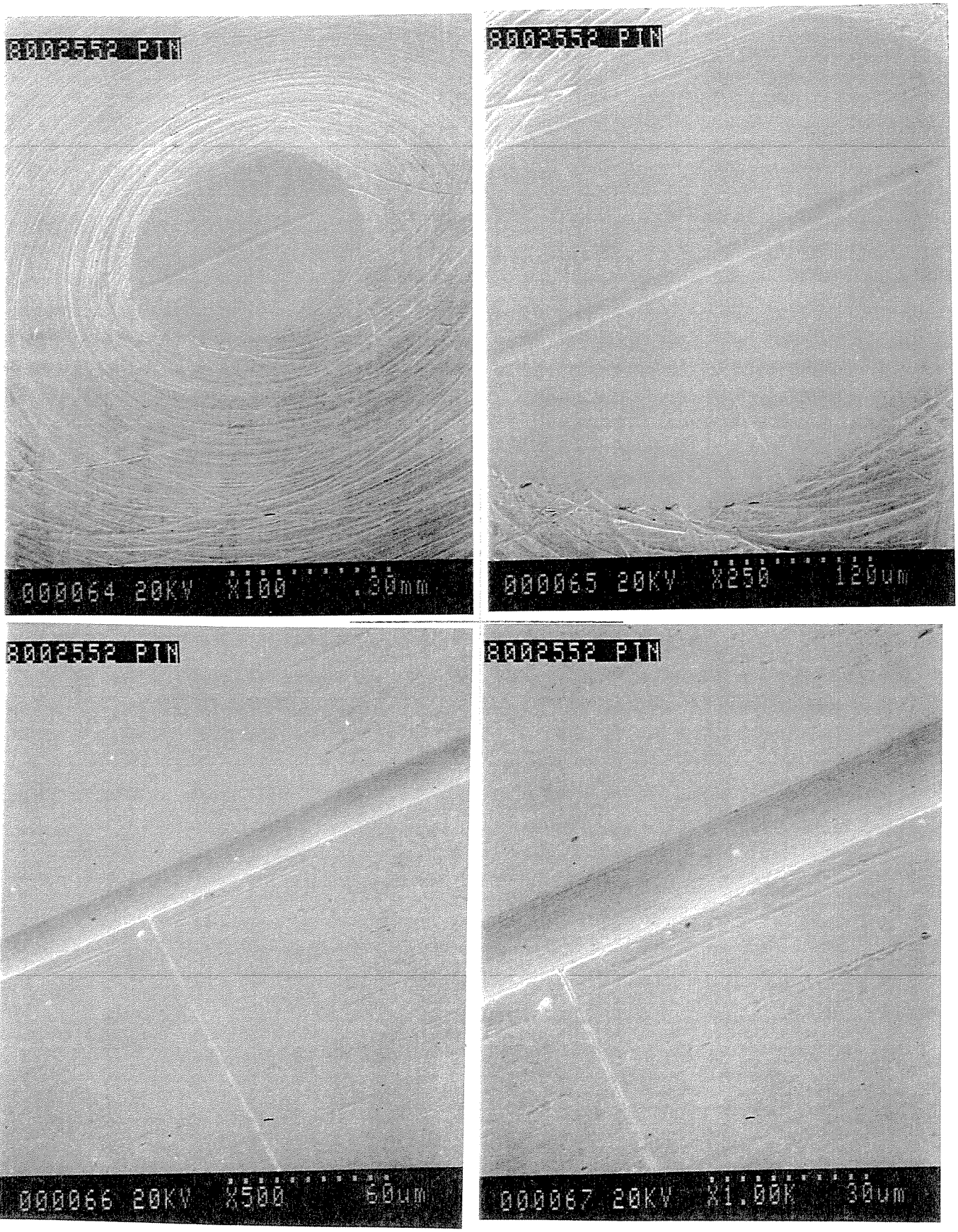


Falex Test 8002551 Pin-on-disk
Black iron disk

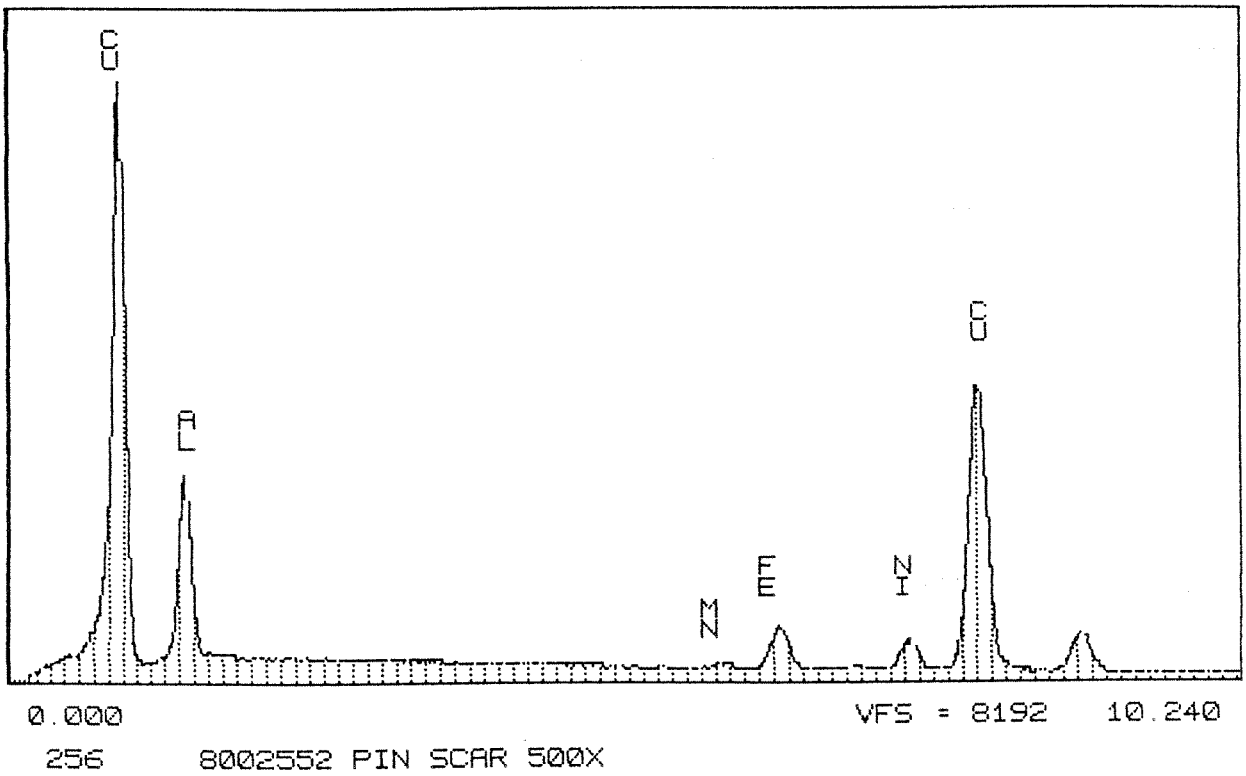




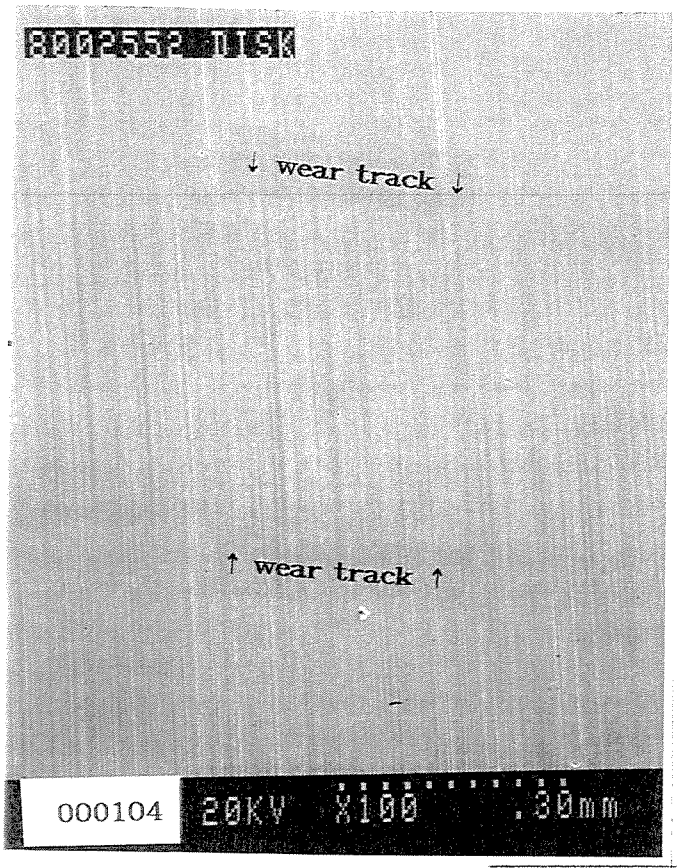
Falex Test 8002552 Pin-on-disk
Bronze pin

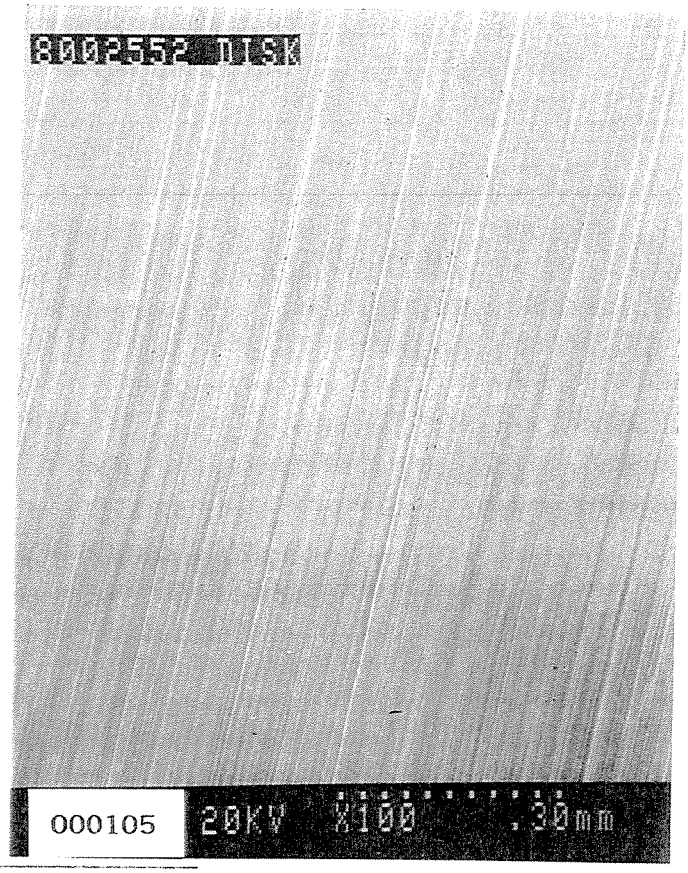


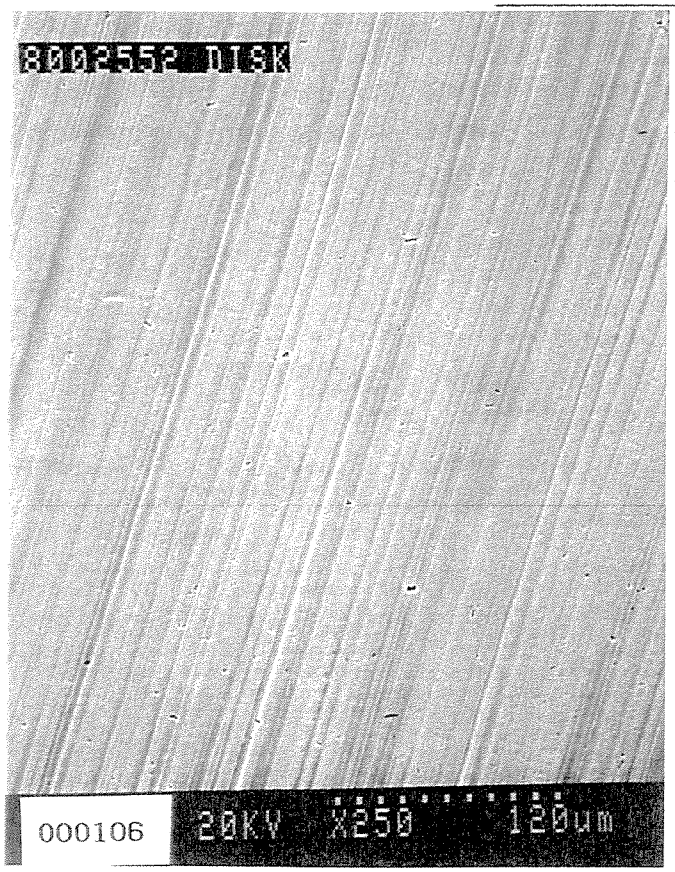
Falex Test 8002552 Pin-on-disk
Bronze pin

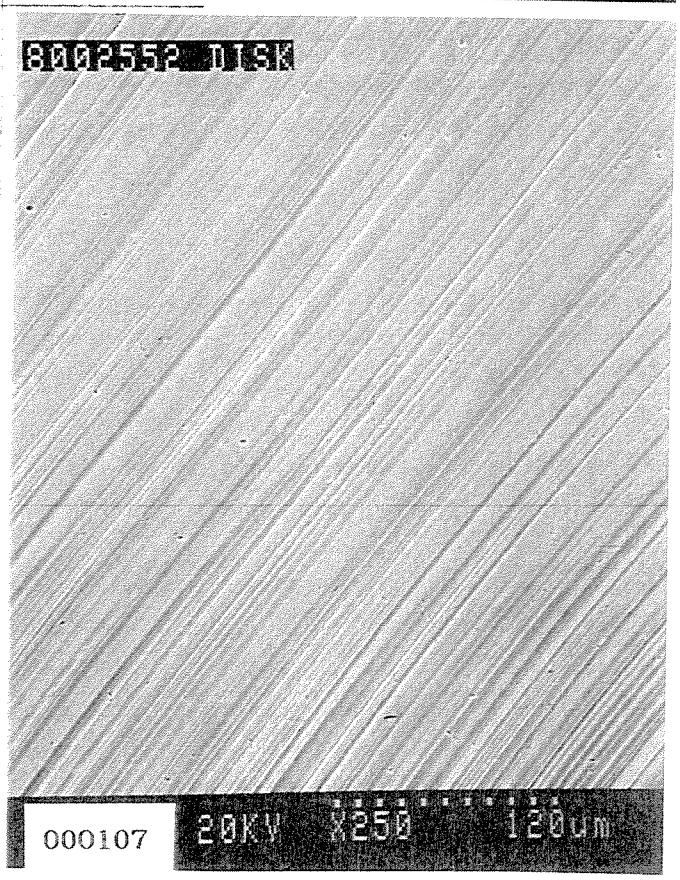


Falex Test 8002552 Pin-on-disk
Black iron disk

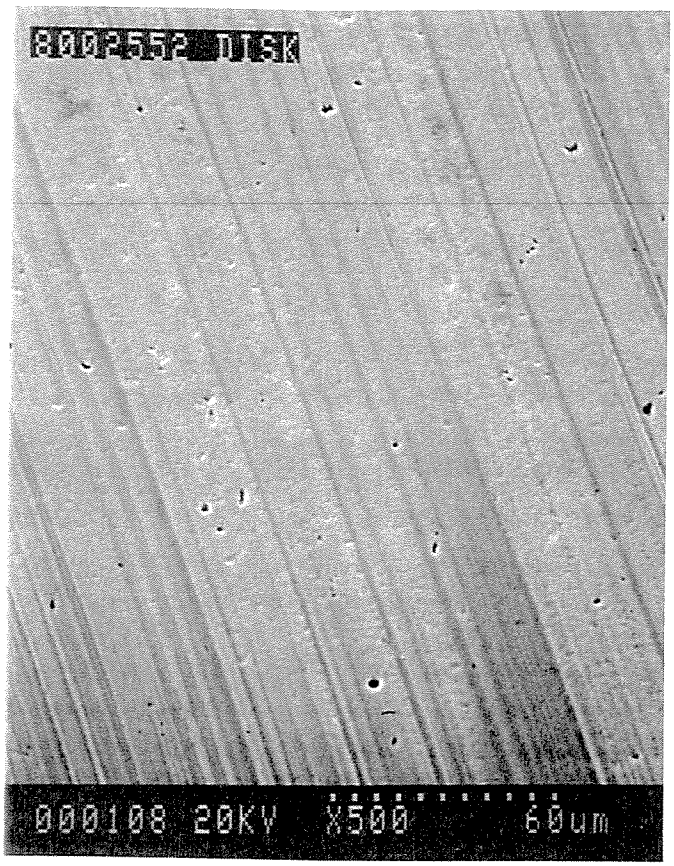


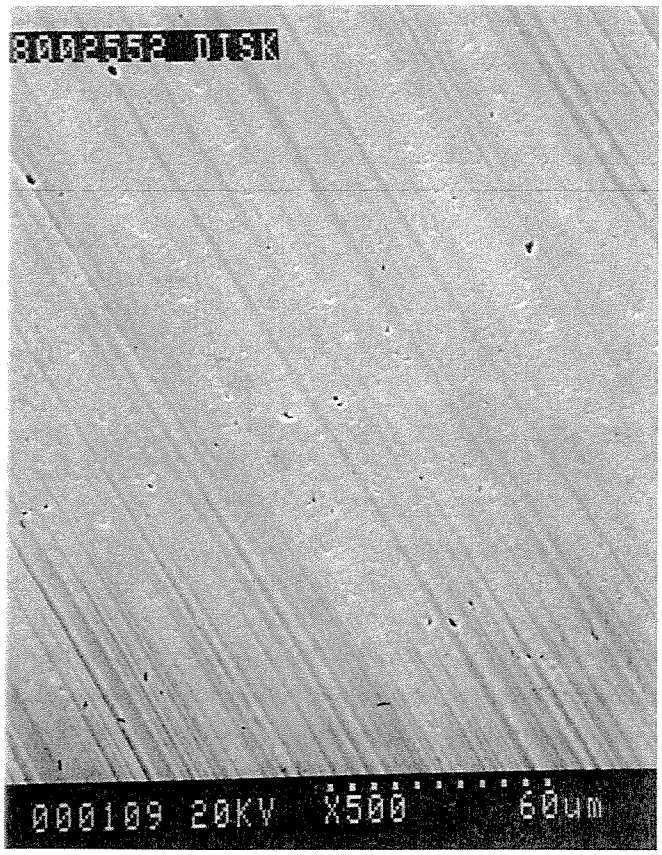


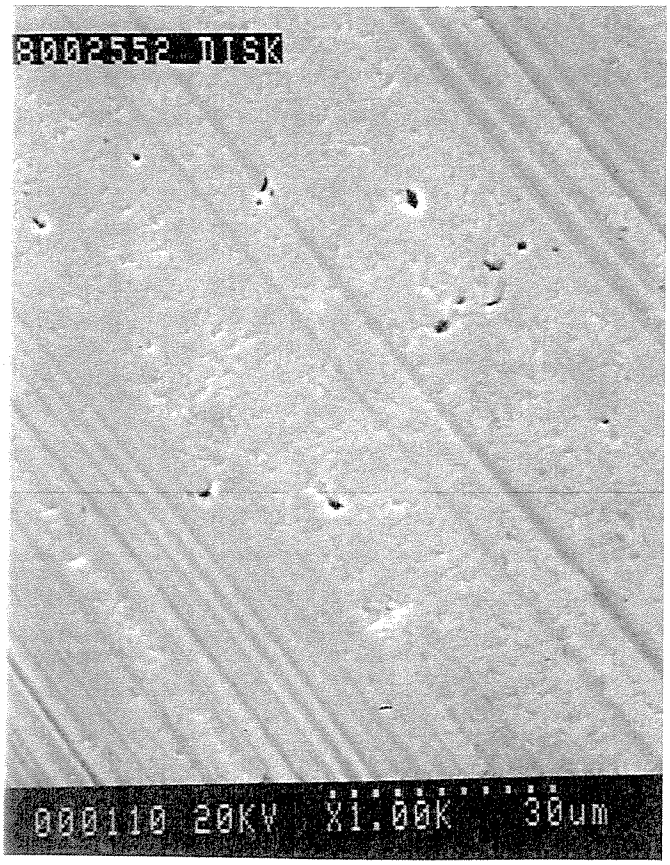


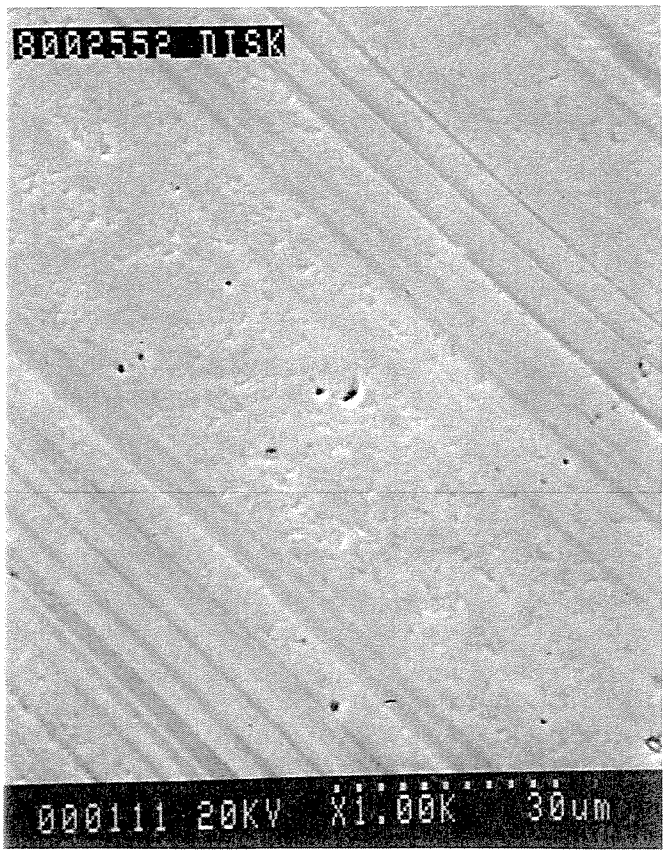


Falex Test 8002552 Pin-on-disk
Black iron disk

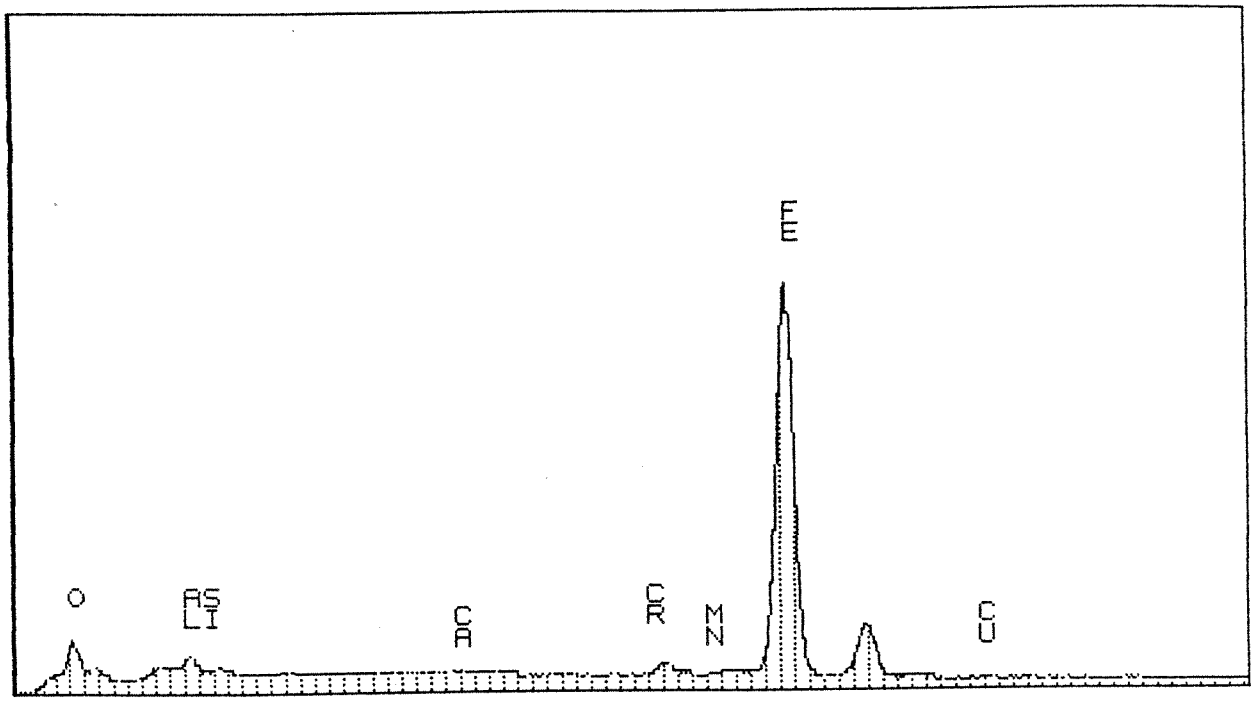


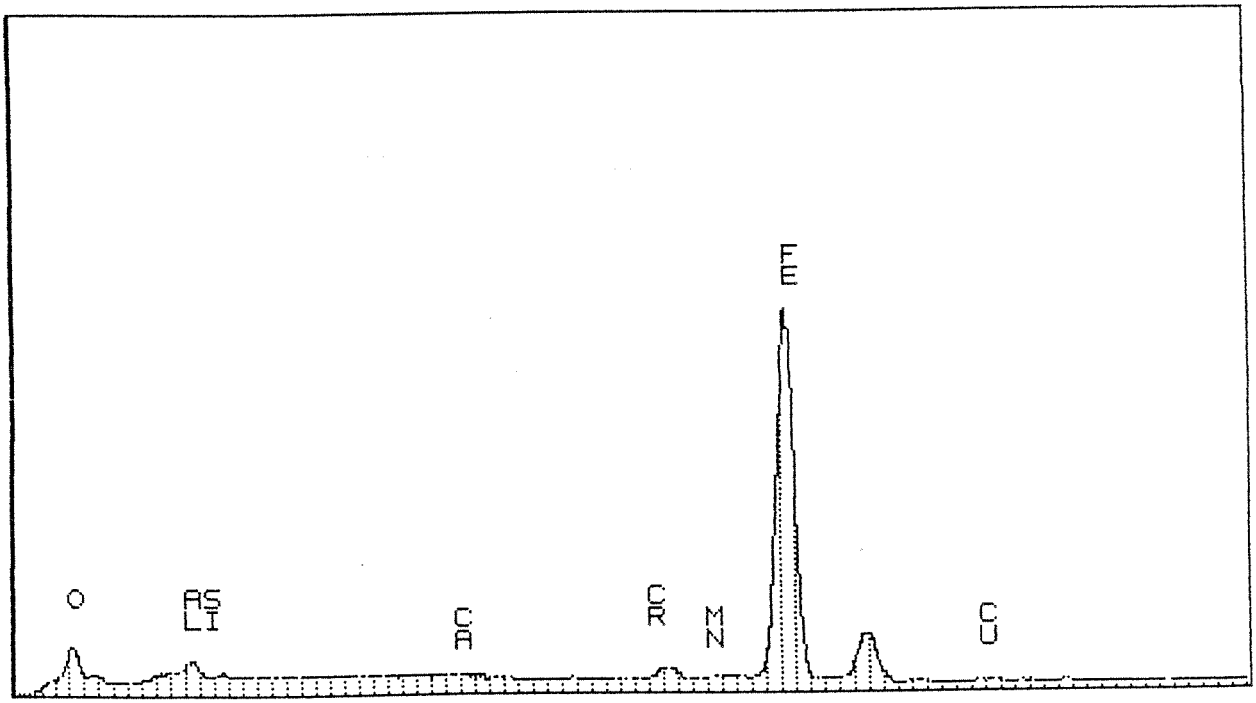




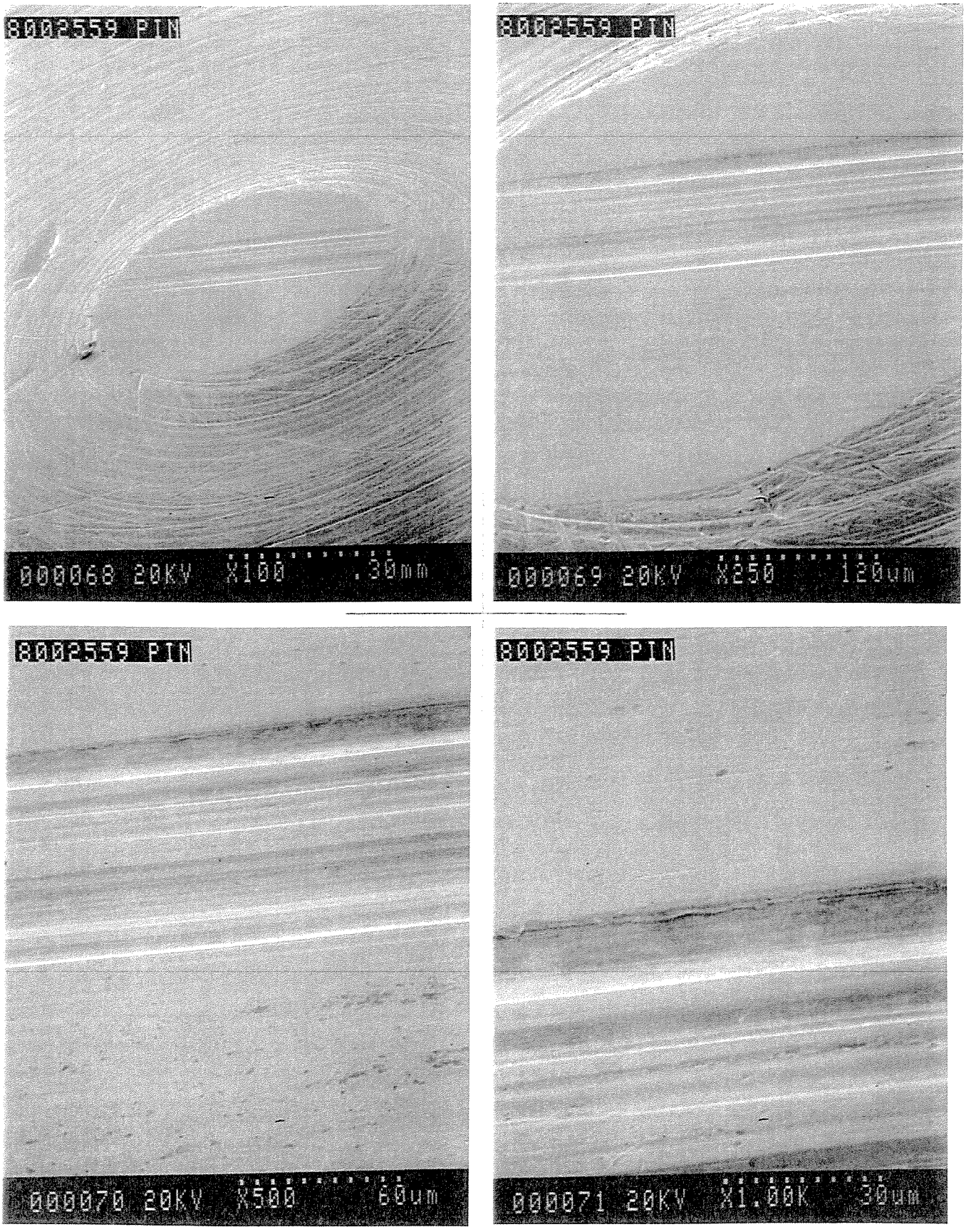


Falex Test 8002552 Pin-on-disk
Black iron disk

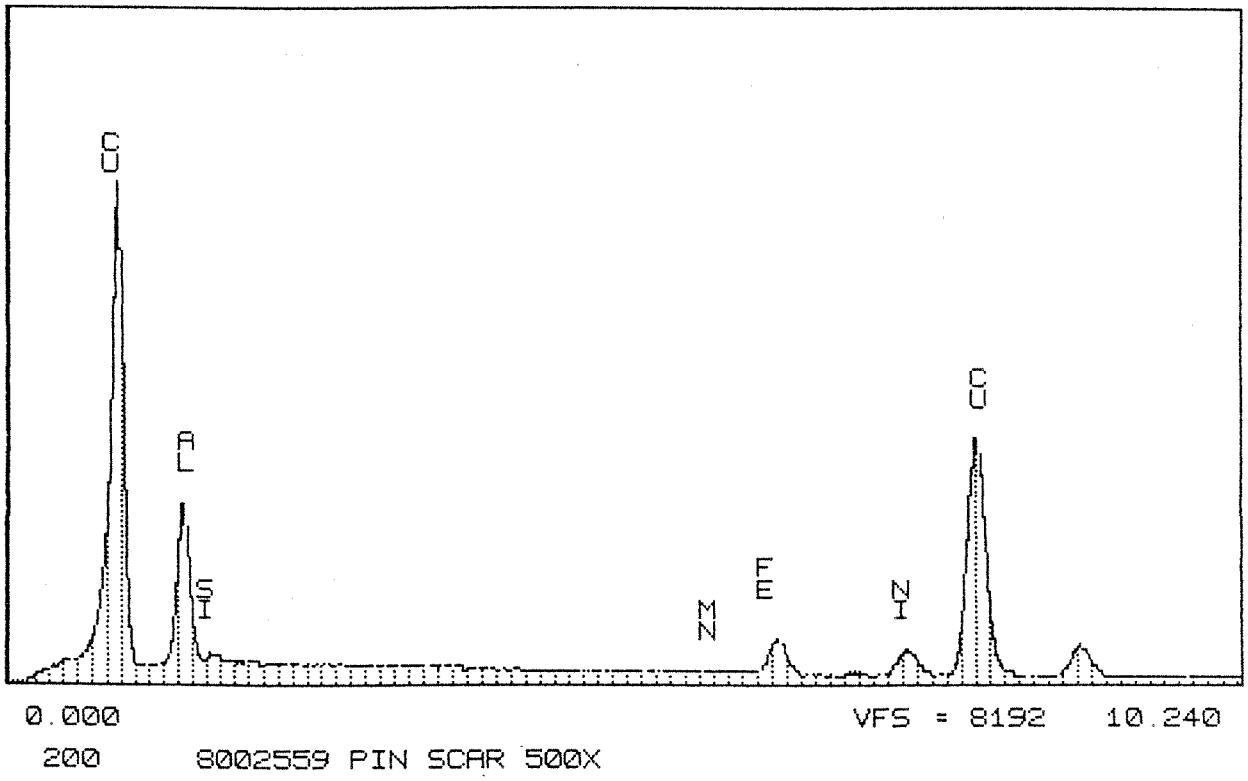




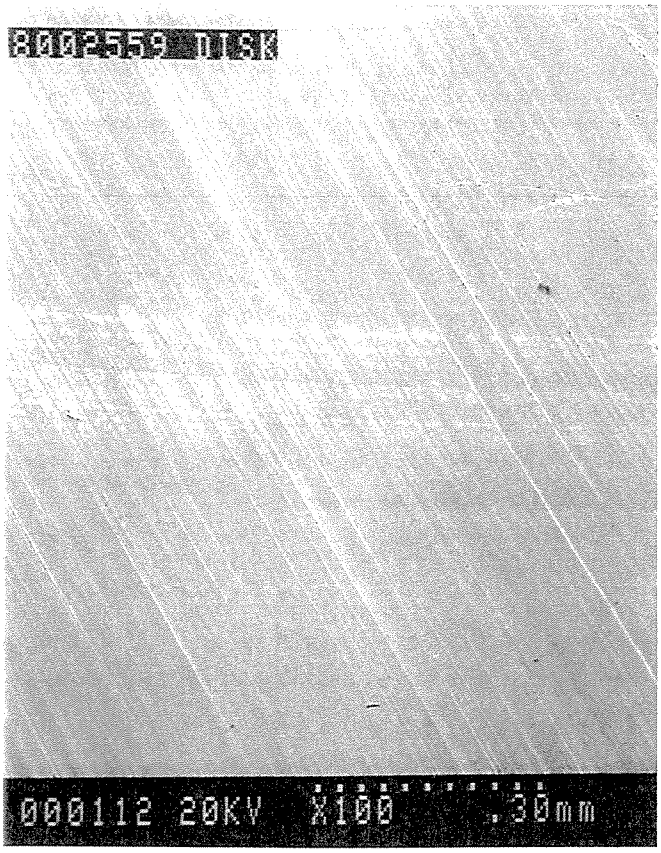
Falex Test 8002559 Pin-on-disk
Bronze pin

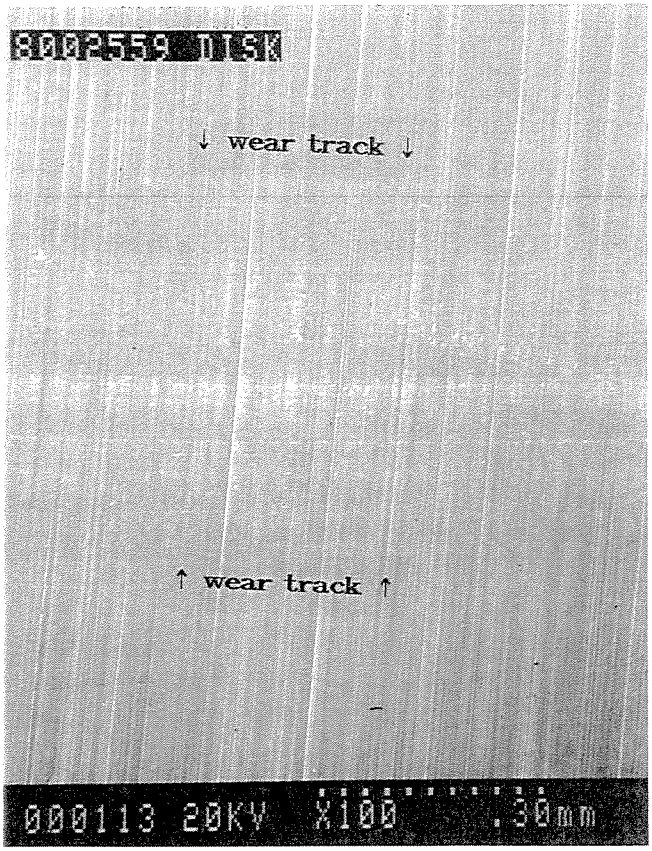


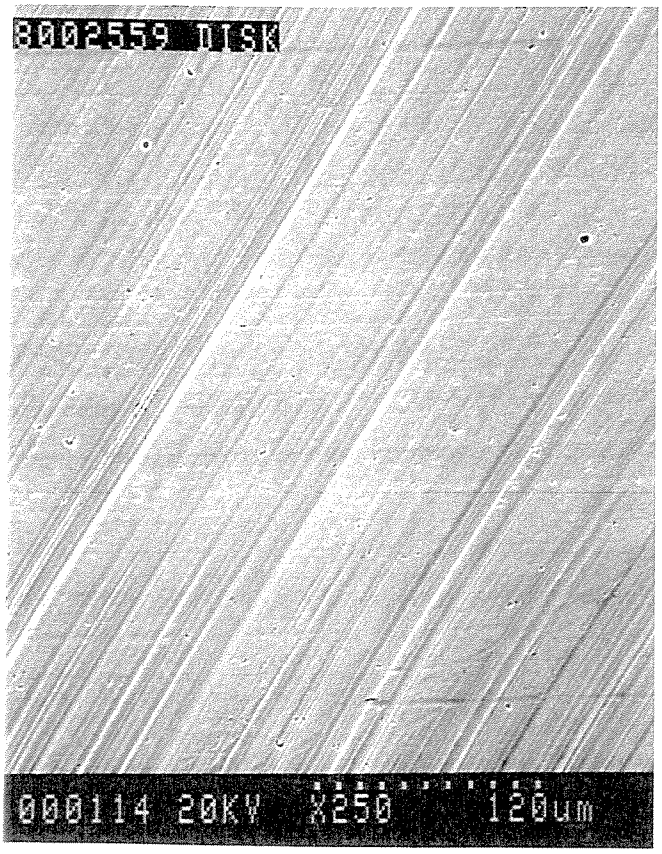
Falex Test 8002559 Pin-on-disk
Bronze pin

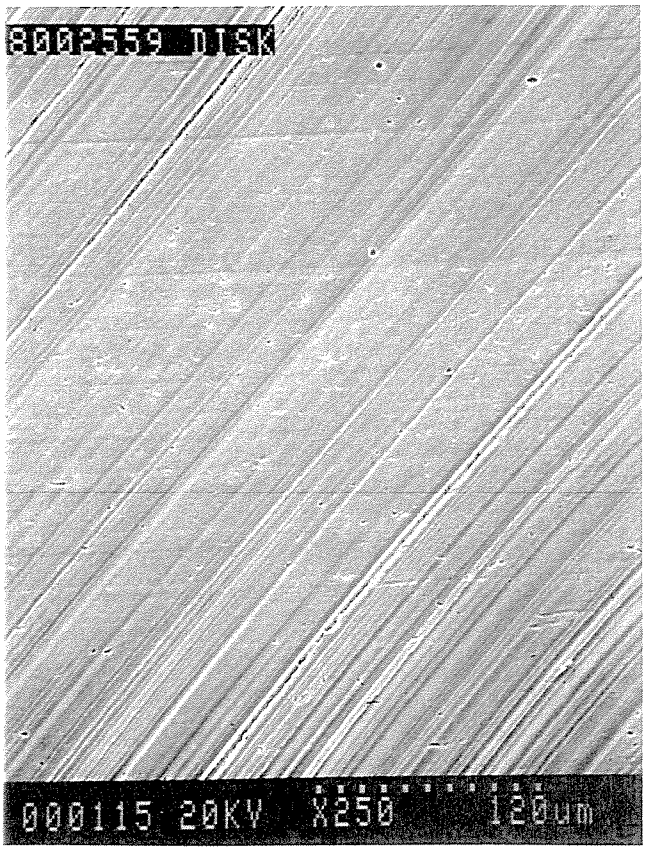


Falex Test 8002559 Pin-on-disk
Black iron disk

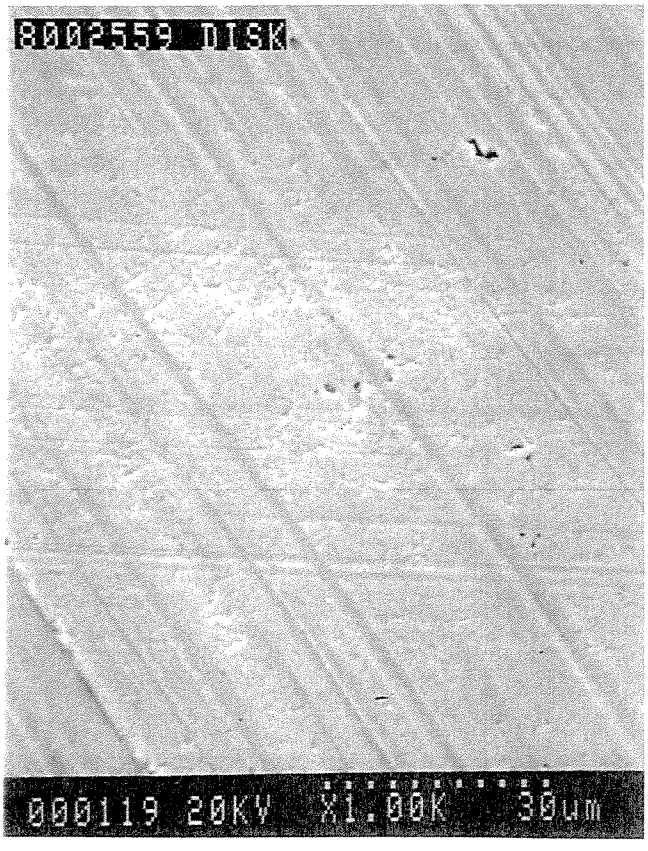




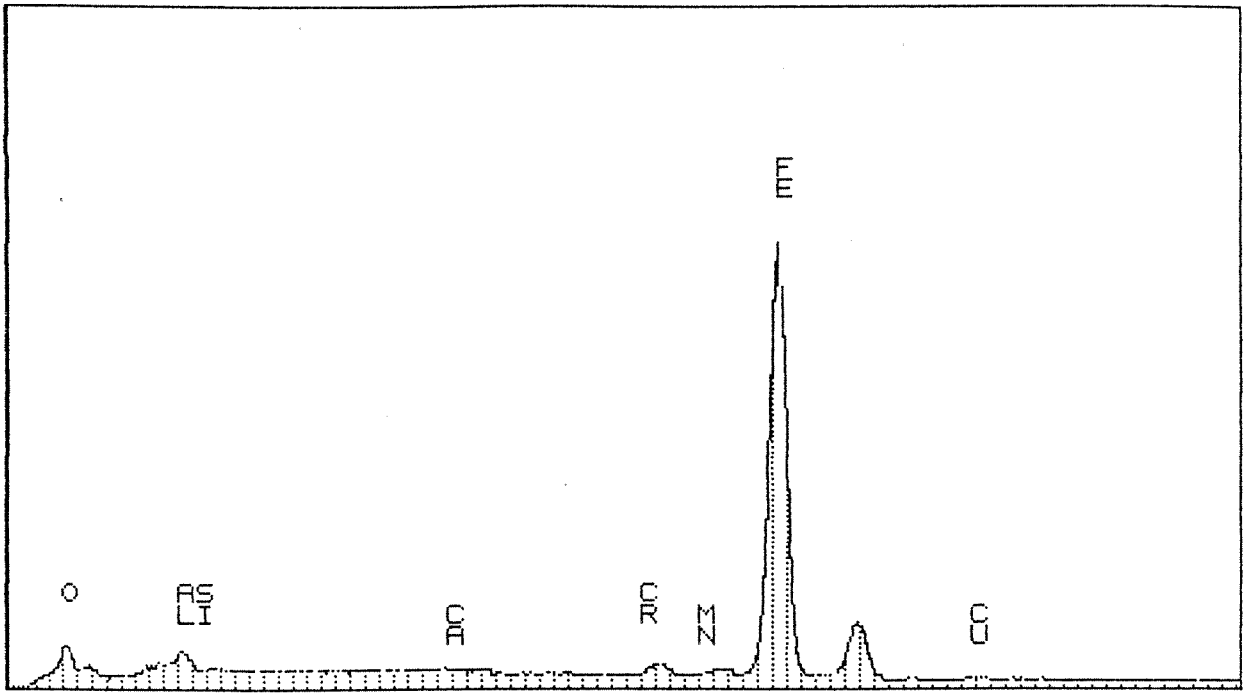


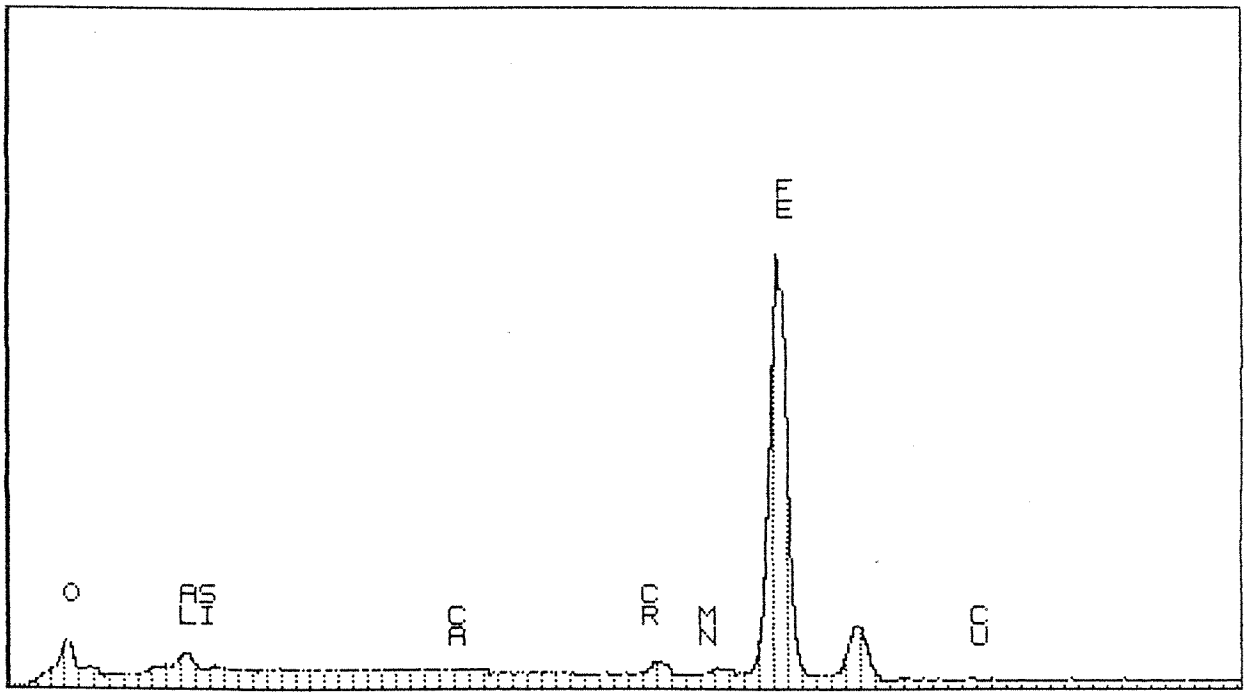


Falex Test 8002559 Pin-on-disk
Black iron disk

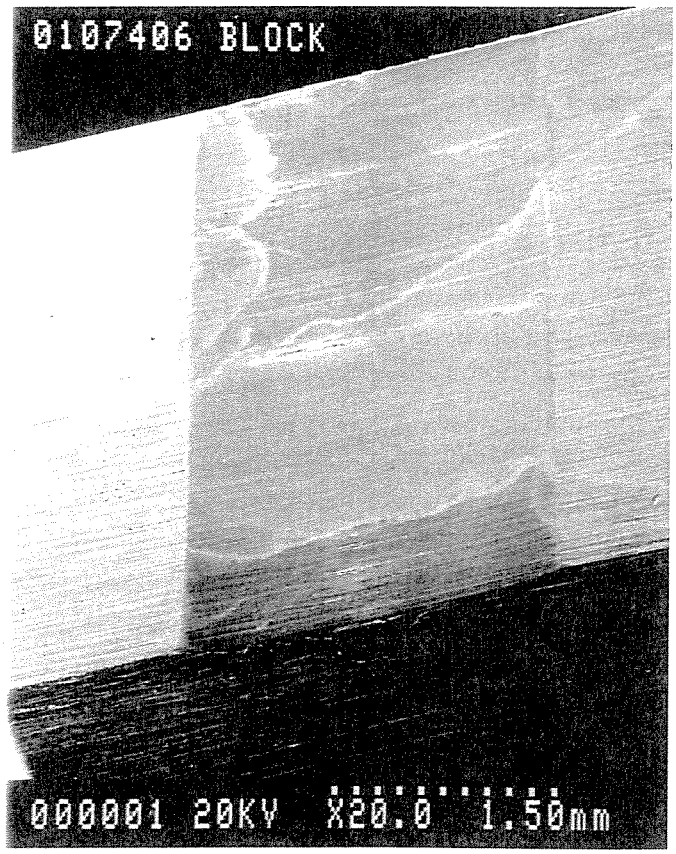


Falex Test 8002559 Pin-on-disk
Black iron disk

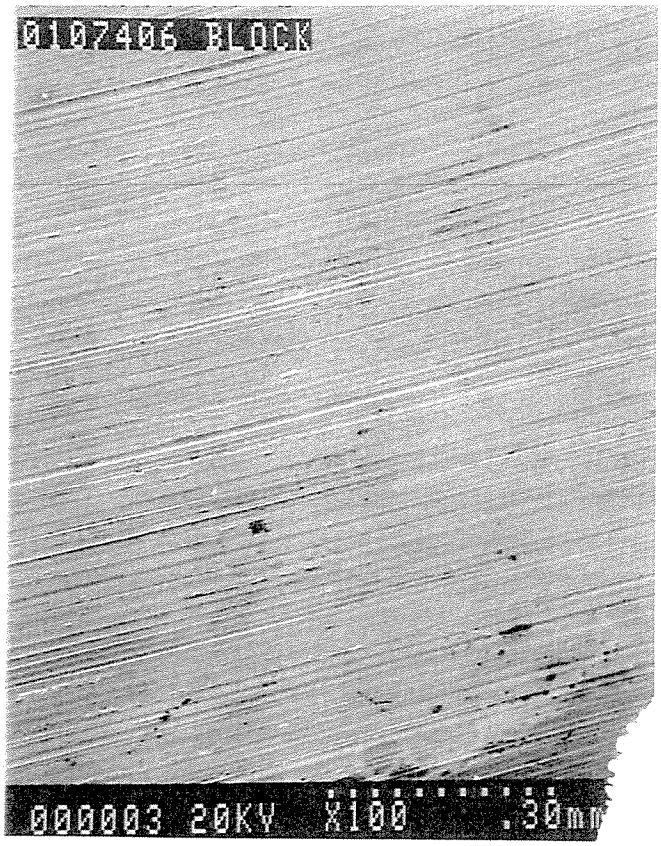


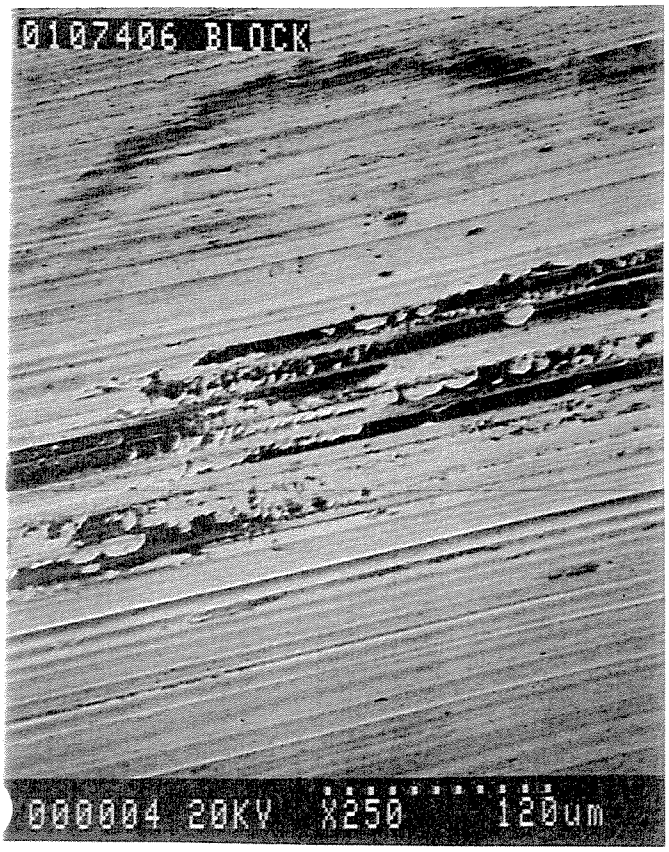


Falex Test 0107406 Block-on-ring
Bronze block

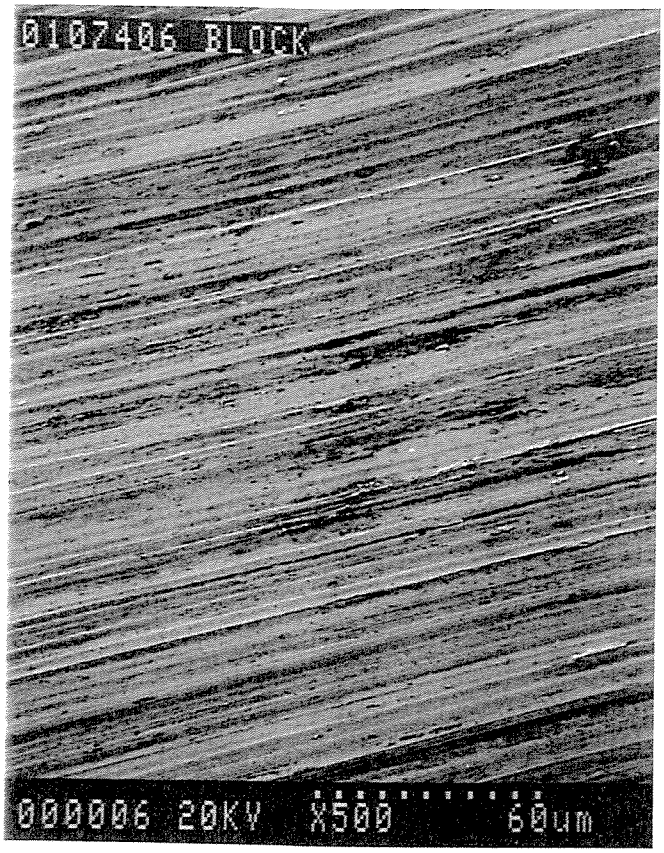


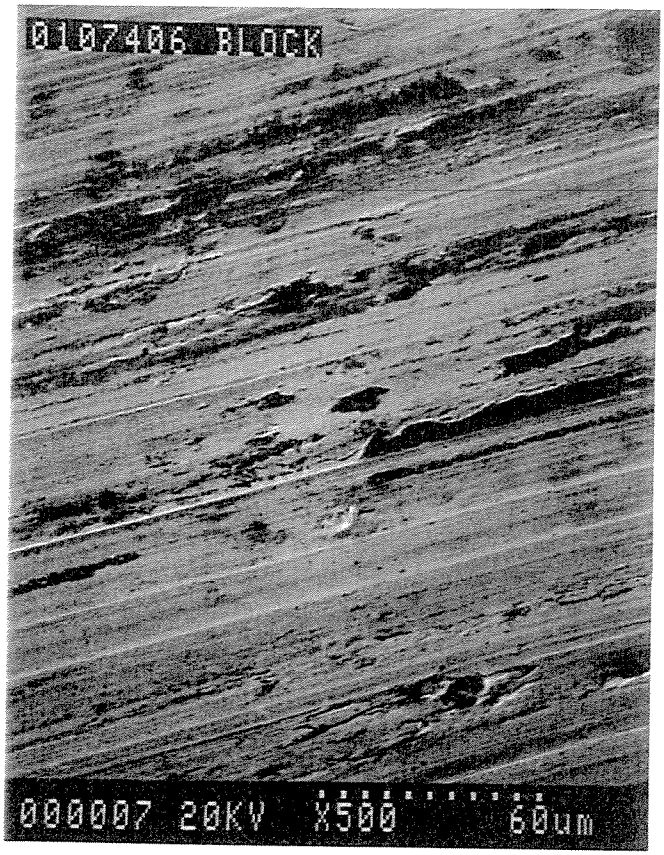
Falex Test 0107406 Block-on-ring
Bronze block

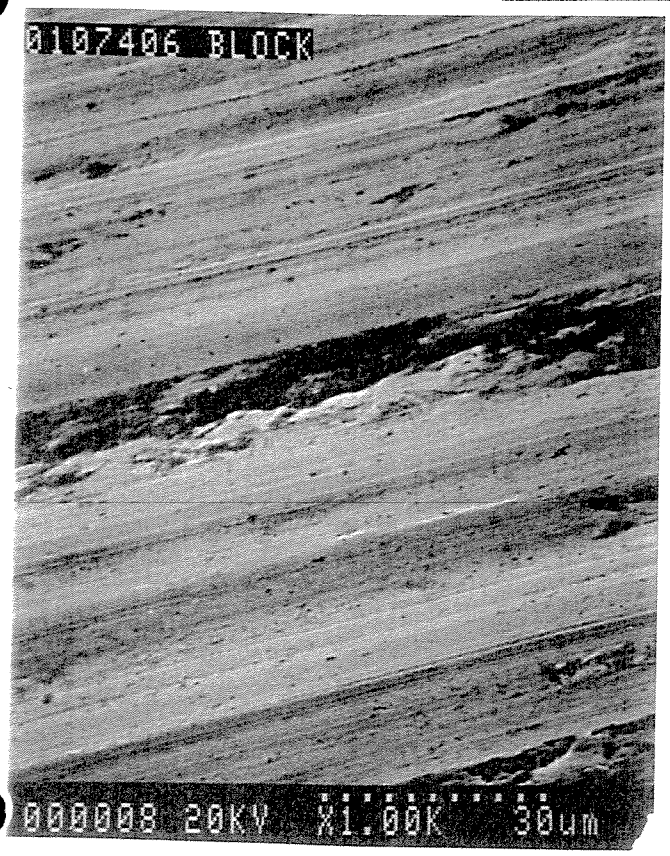


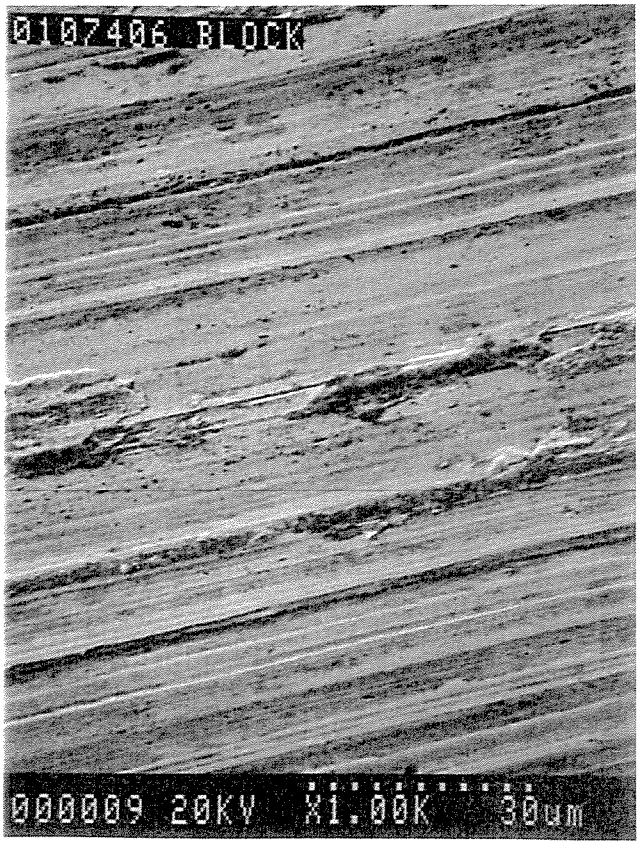


Falex Test 0107406 Block-on-ring
Bronze block

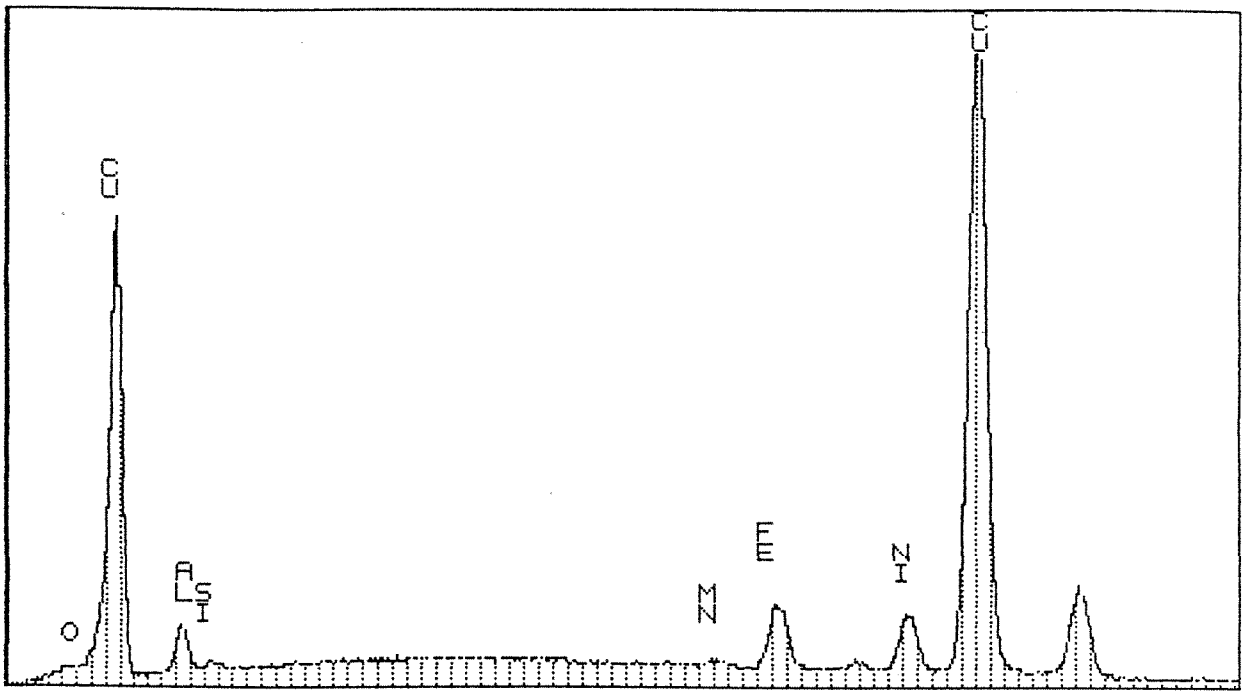


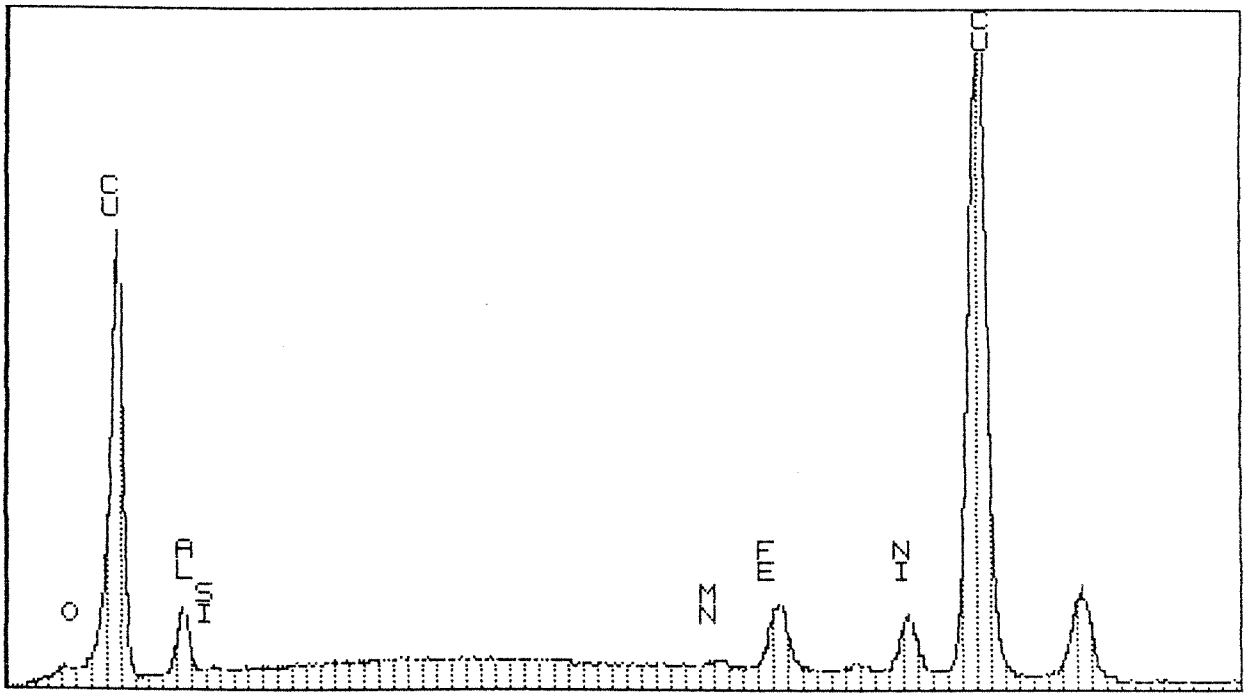




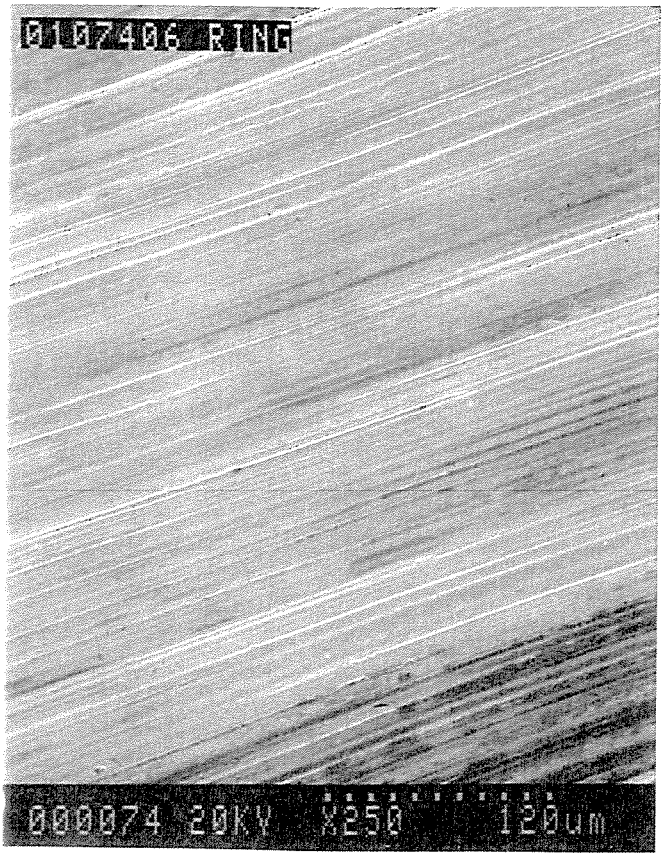


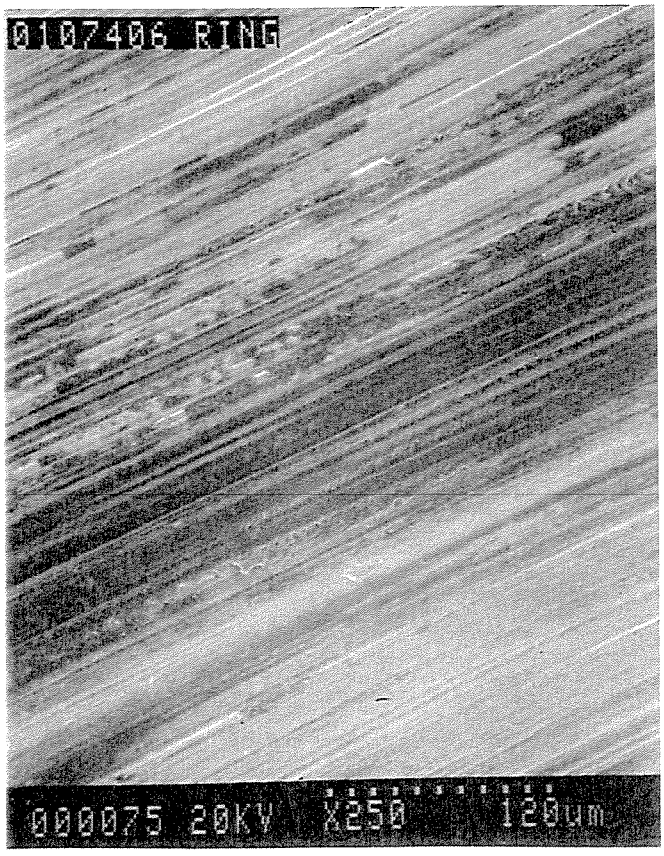
Falex Test 0107406 Block-on-ring
Bronze block



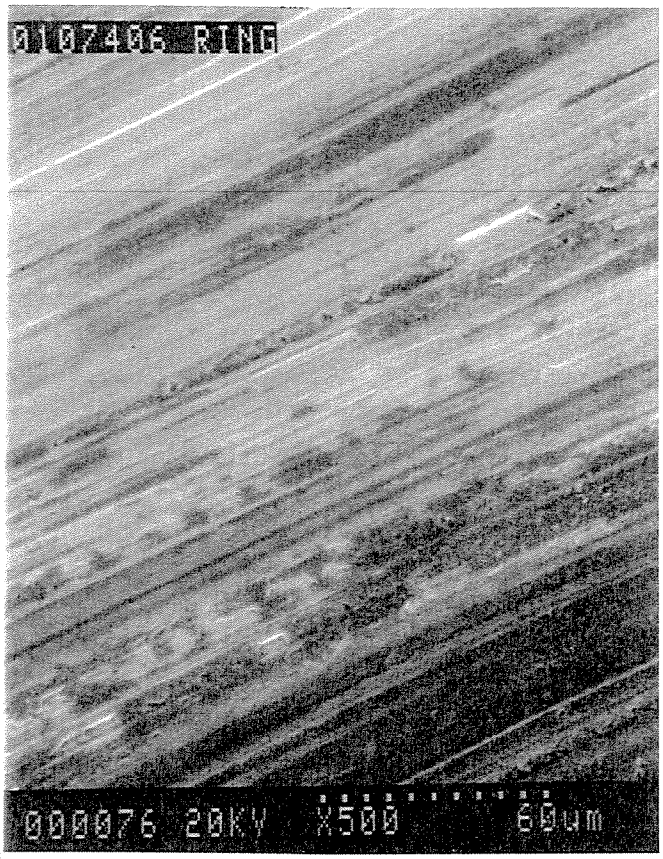


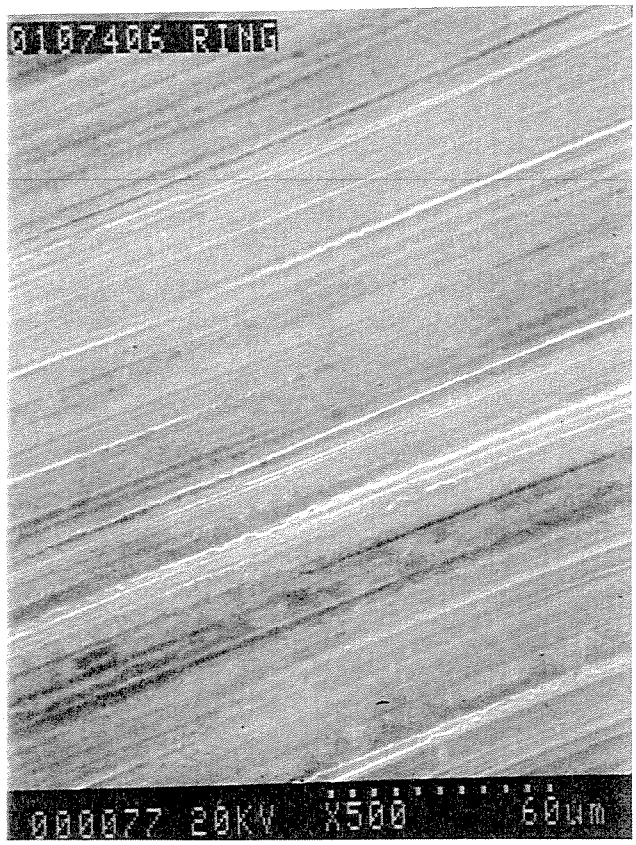
Falex Test 0107406 Block-on-ring
Black iron ring



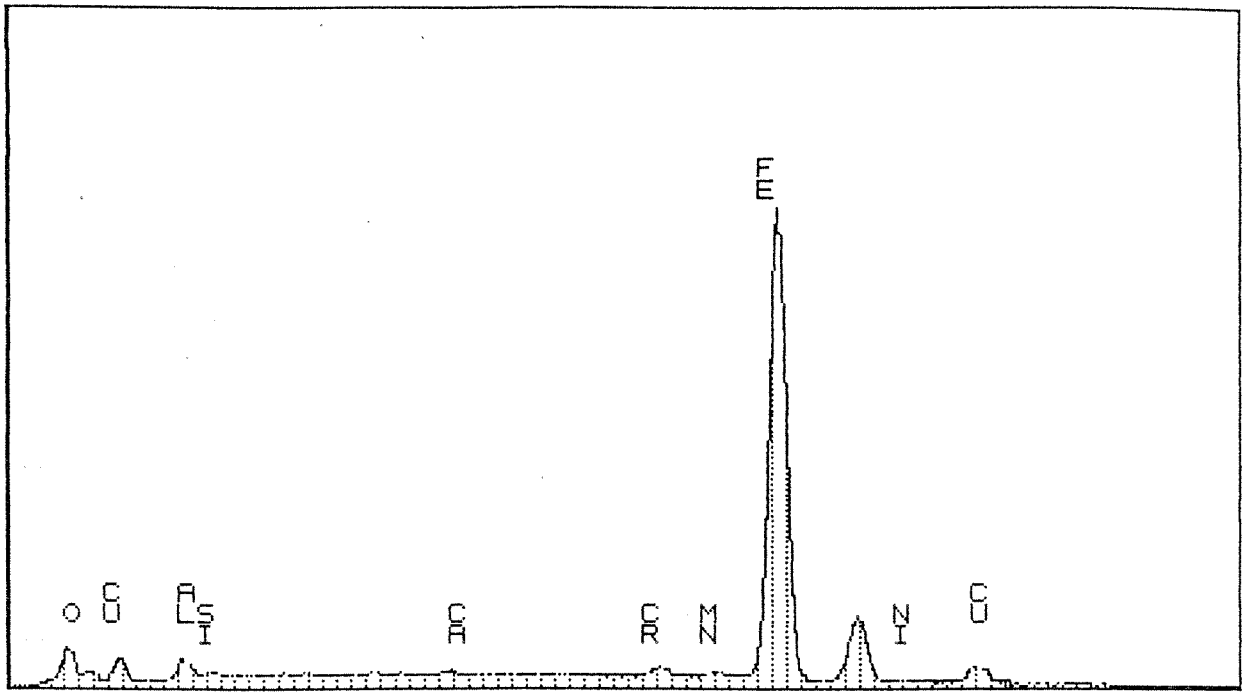


Falex Test 0107406 Block-on-ring
Black iron ring



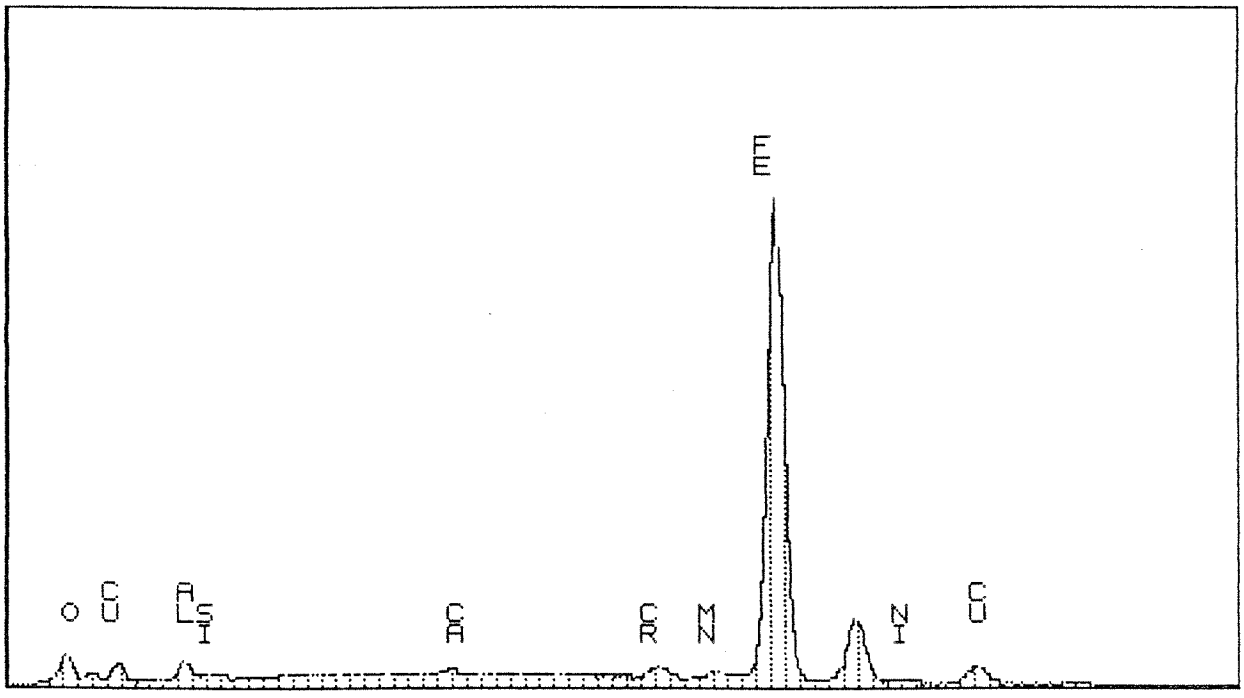


Falex Test 0107406 Block-on-ring
Black iron ring



0.000 VFS = 8192 10.240

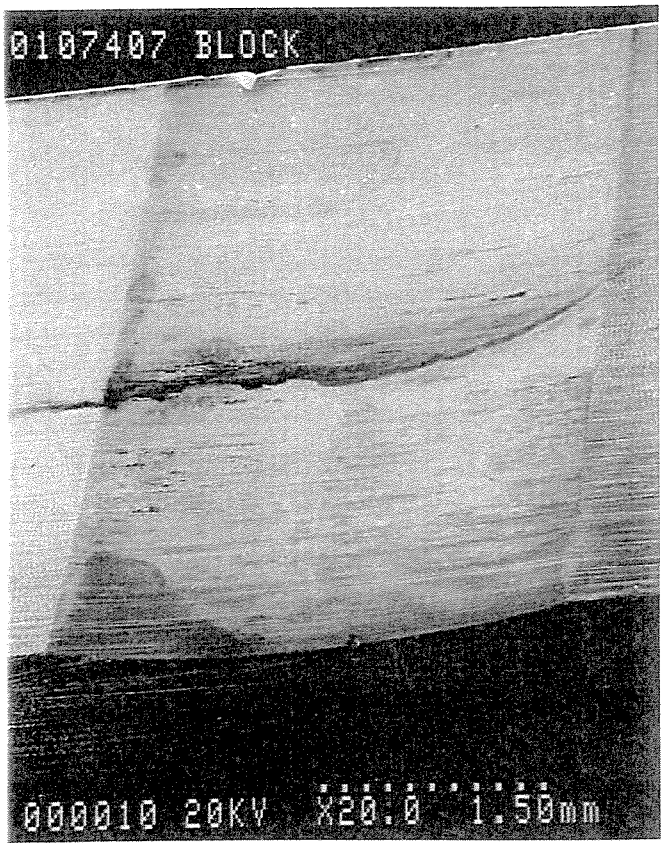
200 0107406 RING SCAR 50X AREA 1



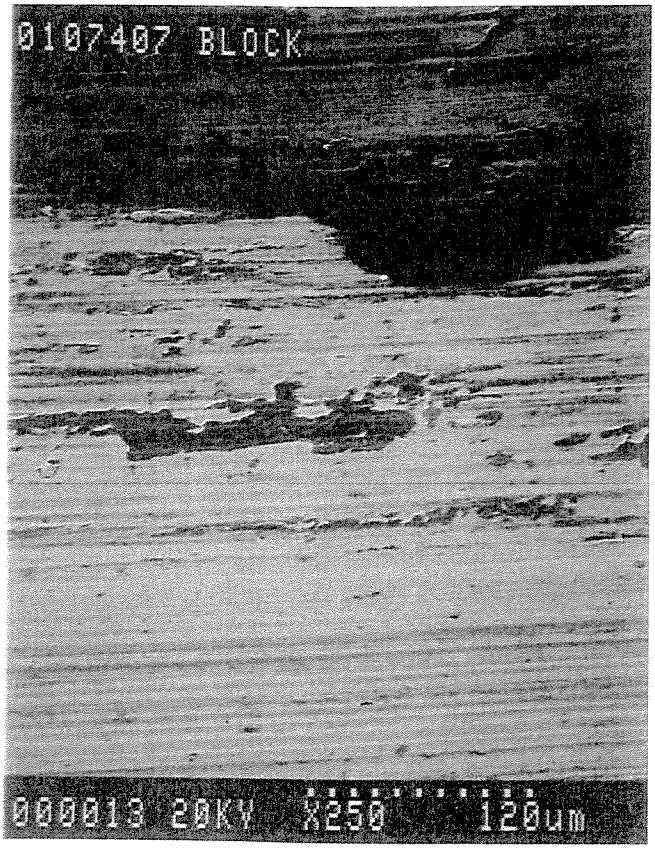
0.000 VFS = 8192 10.240

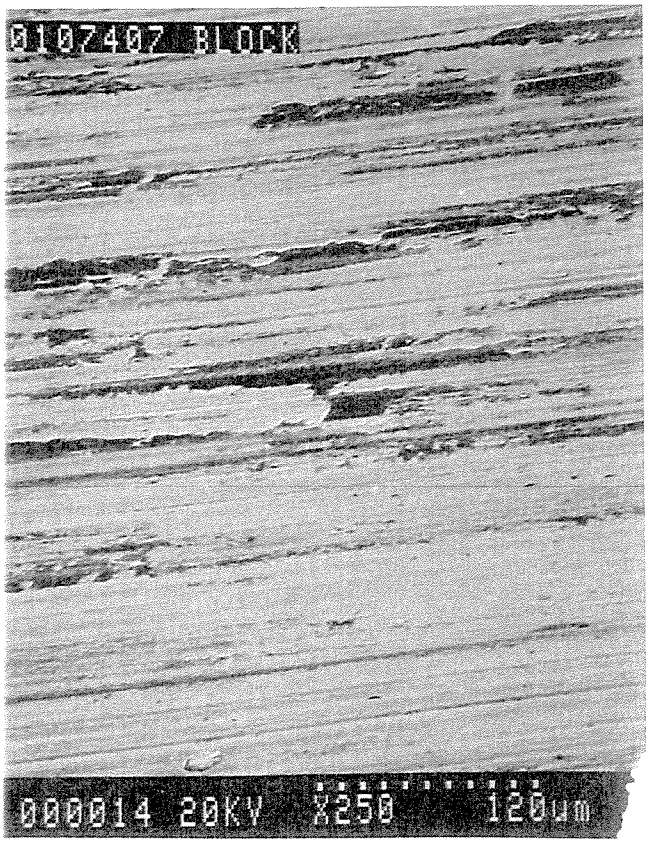
200 0107406 RING SCAR 50X AREA 2

Falex Test 0107407 Block-on-ring
Bronze block

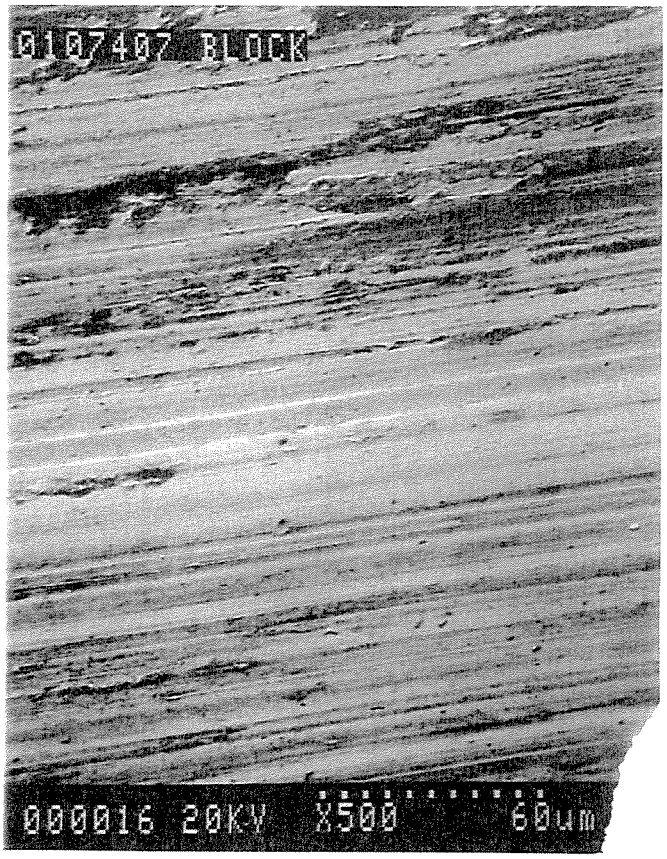


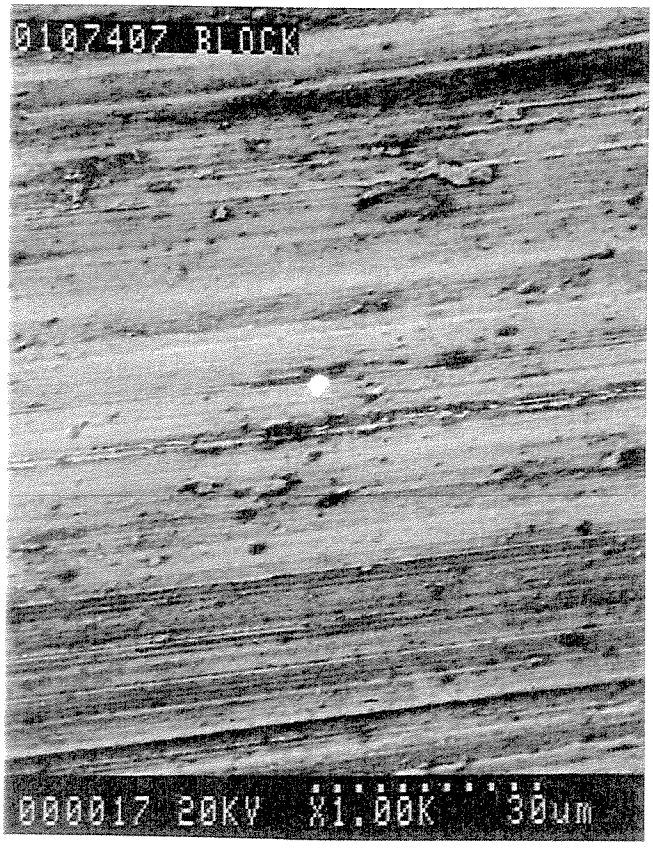
Falex Test 0107407 Block-on-ring
Bronze block

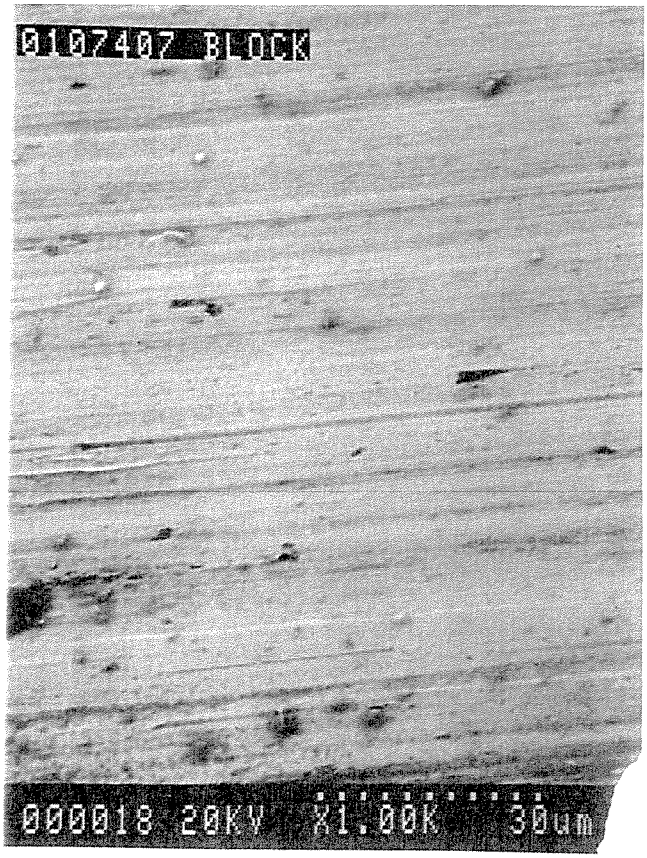




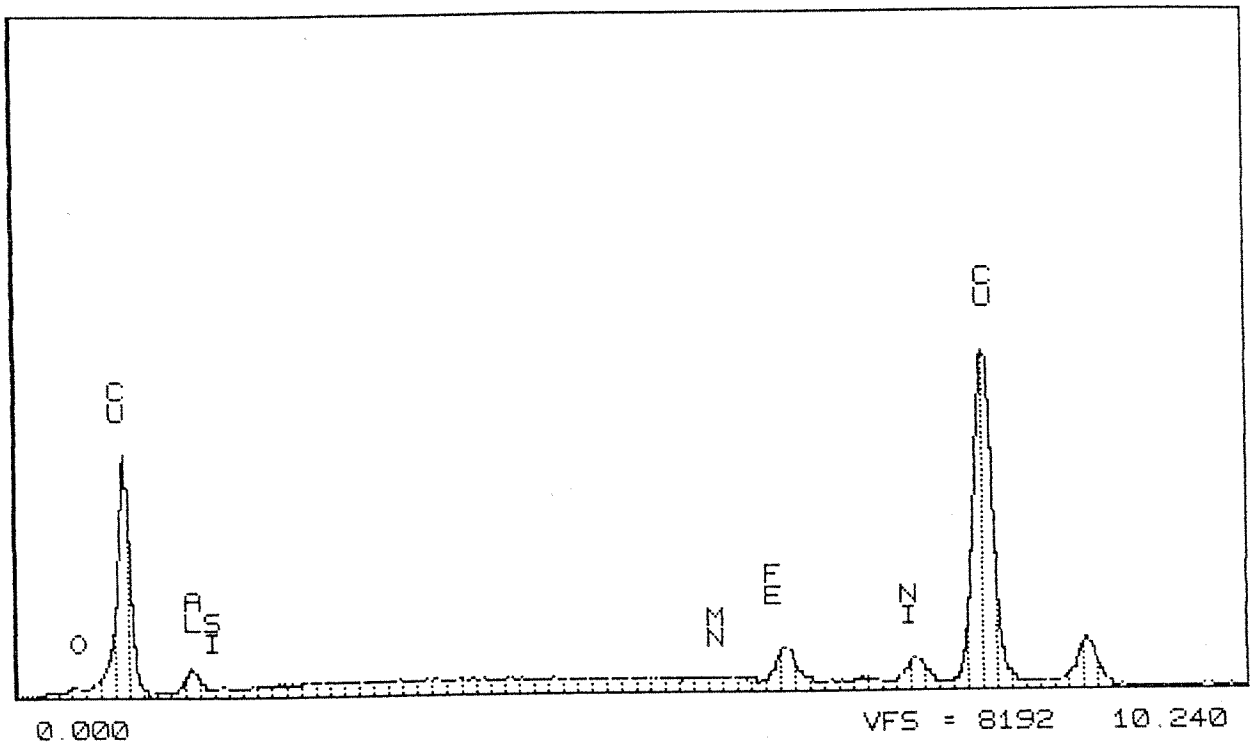
Falex Test 0107407 Block-on-ring
Bronze block

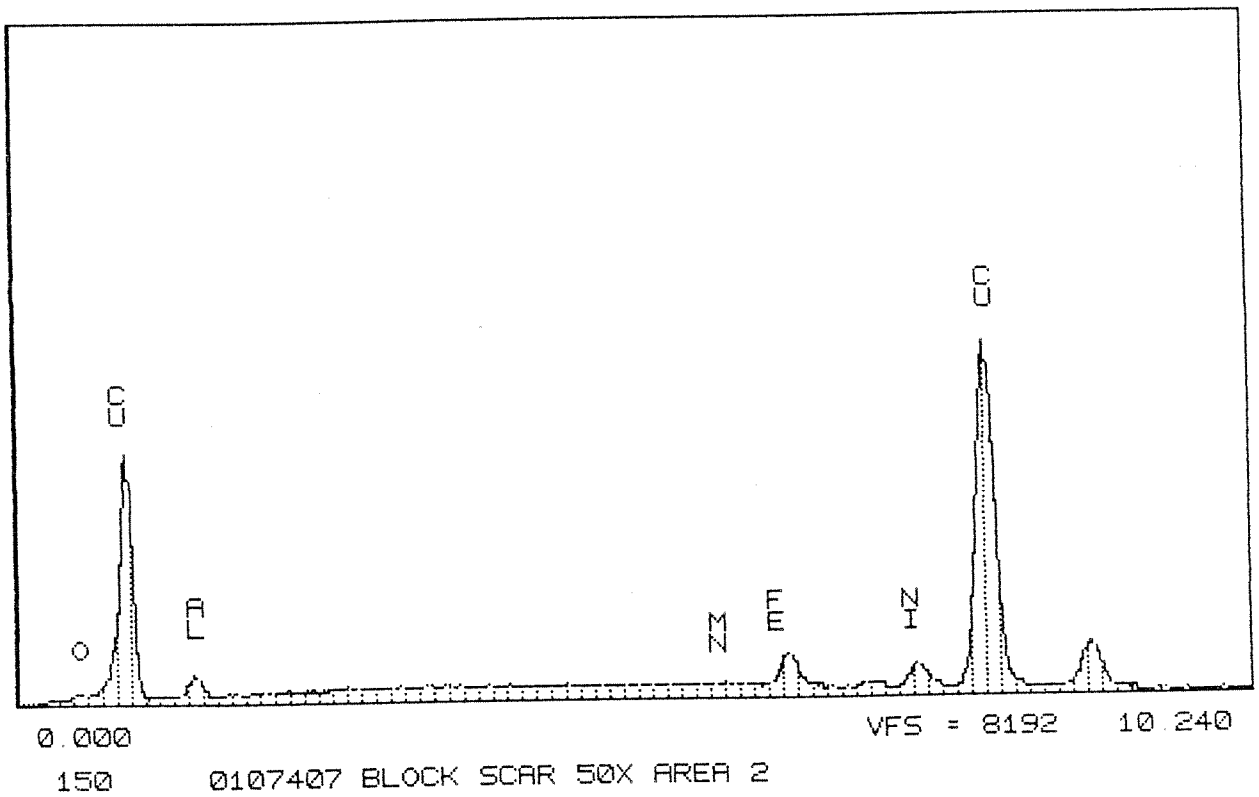




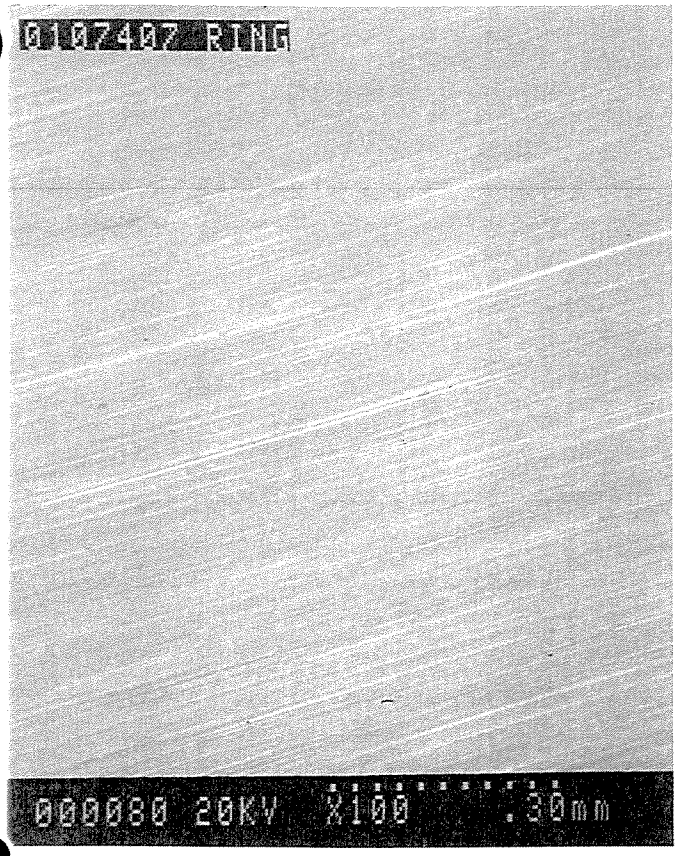


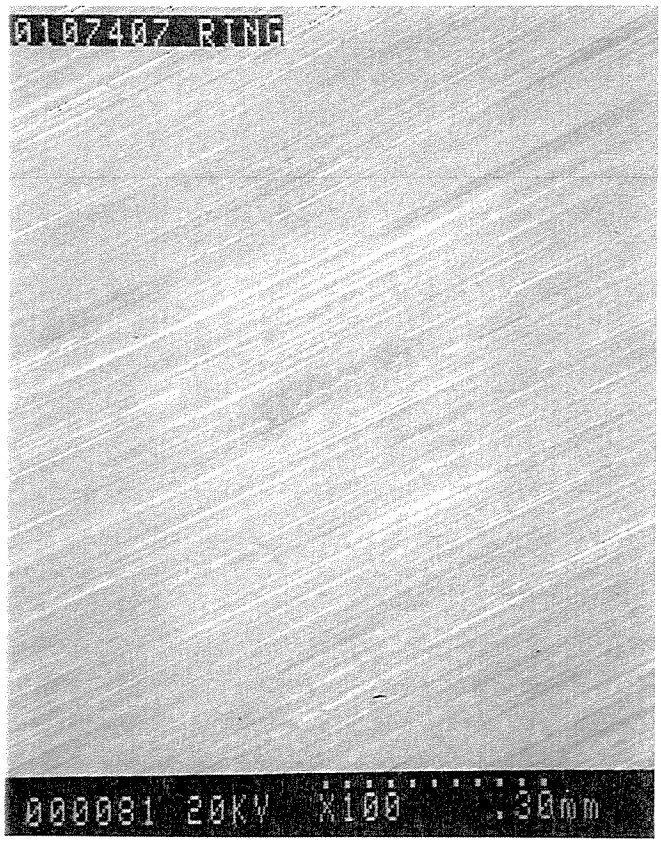
Falex Test 0107407 Block-on-ring
Bronze block

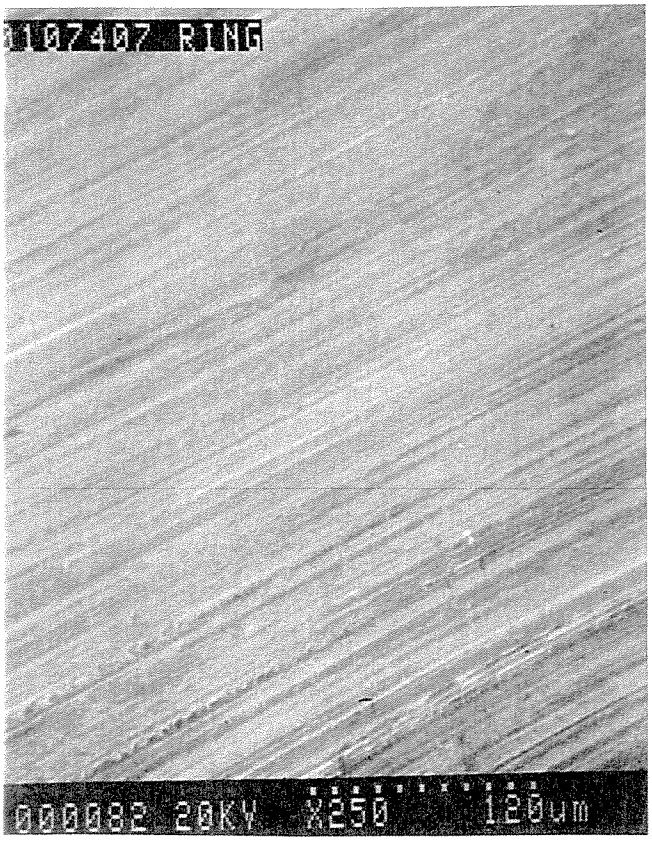


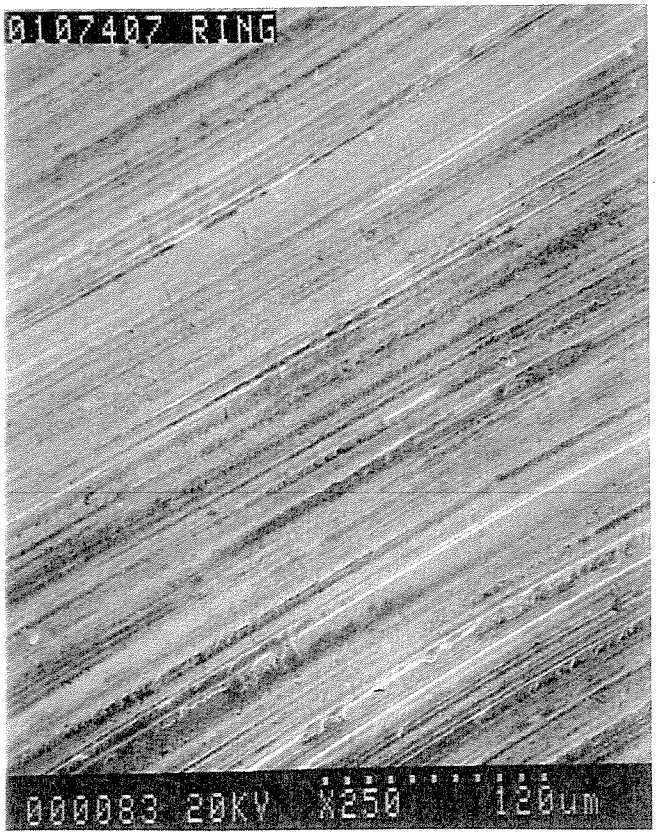


Falex Test 0107407 Block-on-ring
Black iron ring

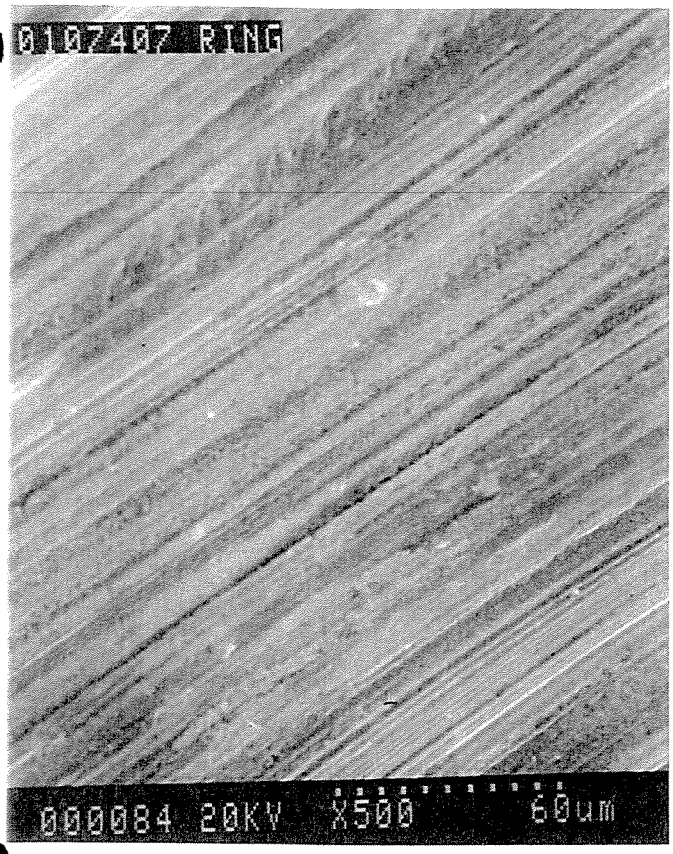


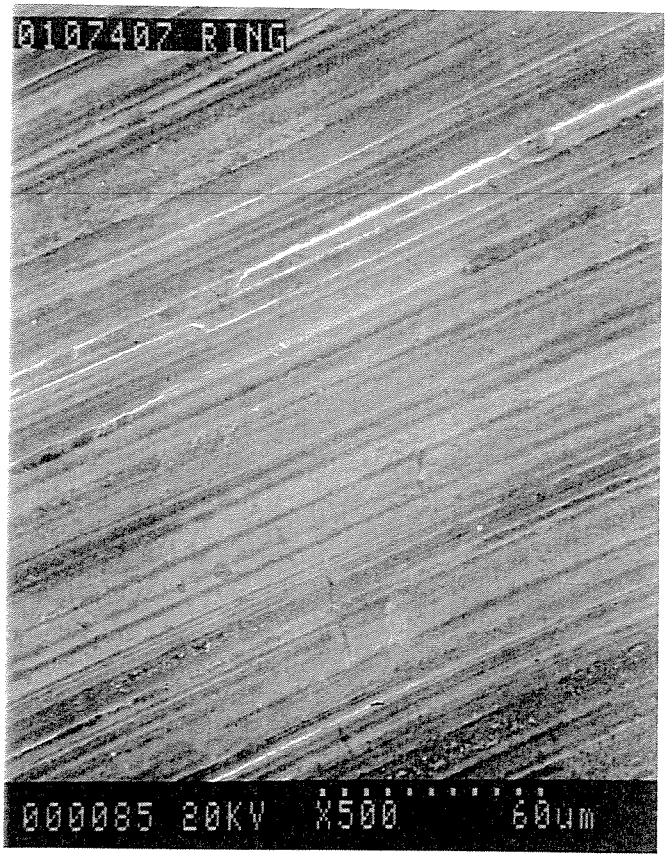


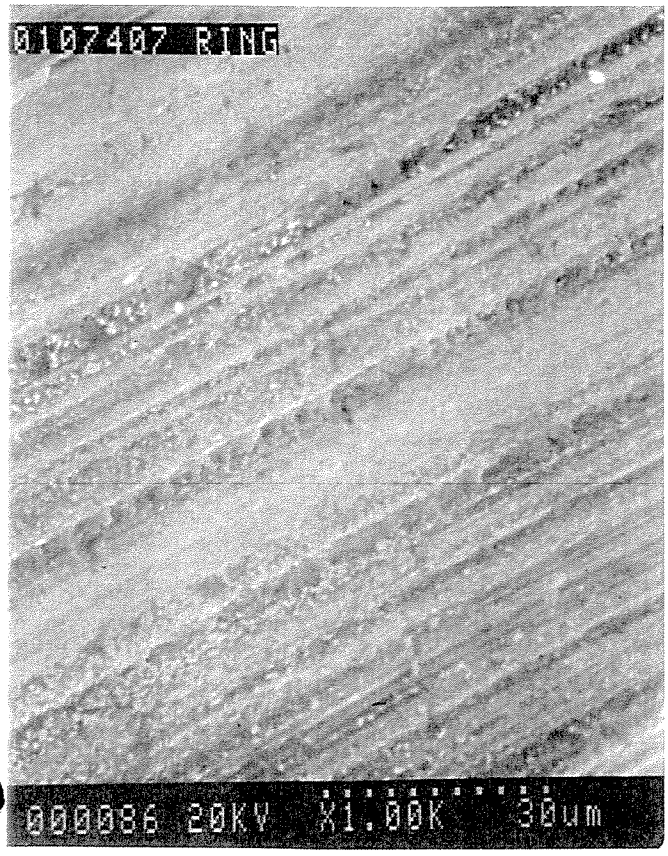


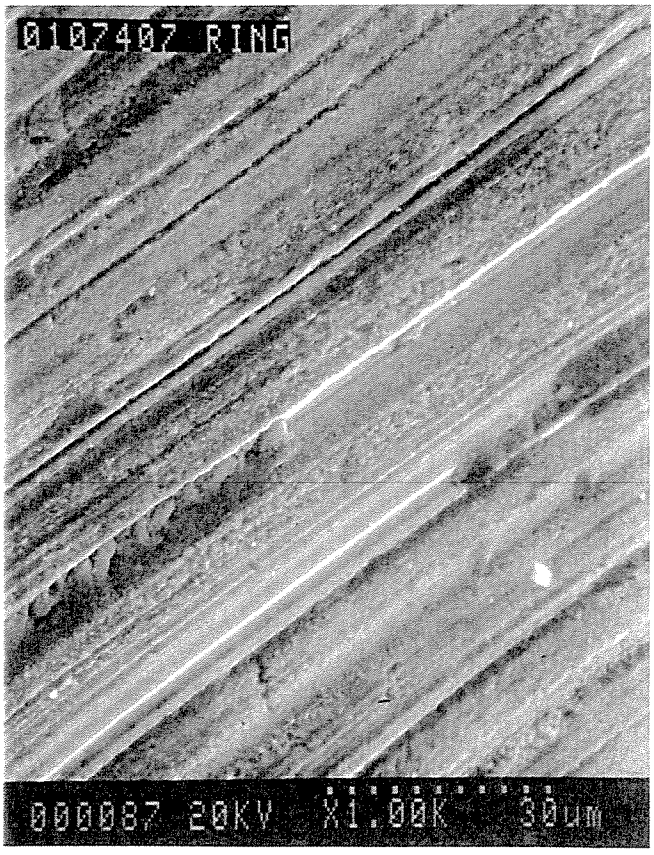


Falex Test 0107407 Block-on-ring
Black iron ring

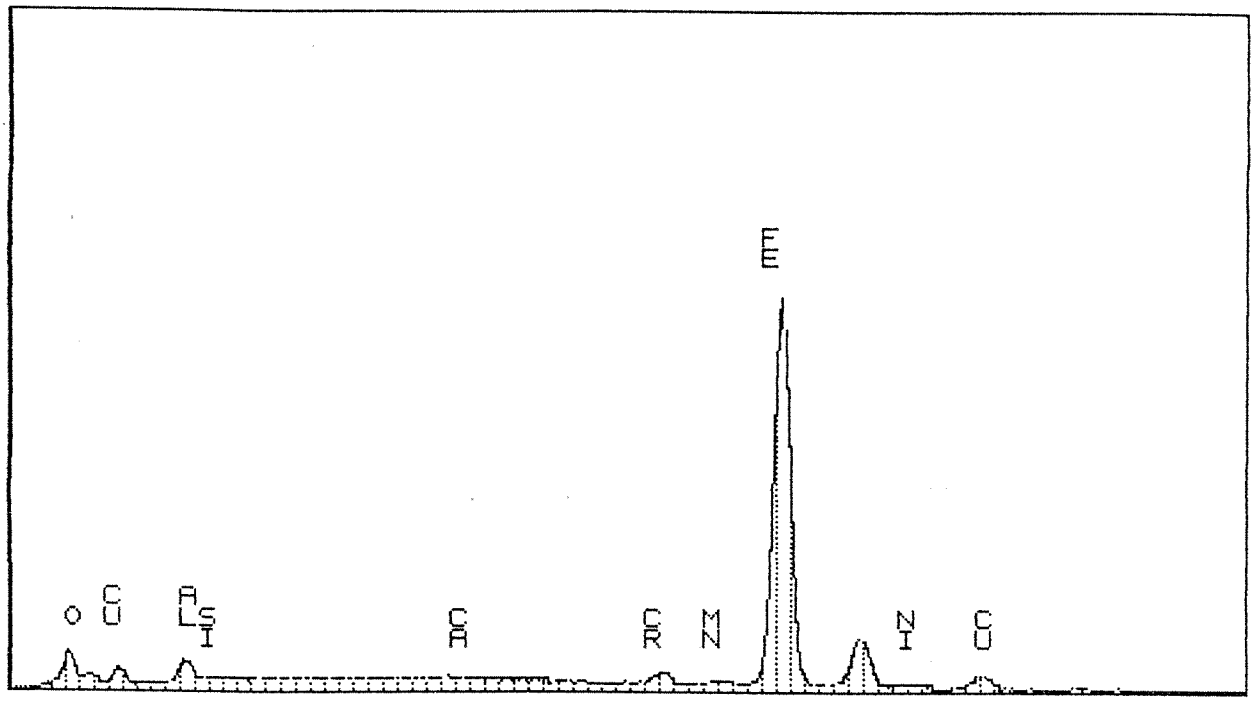


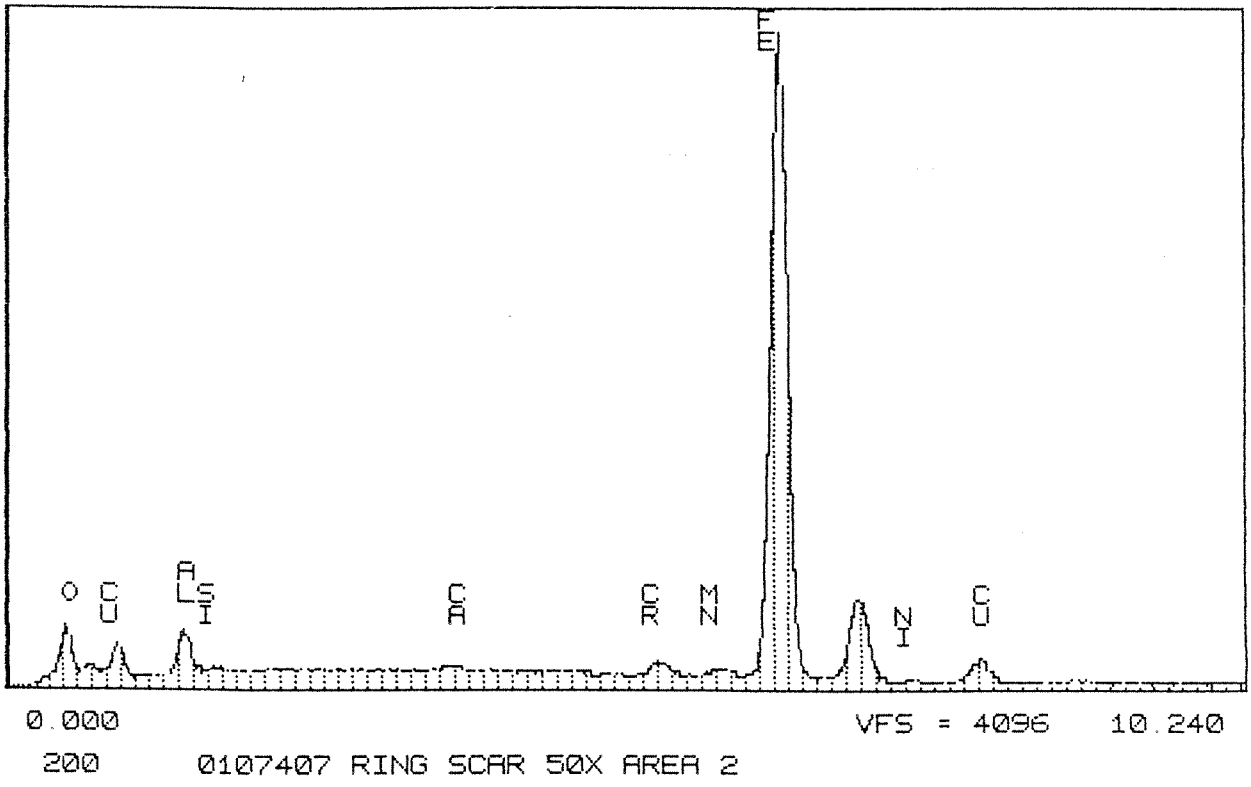




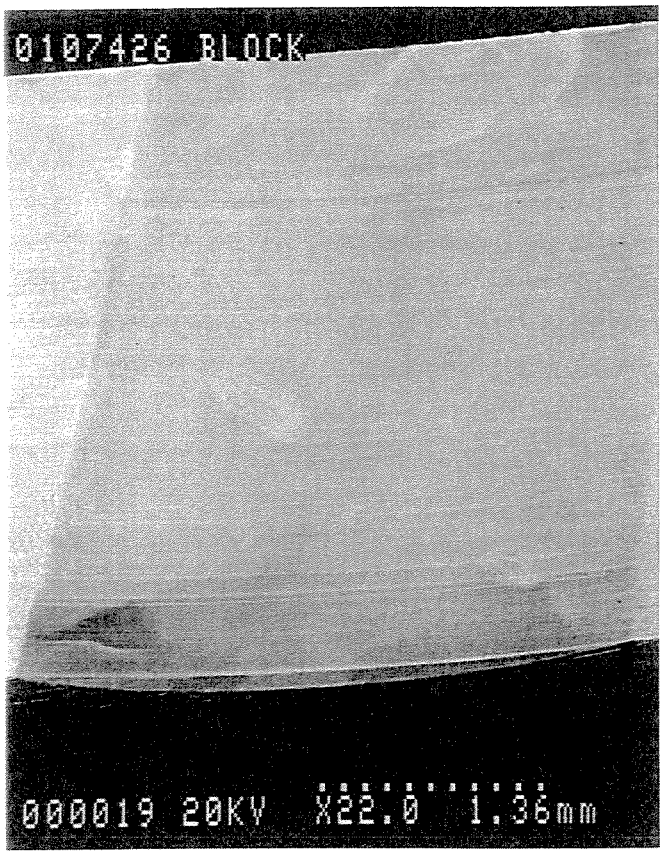


Falex Test 0107407 Block-on-ring
Black iron ring

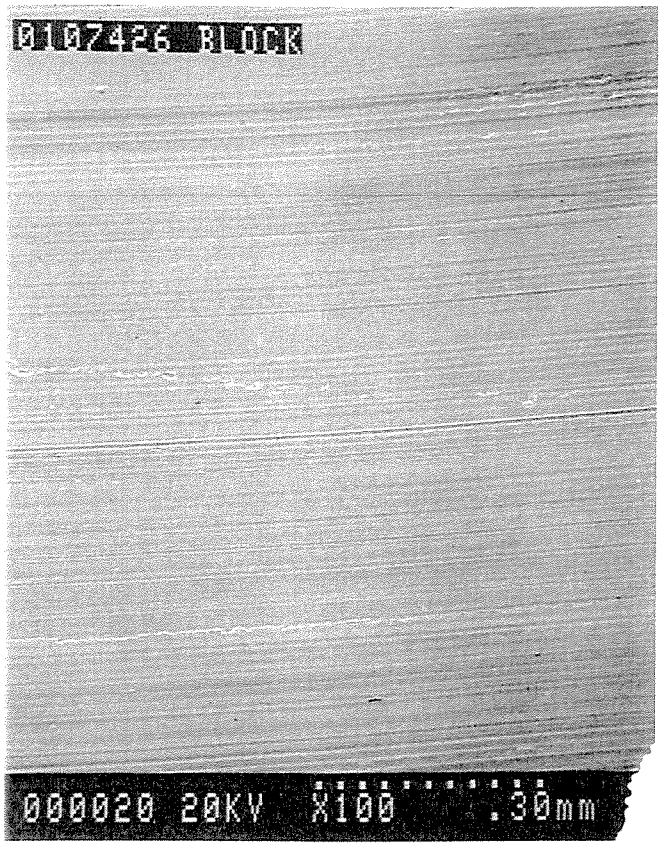


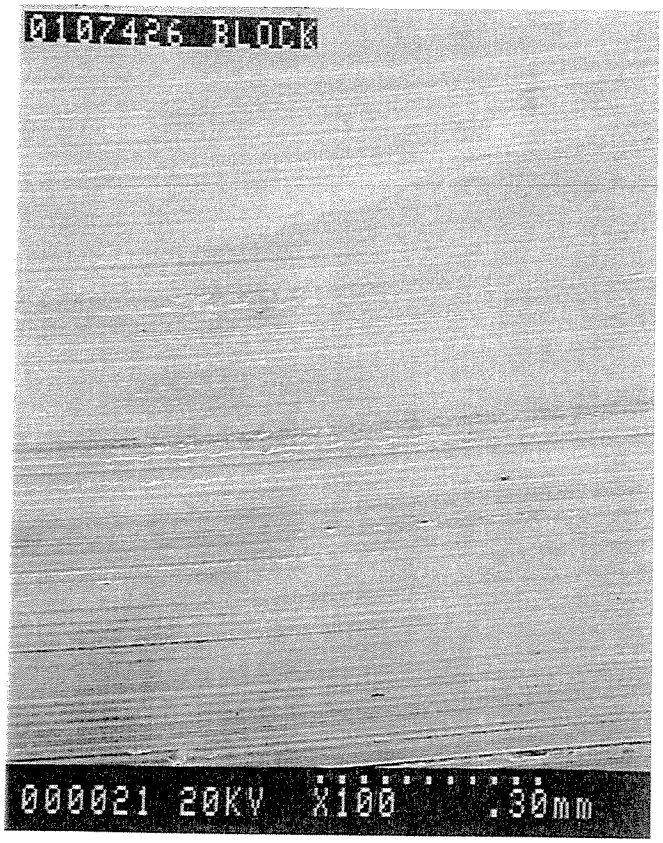


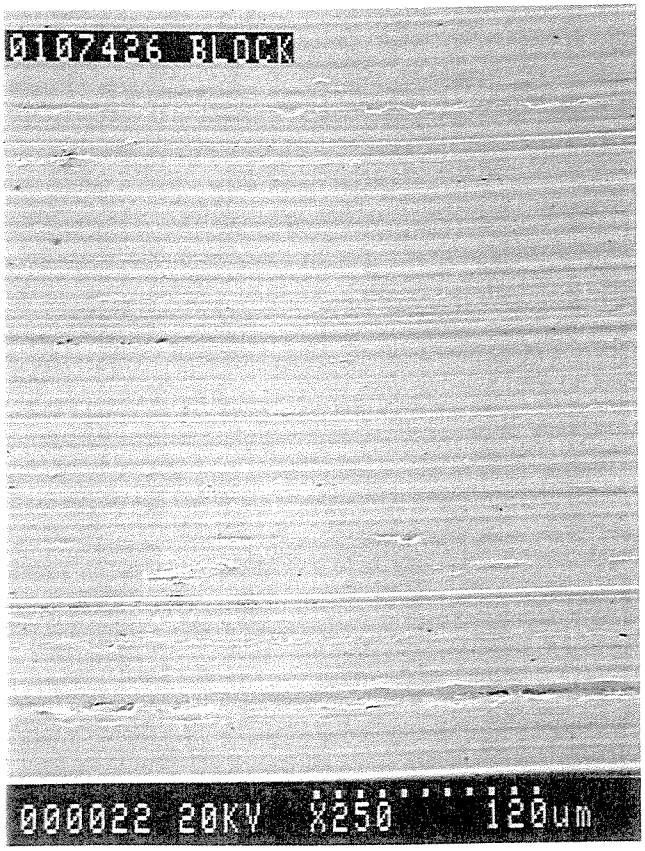
Falex Test 0107426 Block-on-ring
Bronze block

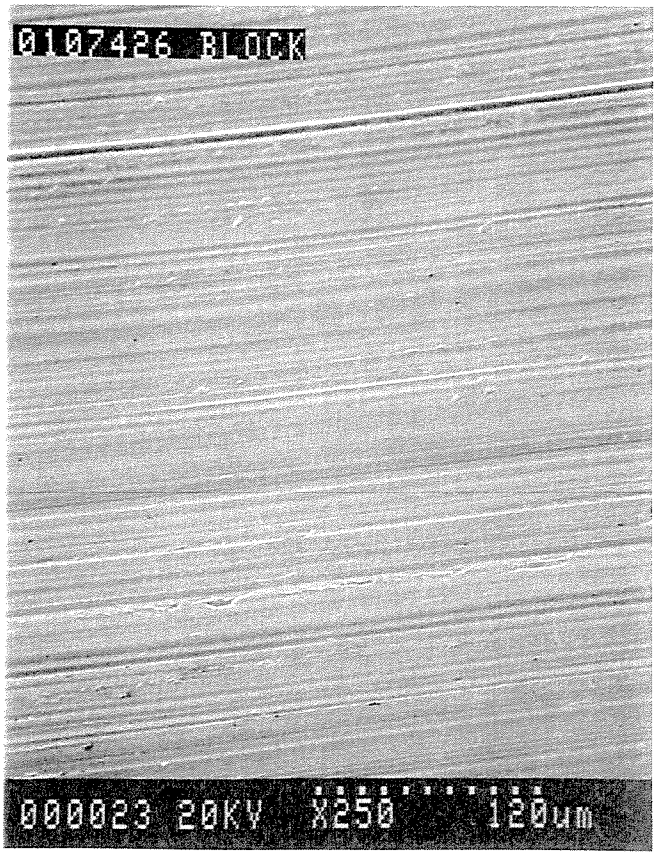


Falex Test 0107426 Block-on-ring
Bronze block

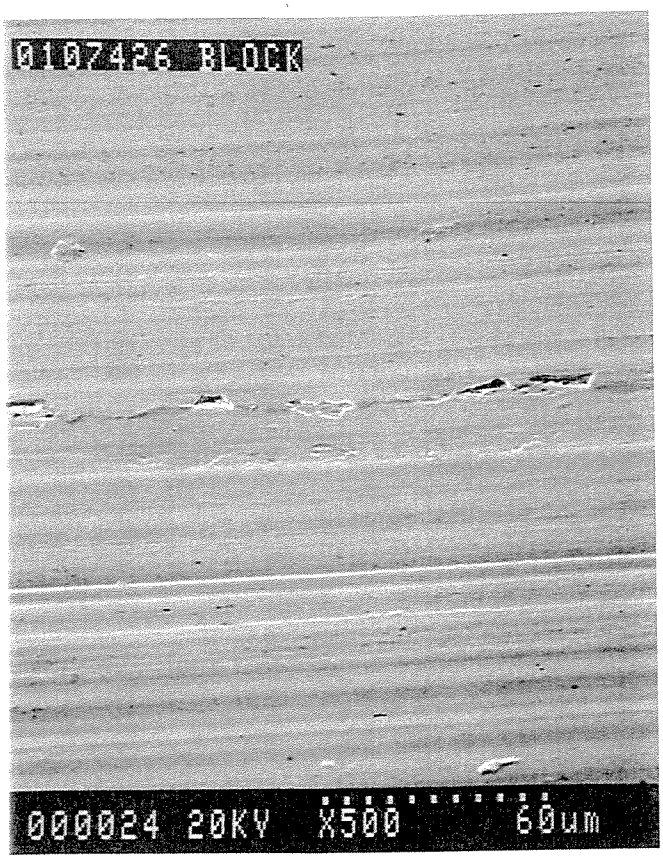


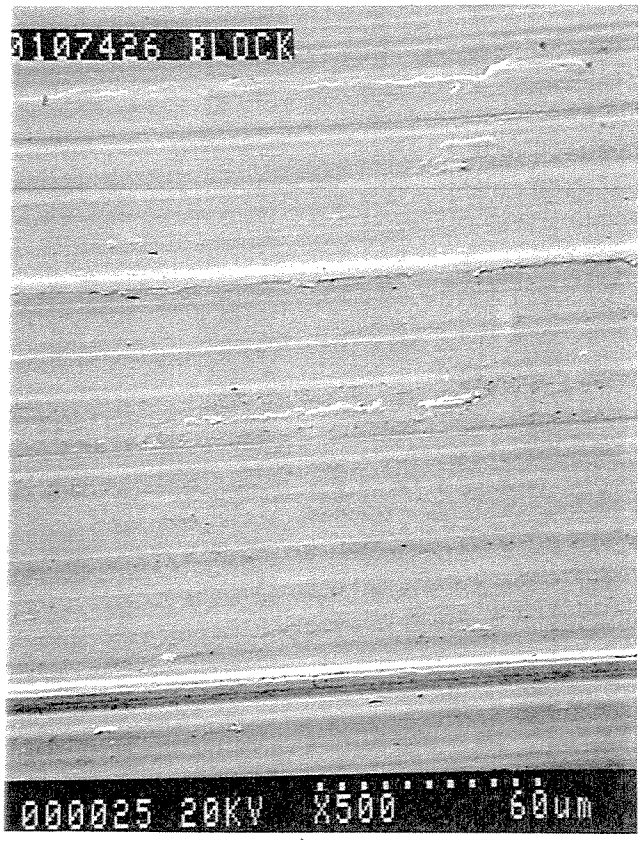


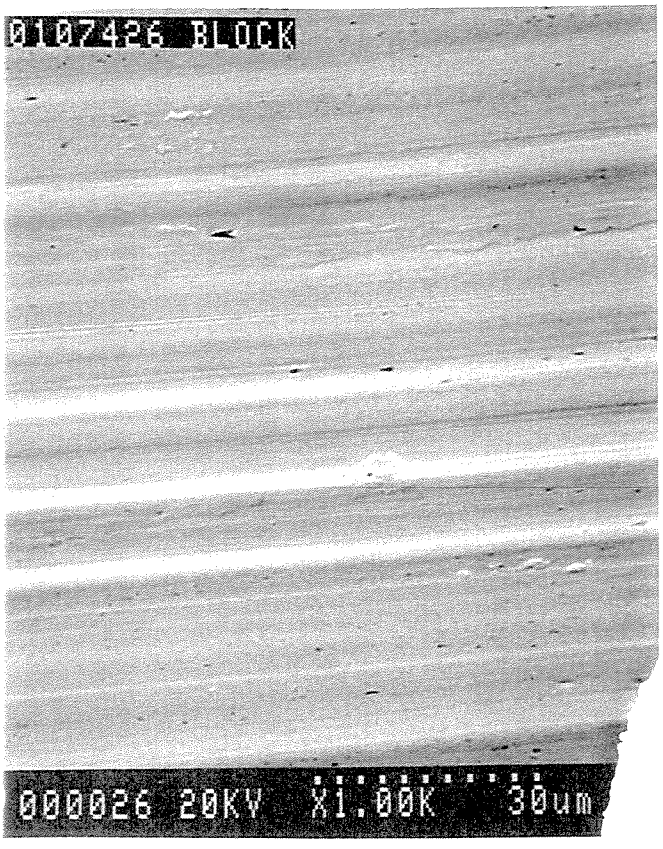


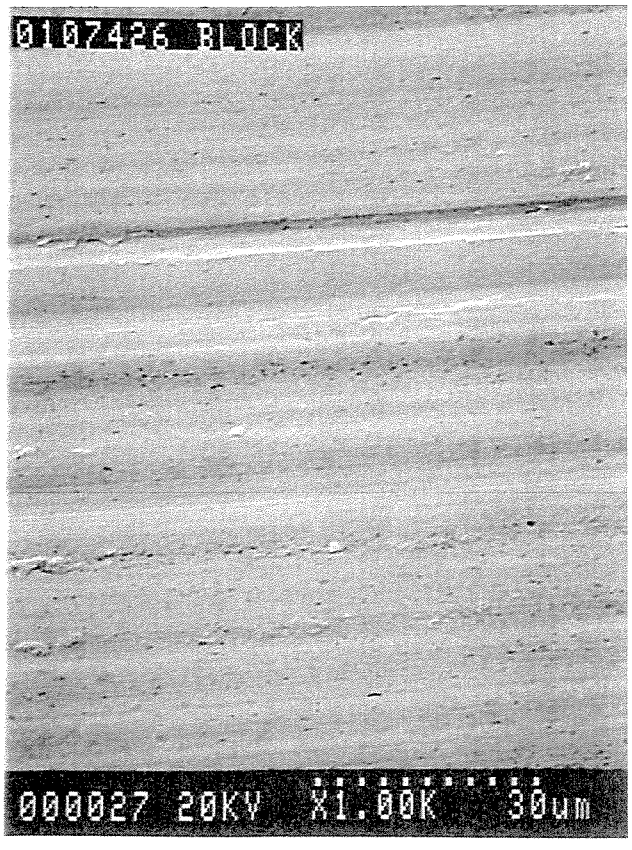


Falex Test 0107426 Block-on-ring
Bronze block

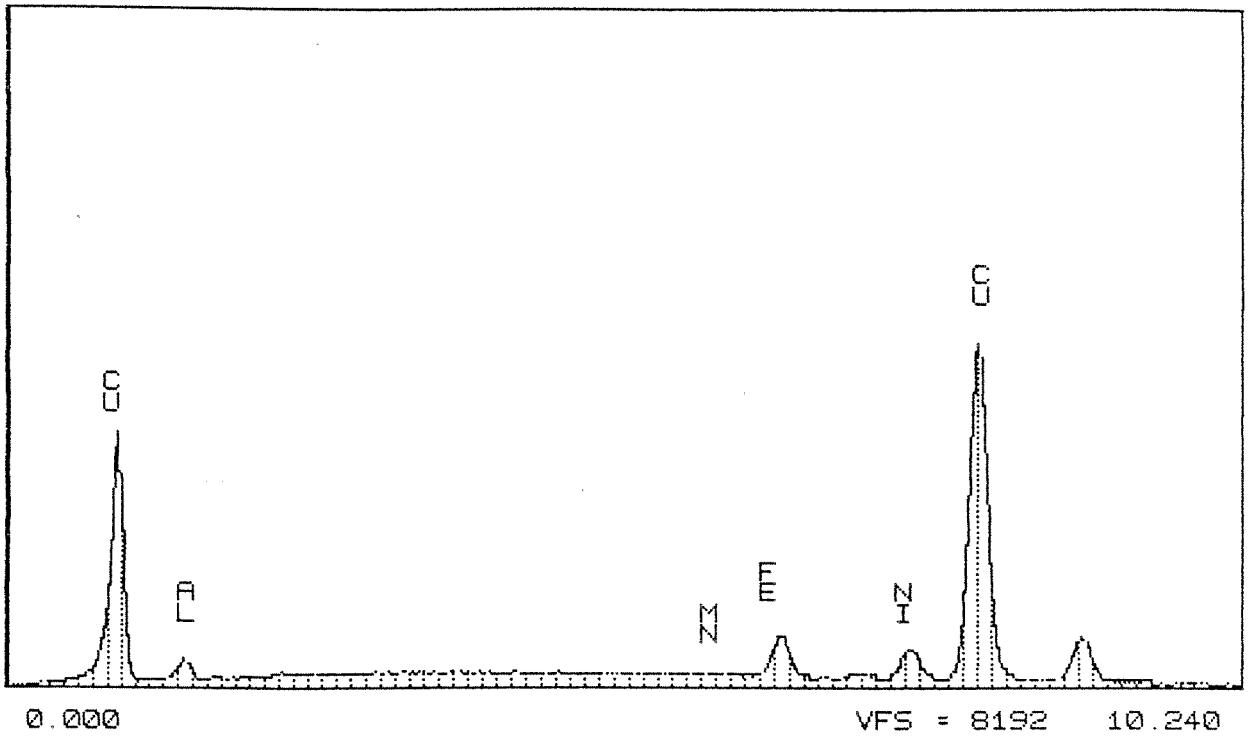


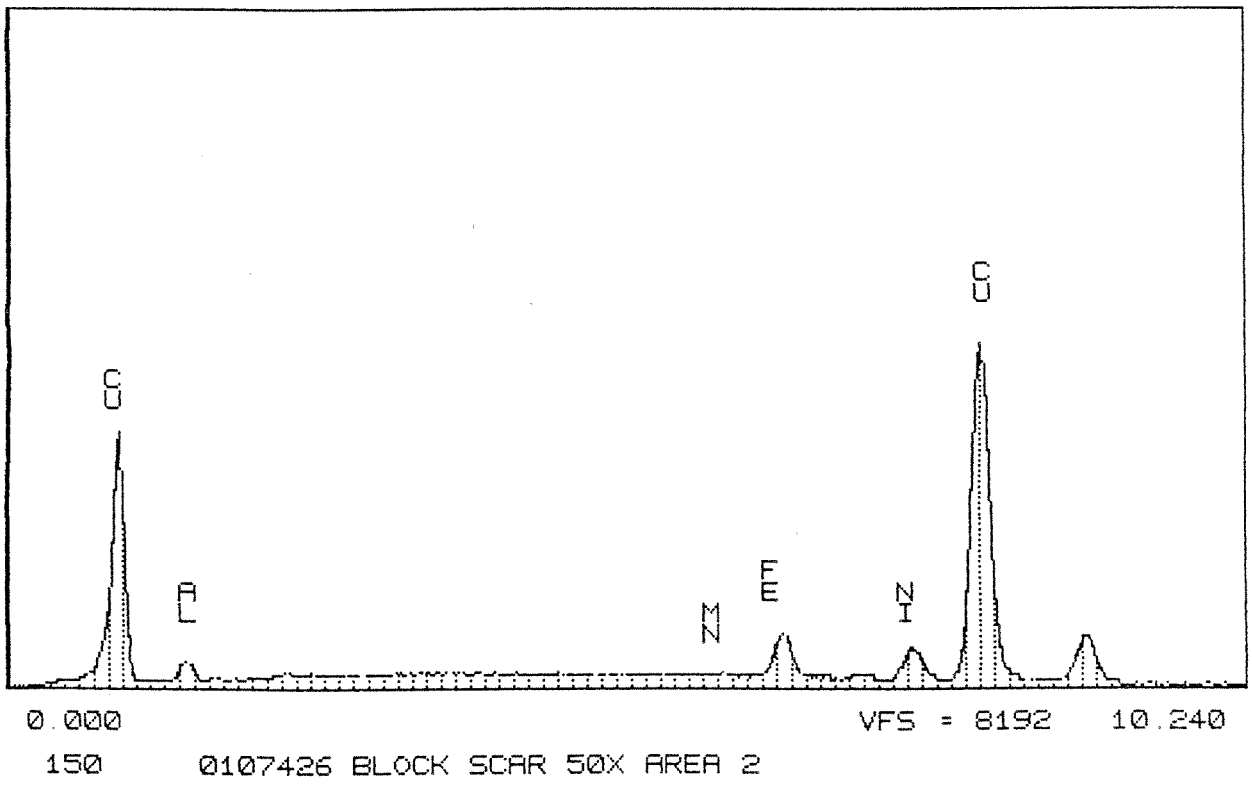




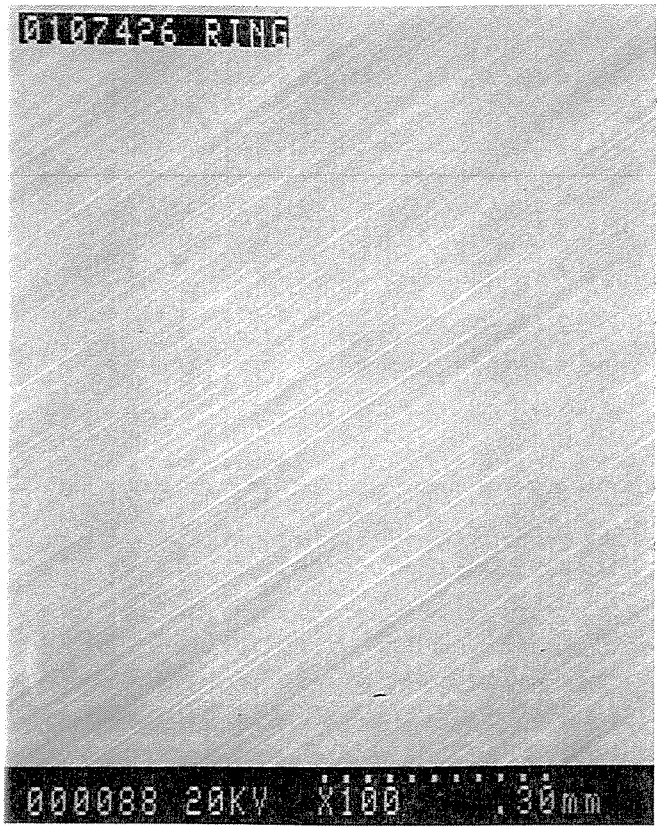


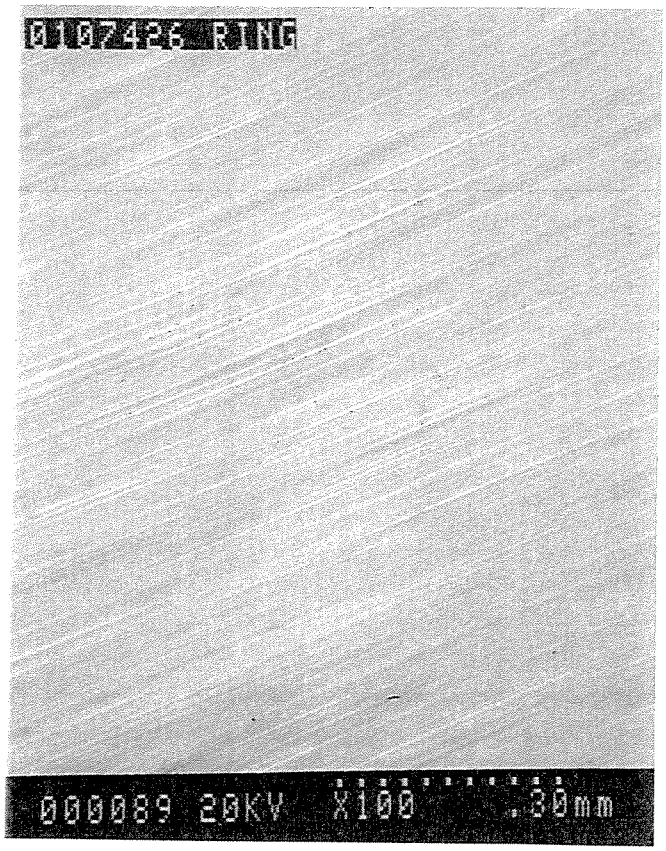
Falex Test 0107426 Block-on-ring
Bronze block

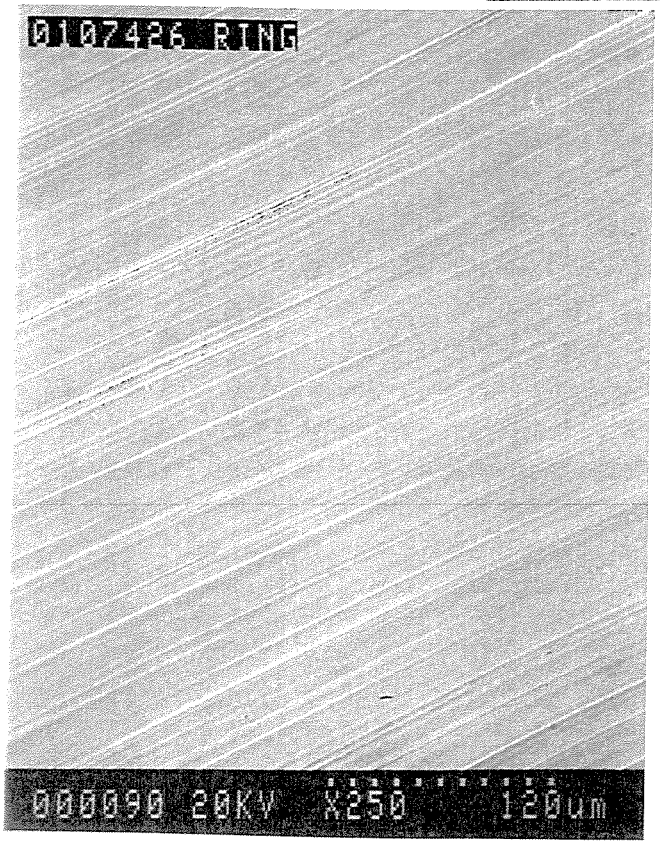


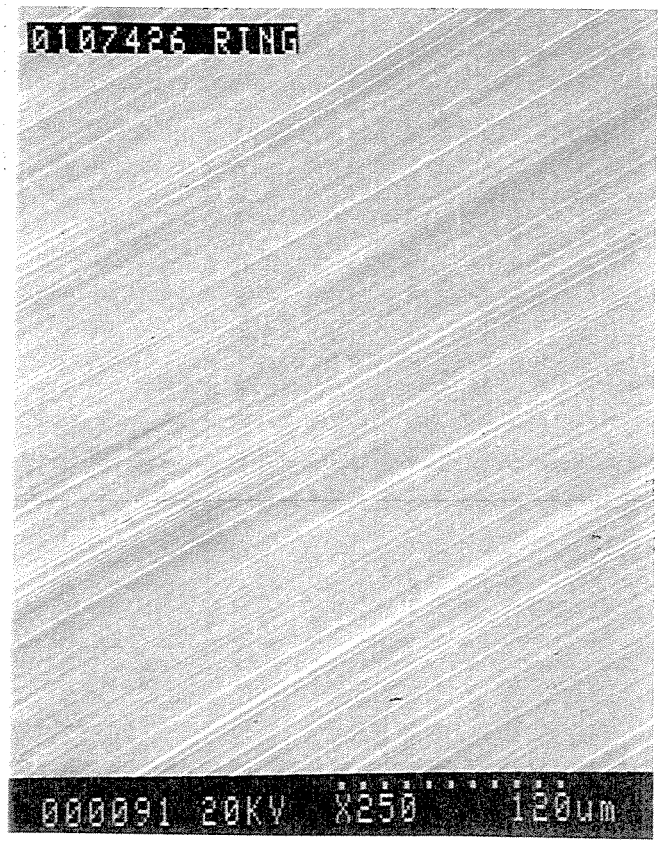


Falex Test 0107426 Block-on-ring
Black iron ring

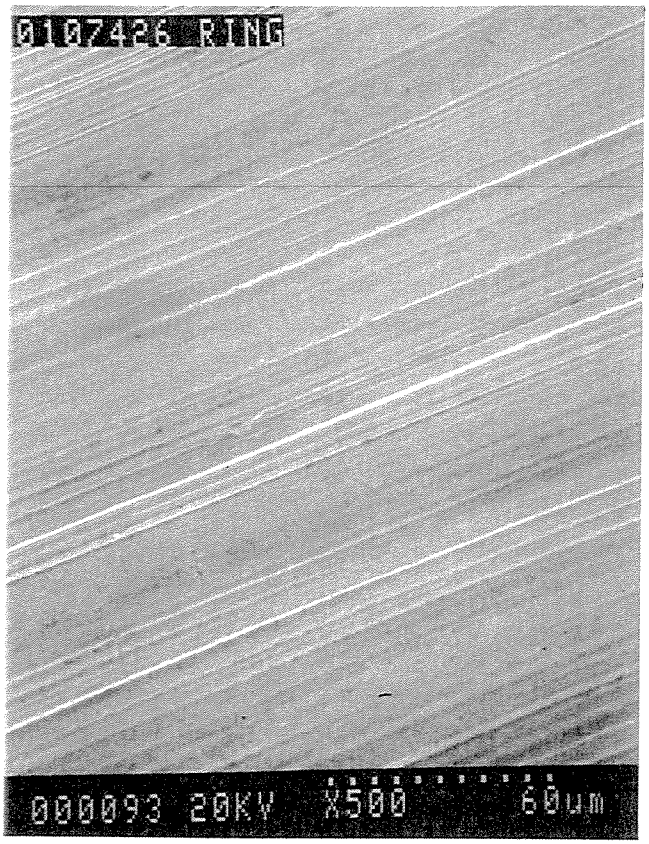


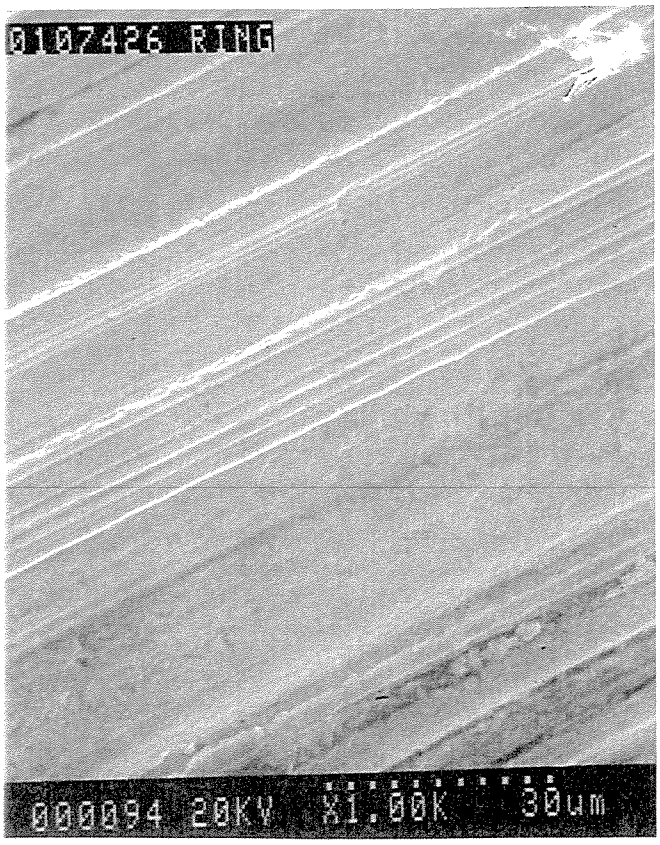


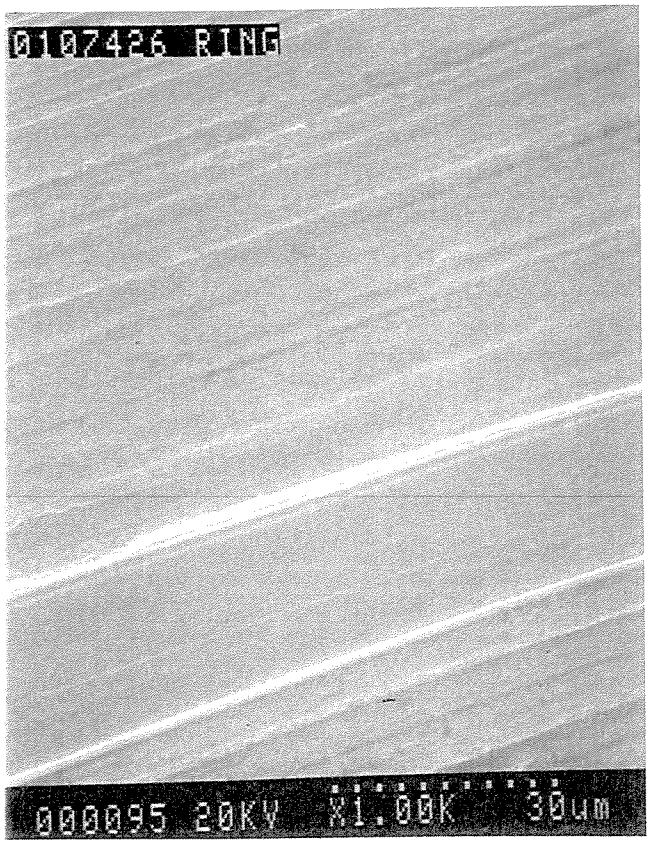




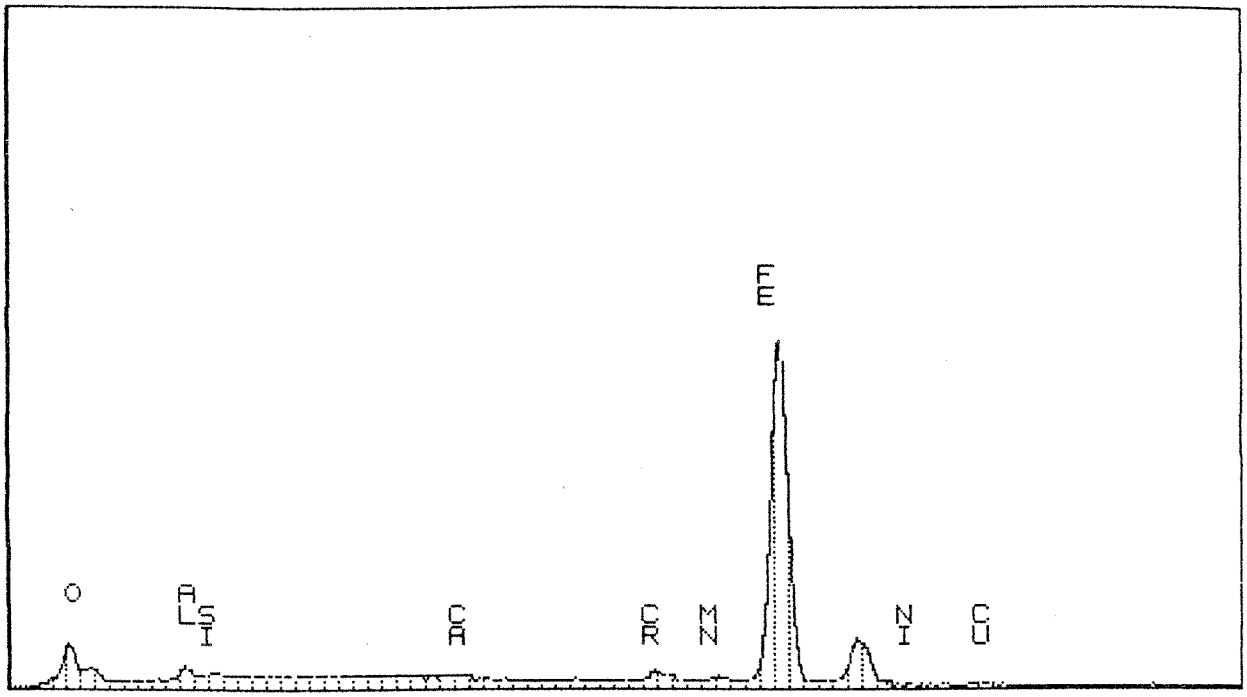
Falex Test 0107426 Block-on-ring
Black iron ring





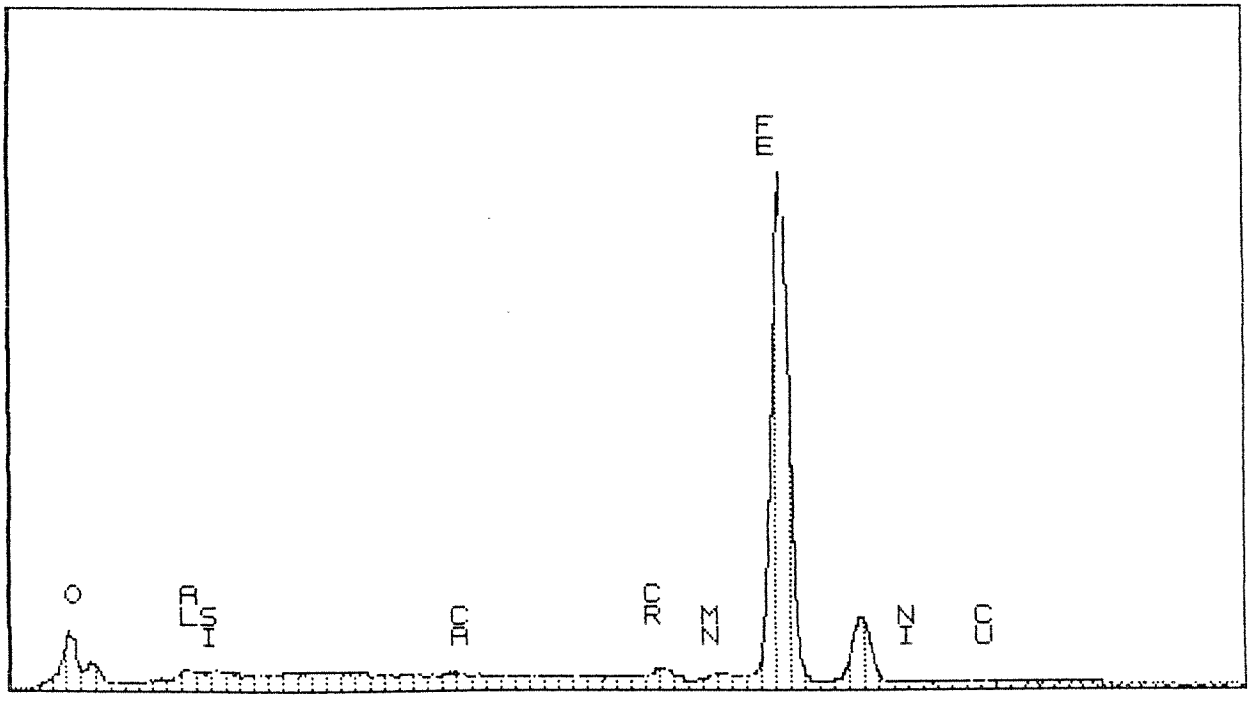


Falex Test 0107426 Block-on-ring
Black iron ring



0.000 VFS = 8192 10.240

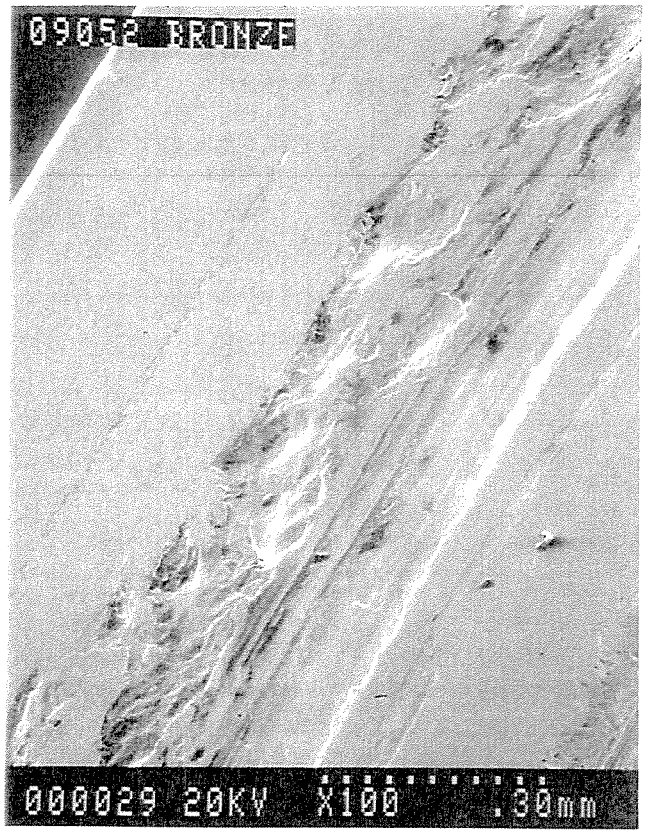
200 0107426 RING SCAR 50X AREA 1



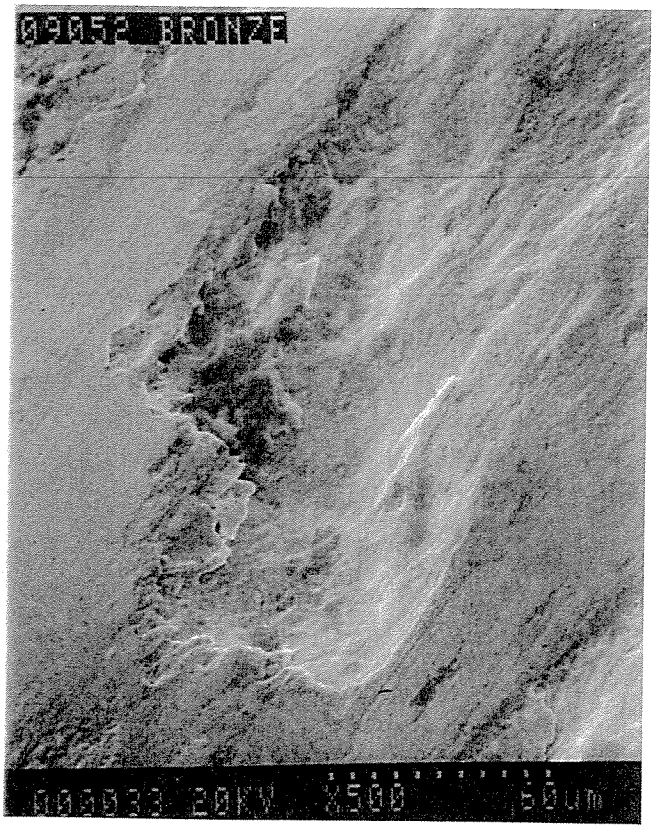
0.000 VFS = 8192 10.240

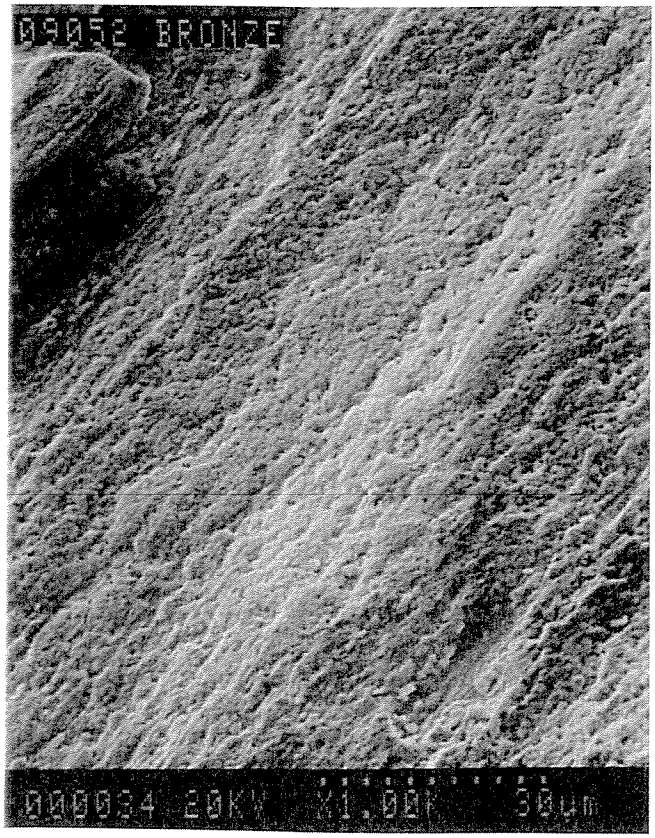
210 0107426 RING SCAR 50X AREA 2

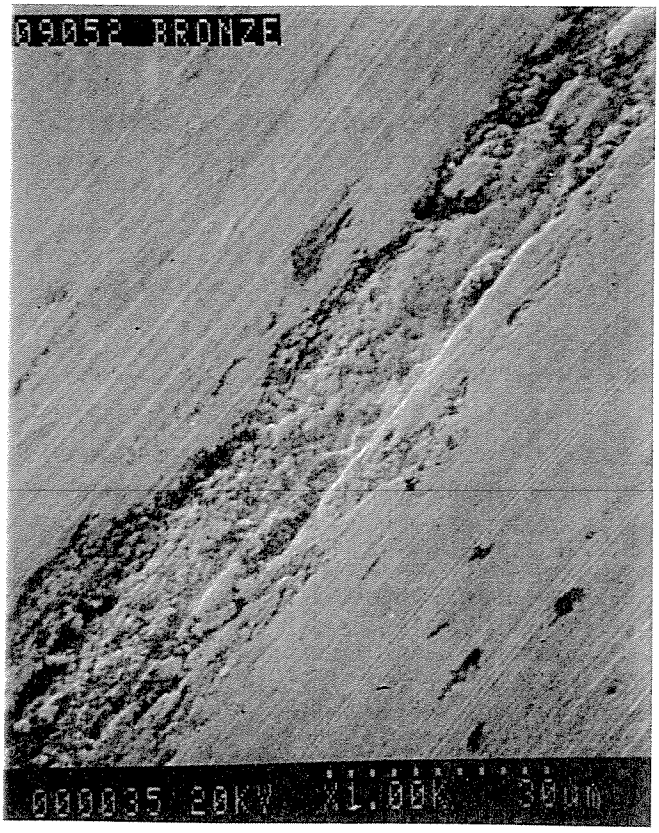
Falex Test 09052 Thrust washer
Bronze rim



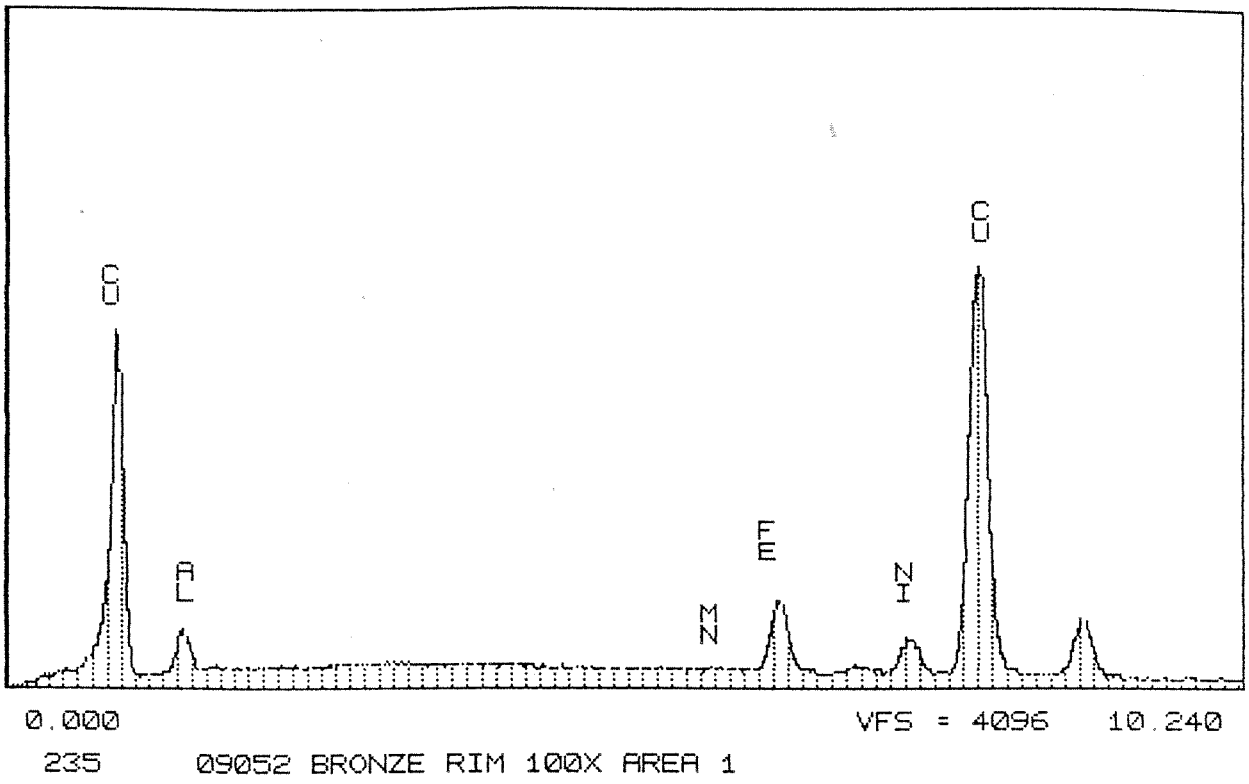
Falex Test 09052 Thrust washer
Bronze rim

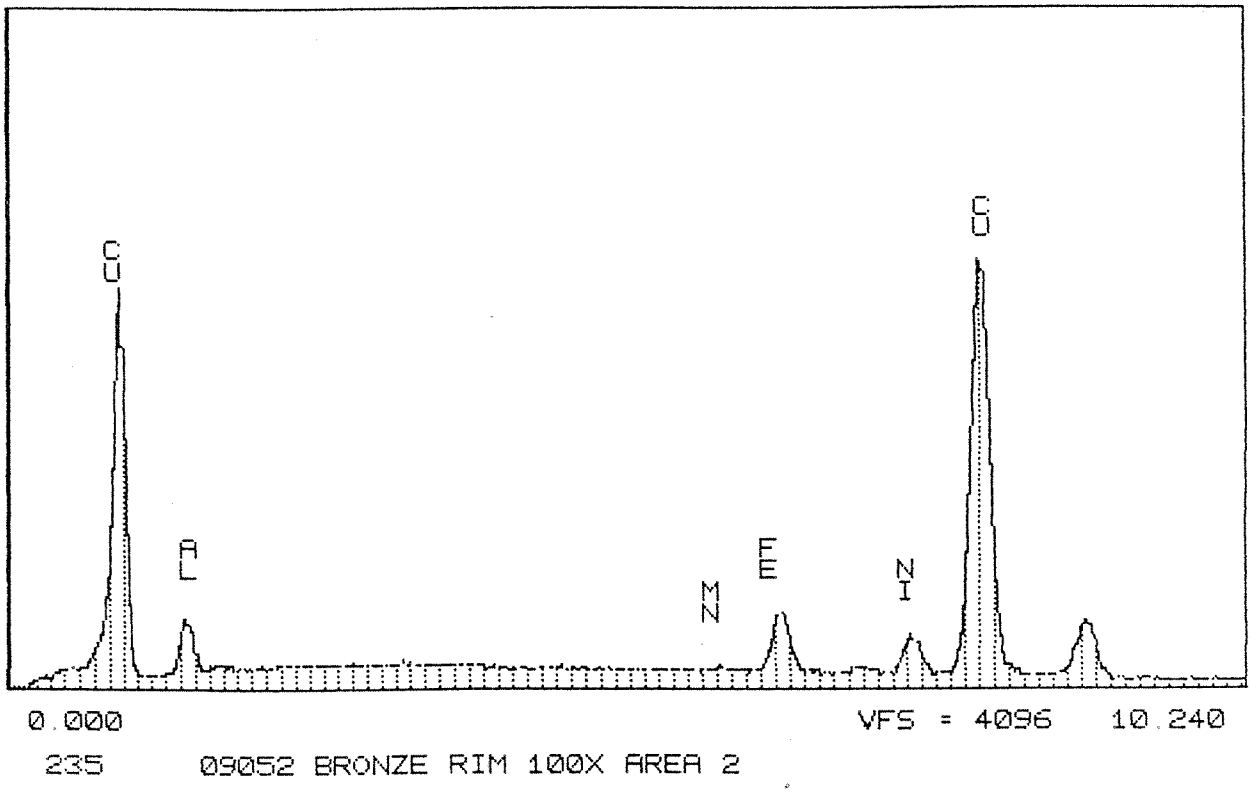






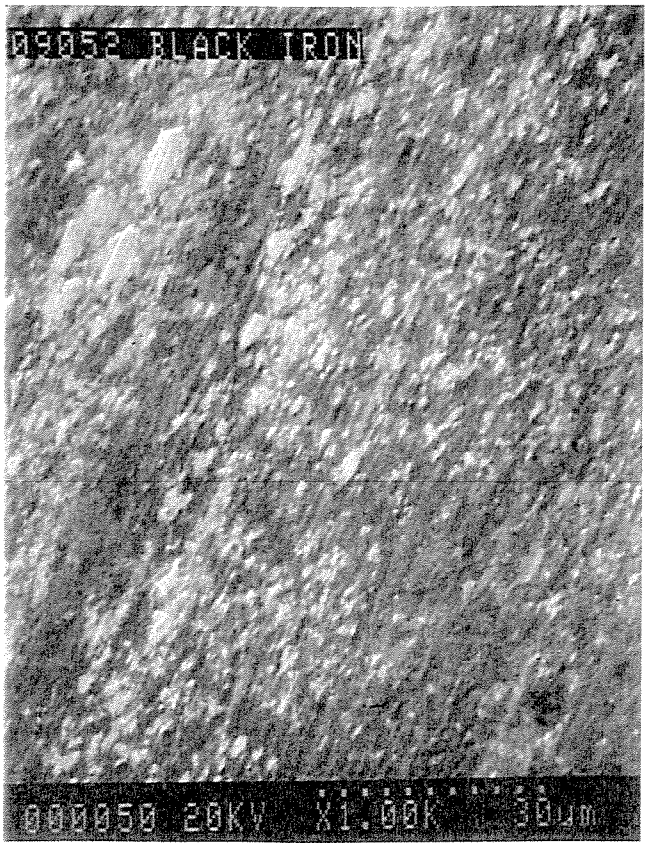
Falex Test 09052 Thrust washer
Bronze rim

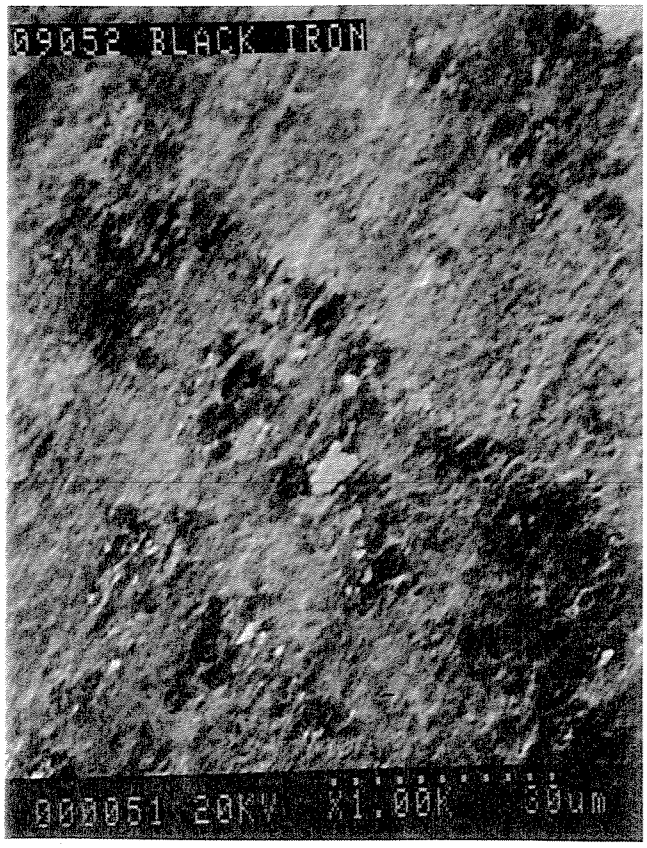




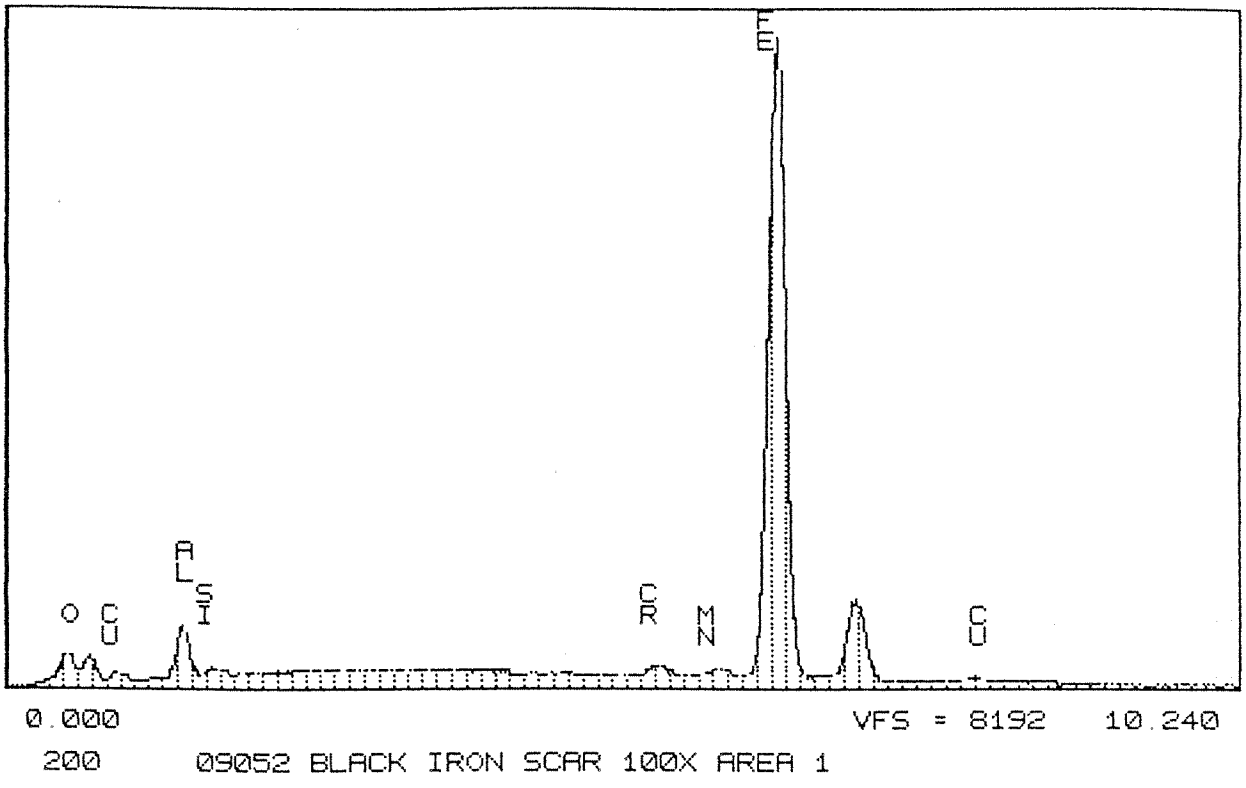
Falex Test 09052 Thrust washer
Black iron washer

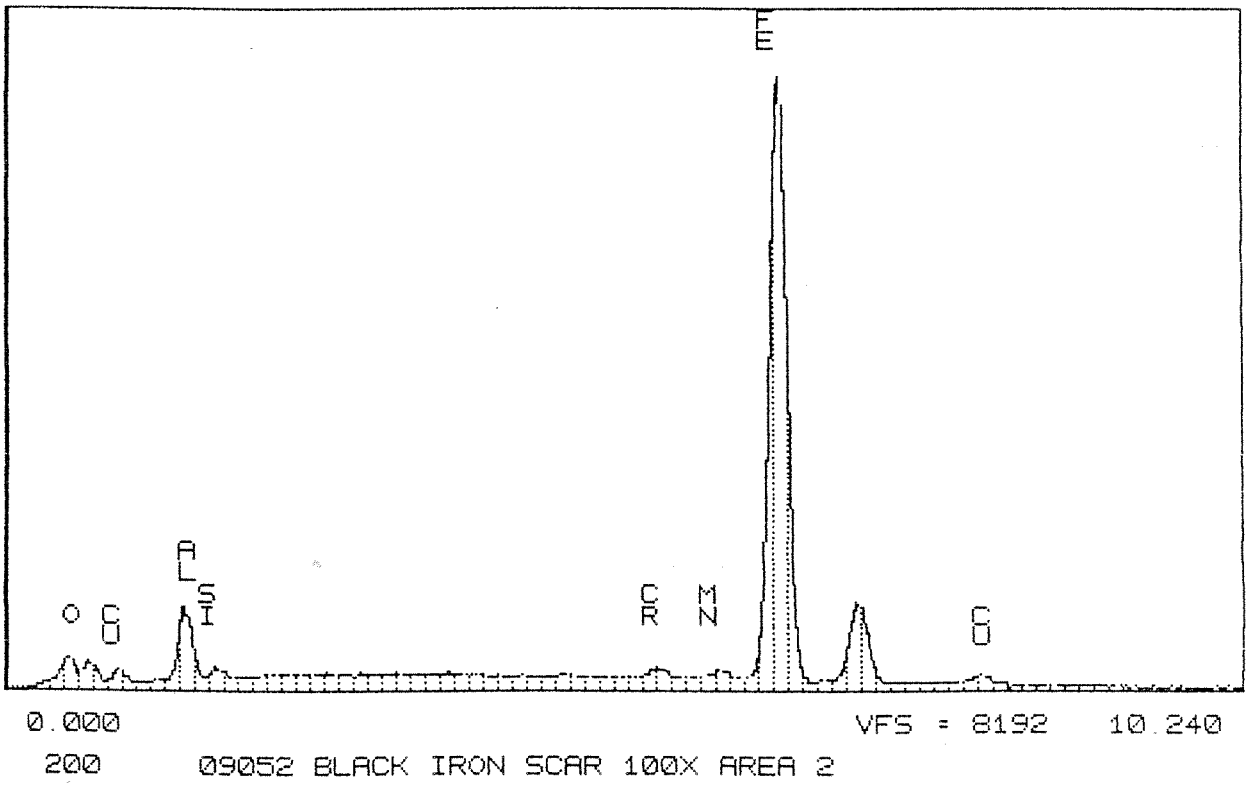
Falex Test 09052 Thrust washer
Black iron washer



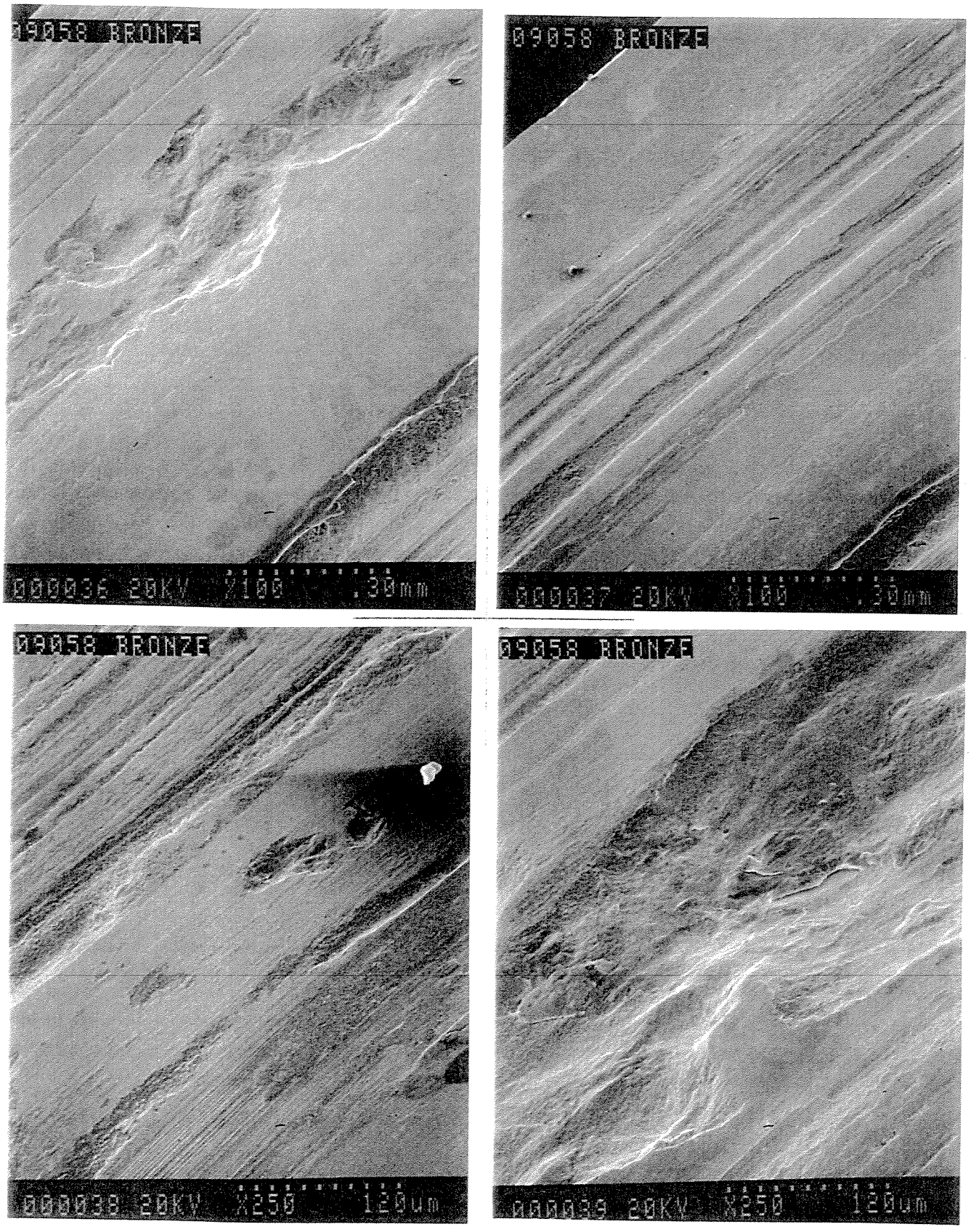


Falex Test 09052 Thrust washer
Black iron washer

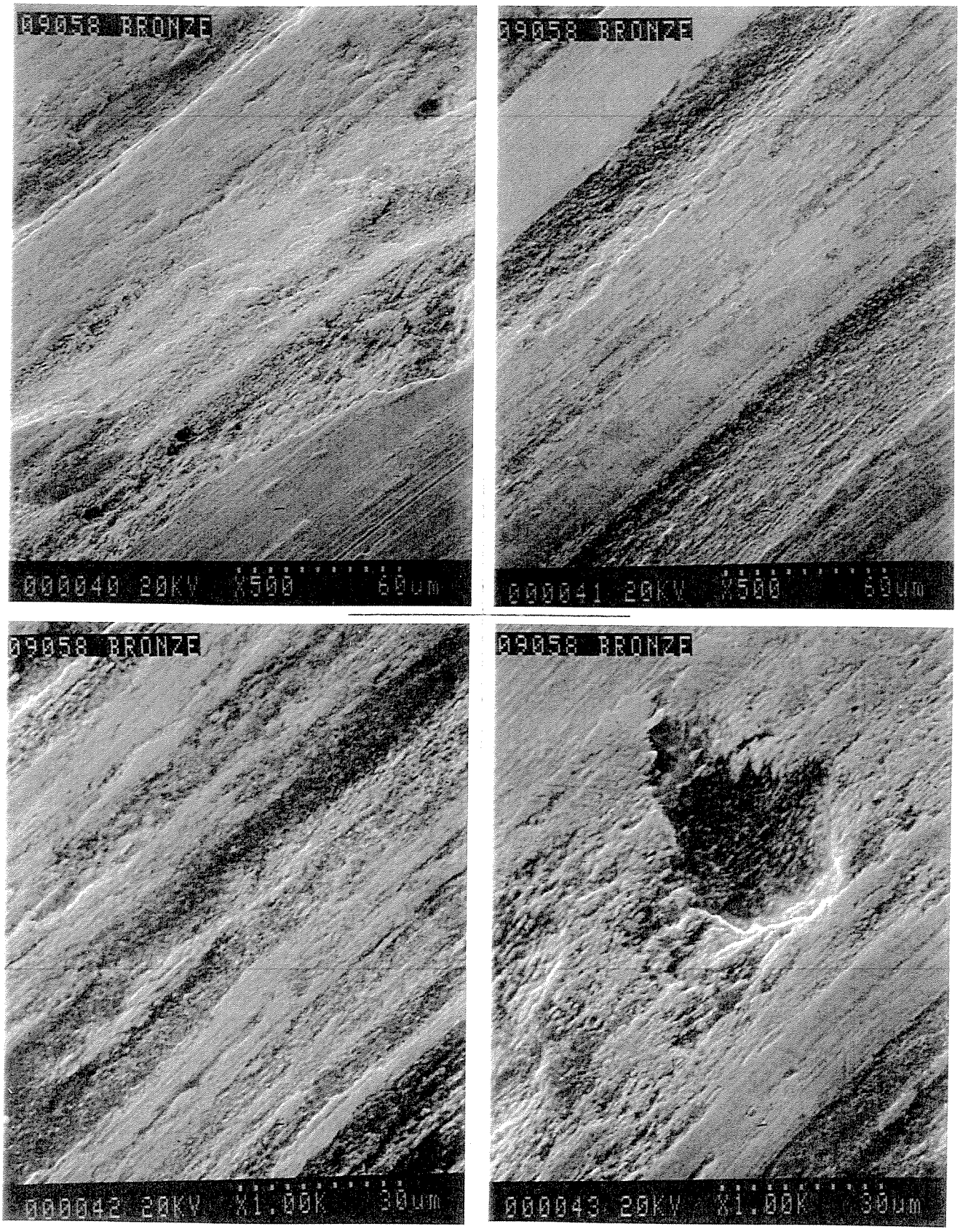




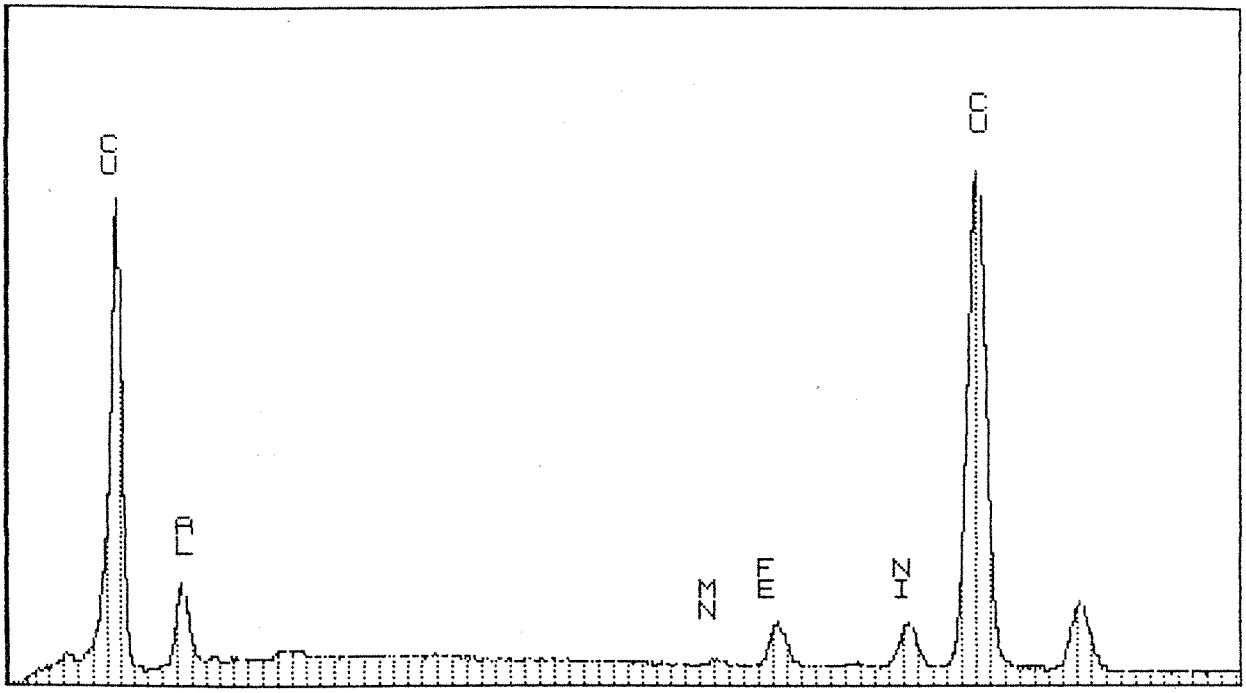
Falex Test 09058 Thrust washer
Bronze rim

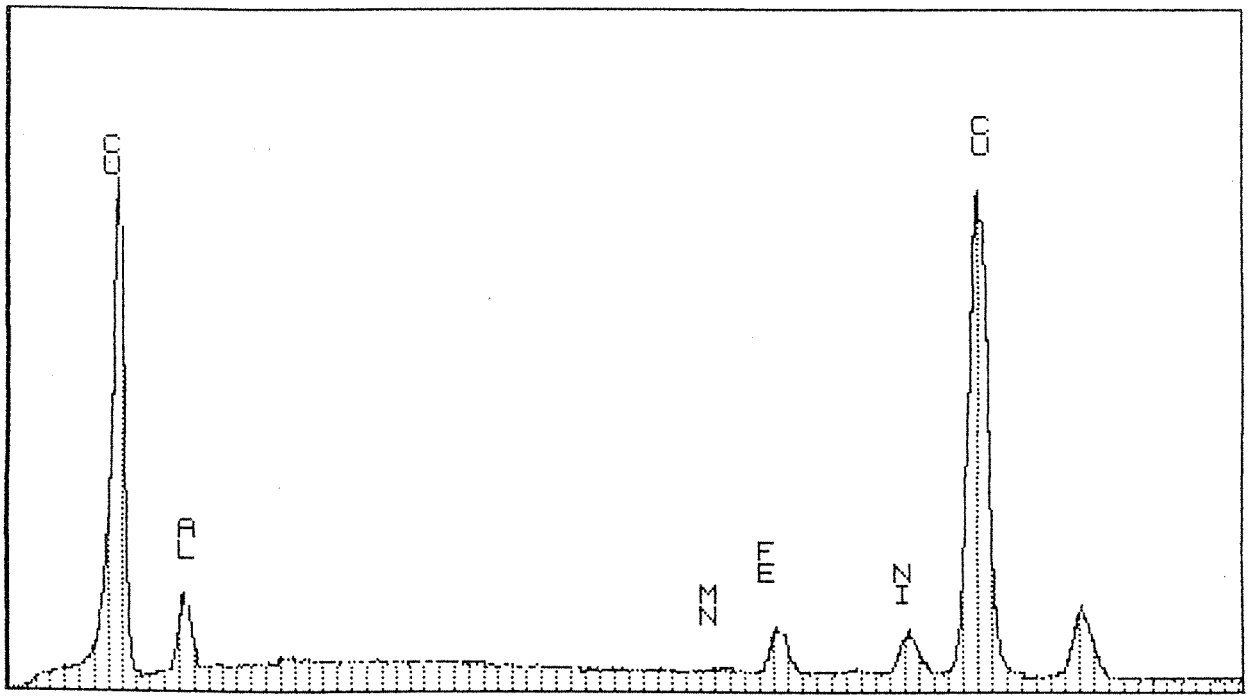


Falex Test 09058 Thrust washer
Bronze rim

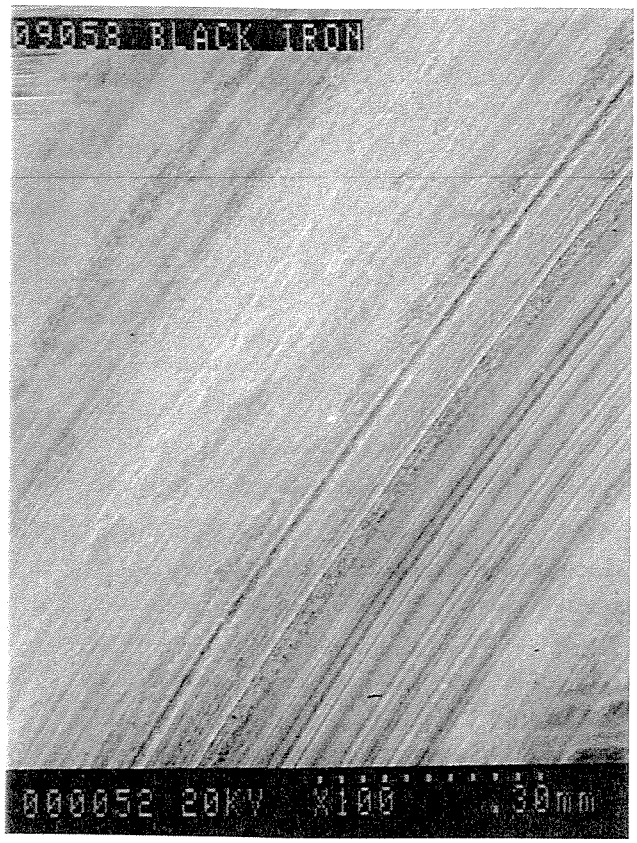


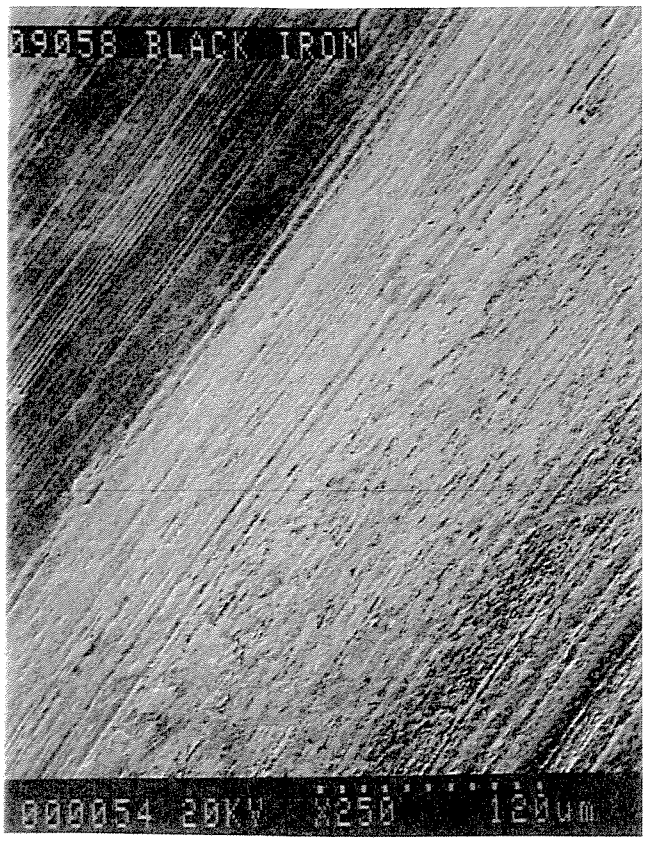
Falex Test 09058 Thrust washer
Bronze rim



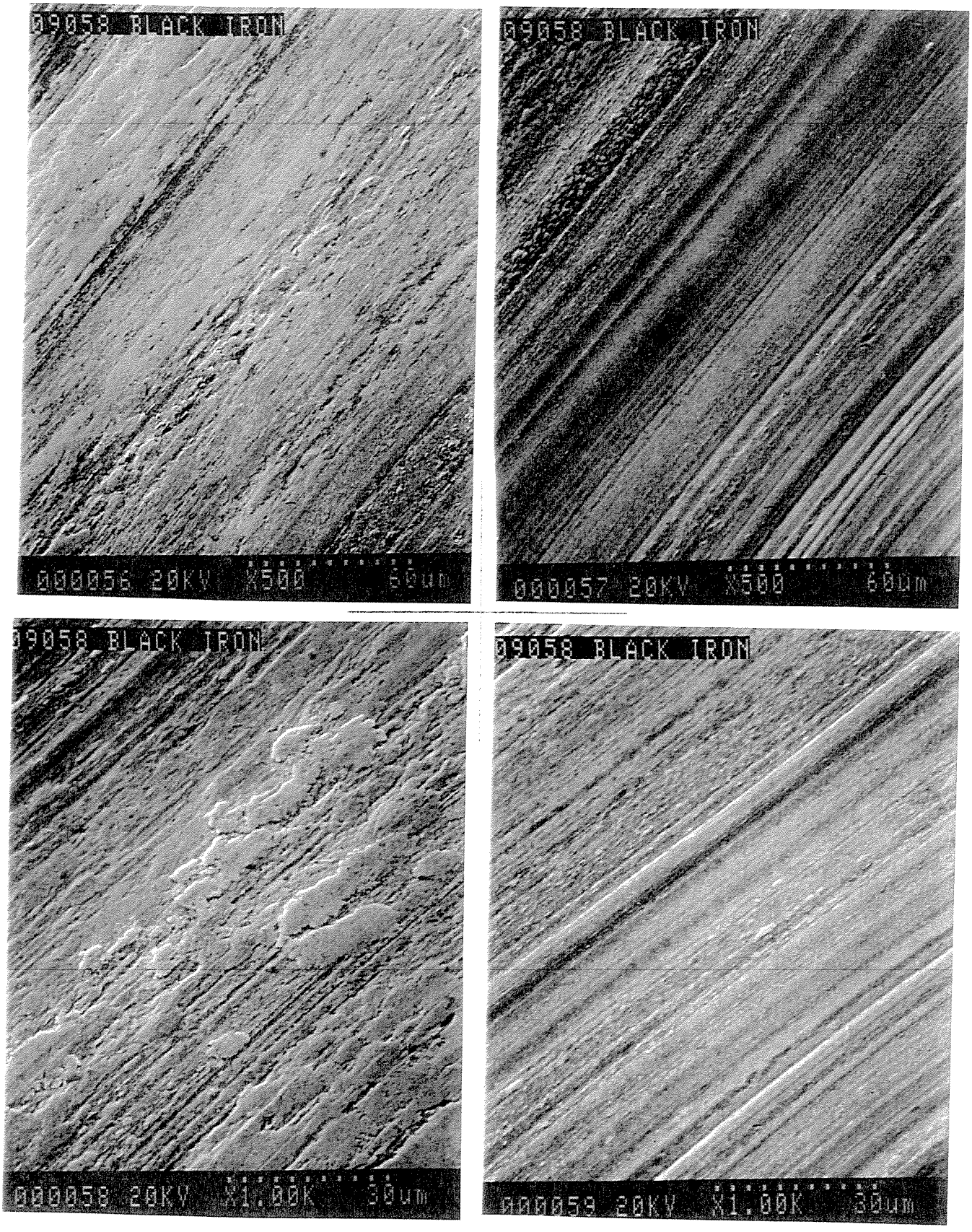


Falex Test 09058 Thrust washer
Black iron washer

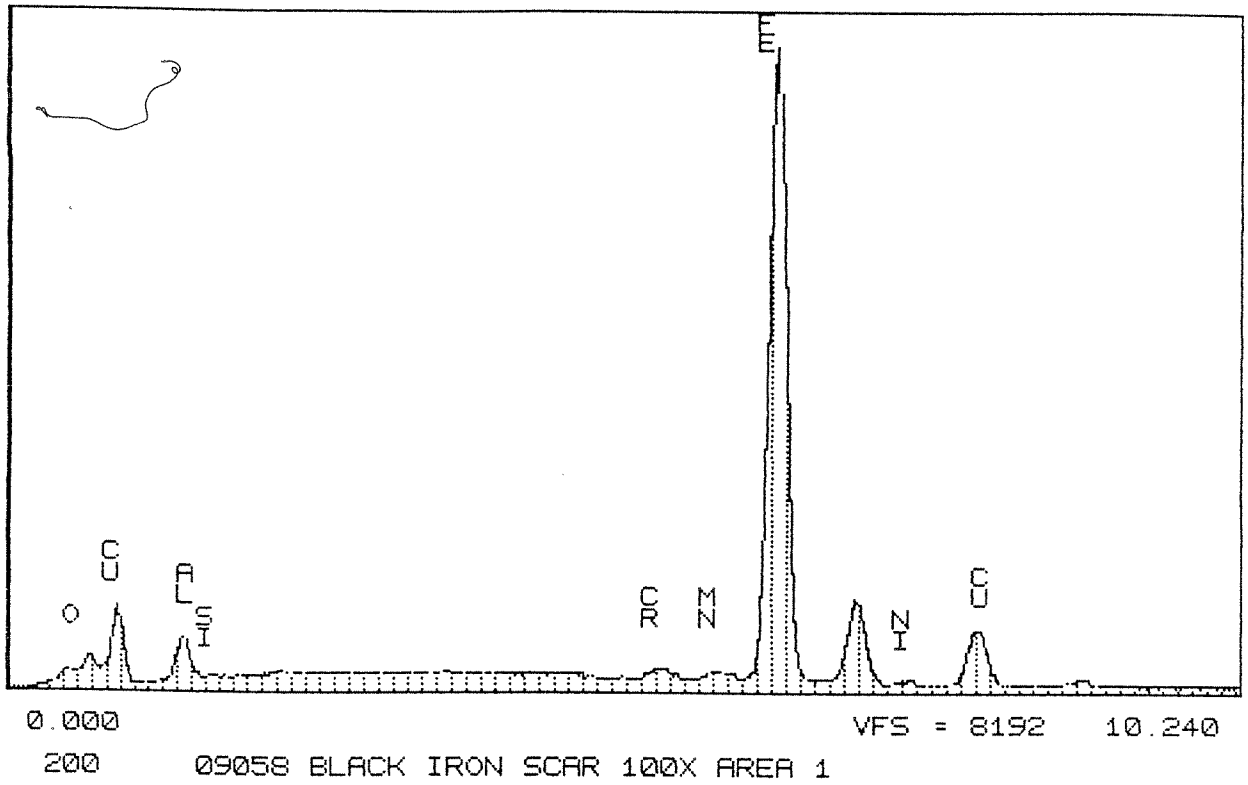


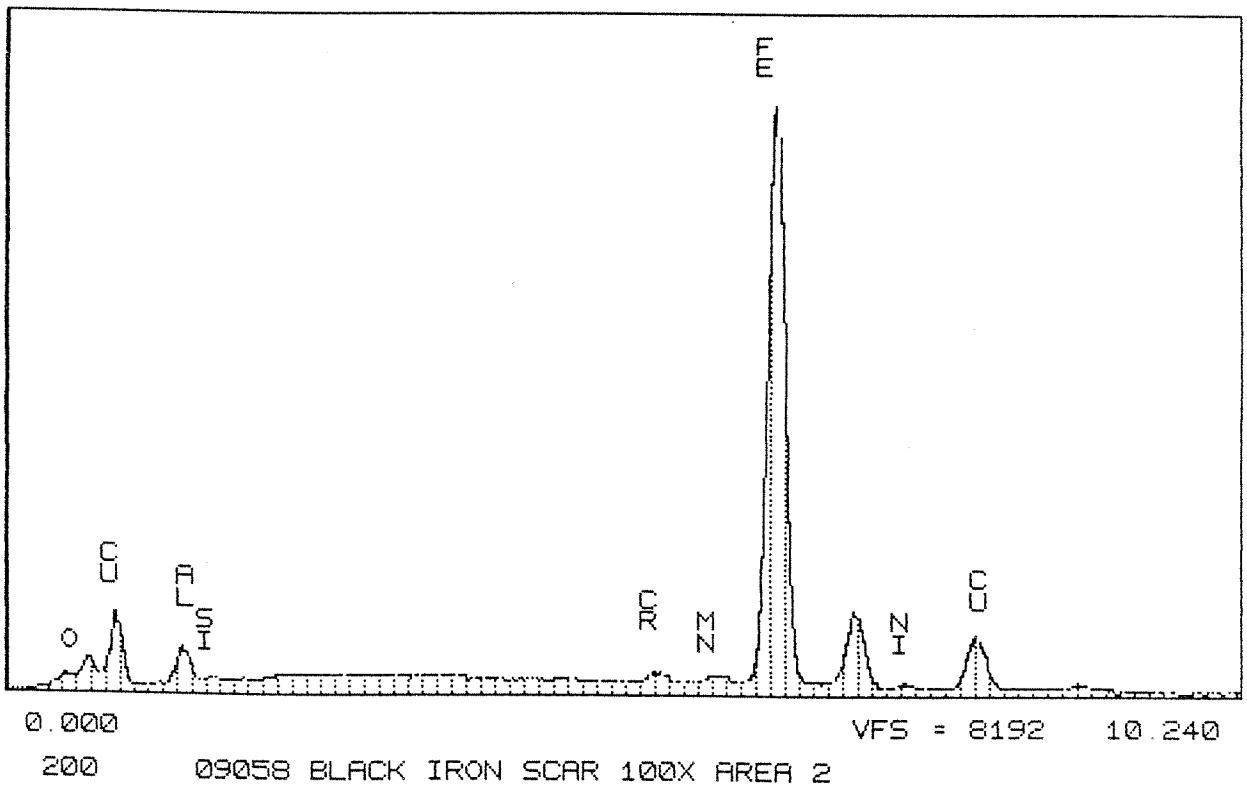


Falex Test 09058 Thrust washer
Black iron washer

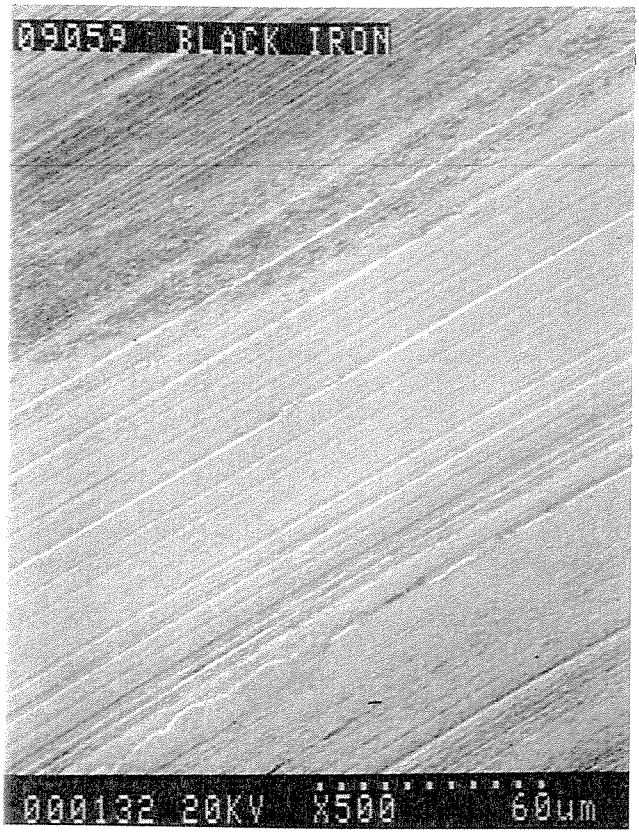


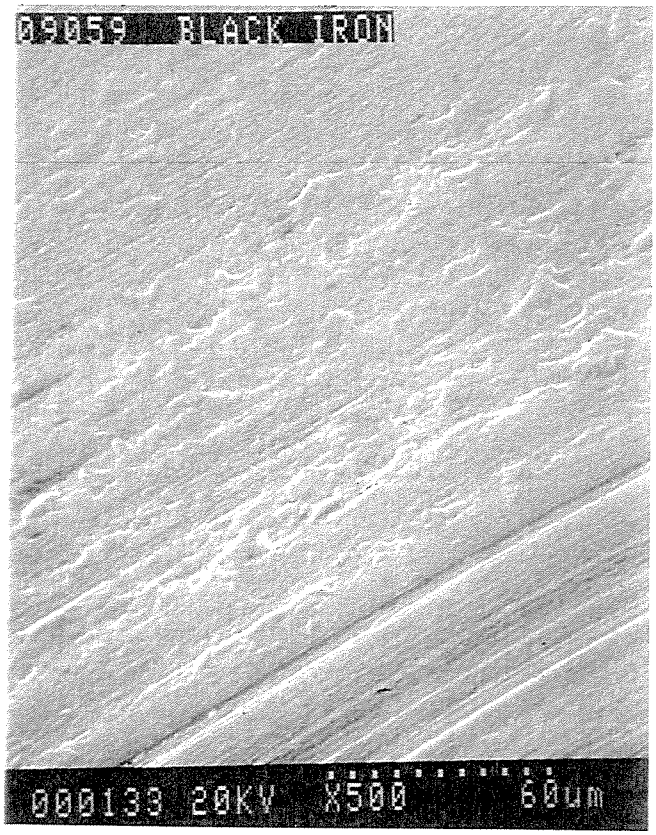
Falex Test 09058 Thrust washer
Black iron washer

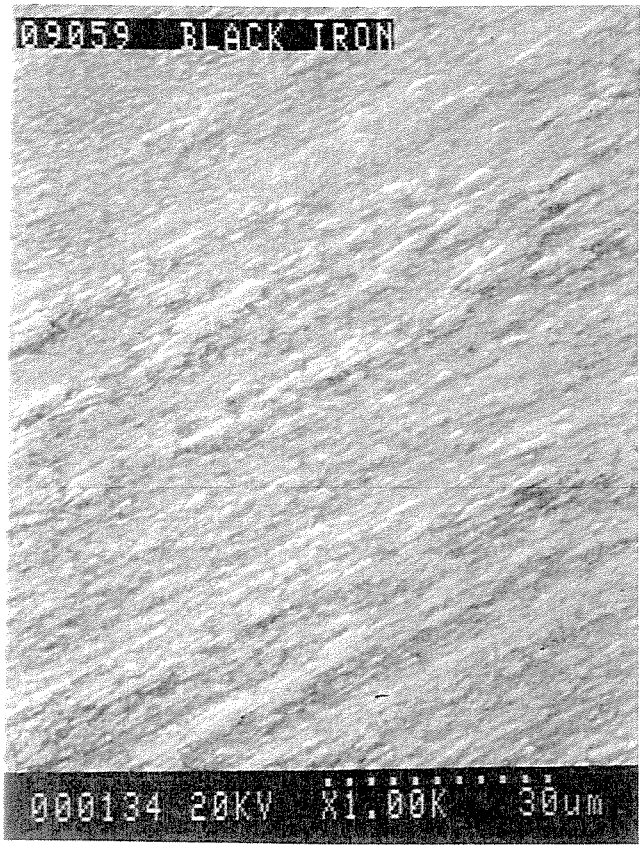


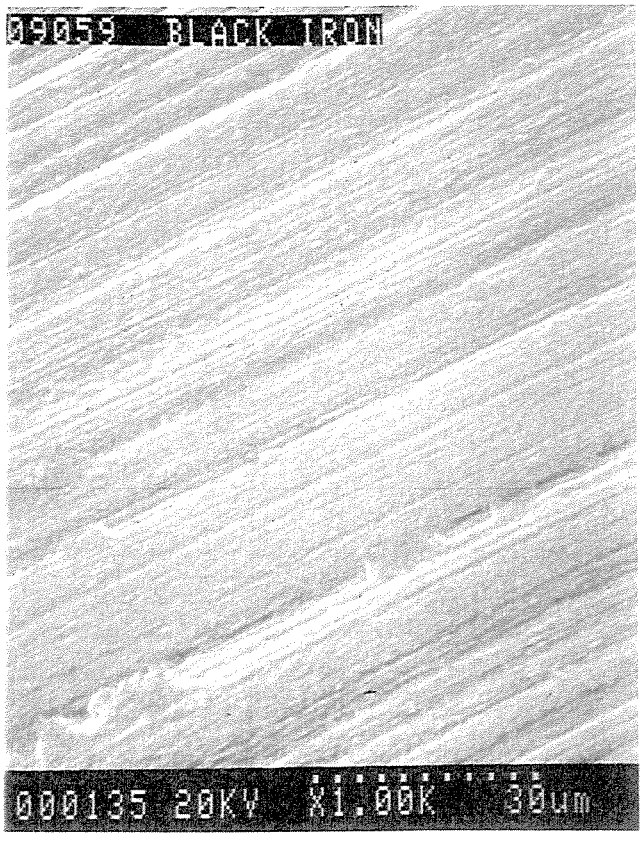


Falex Test 09059 Thrust washer
Black iron washer

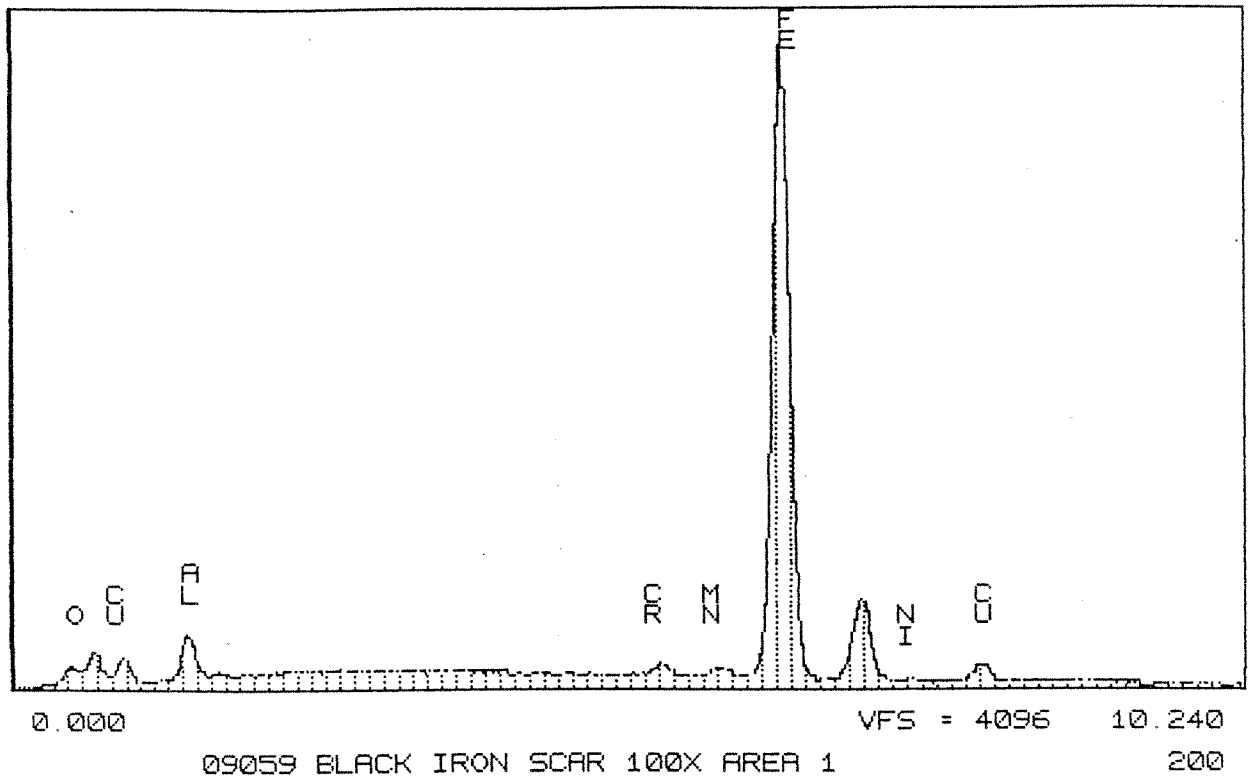


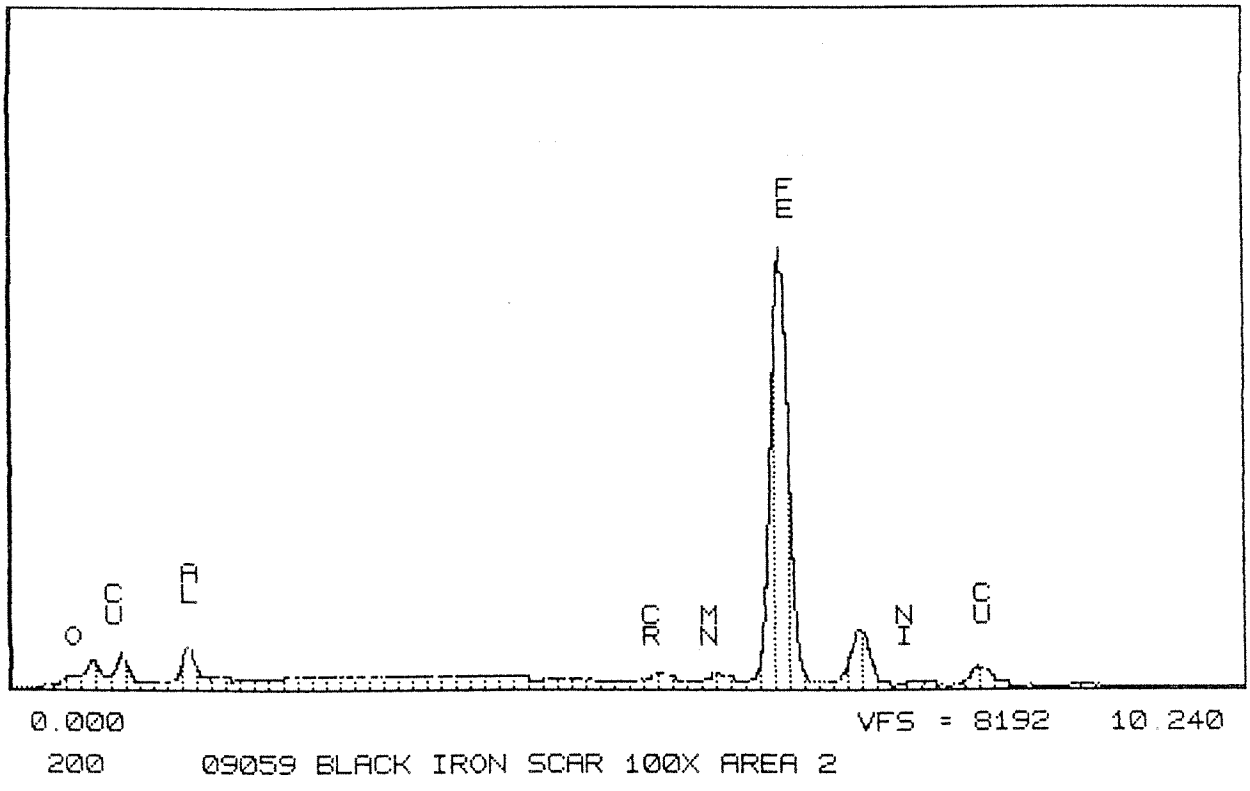




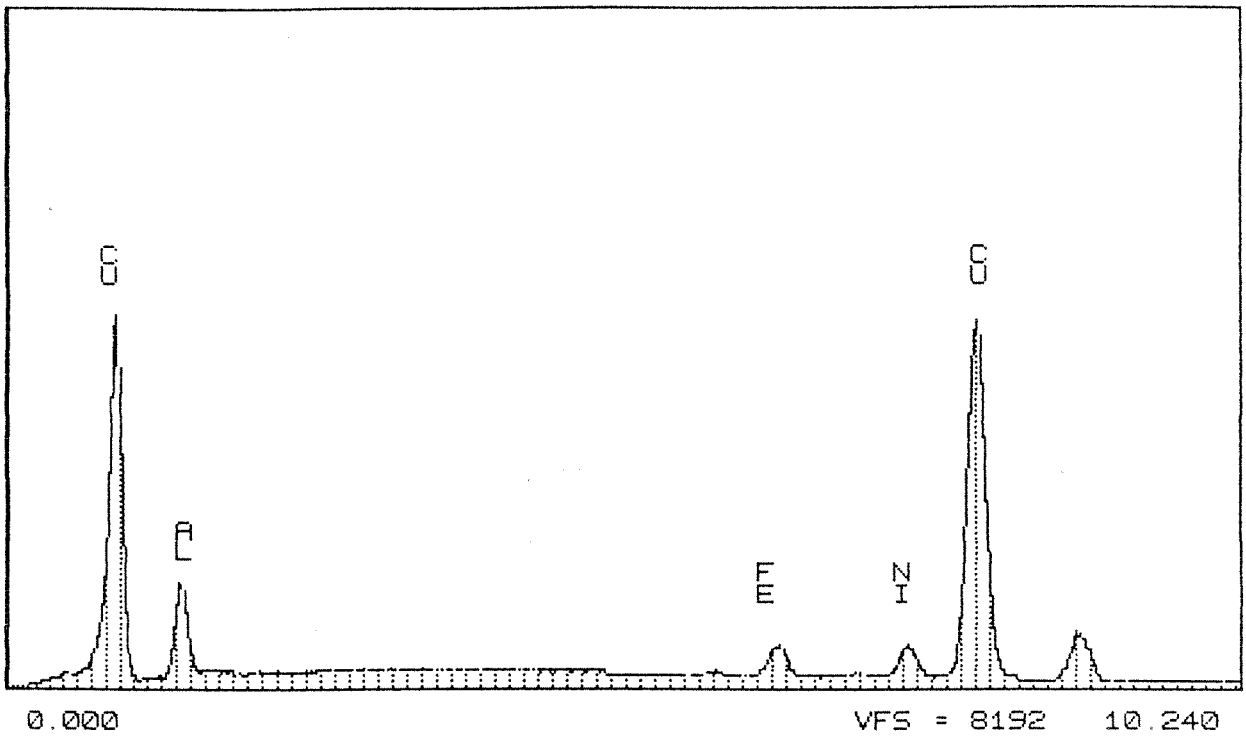


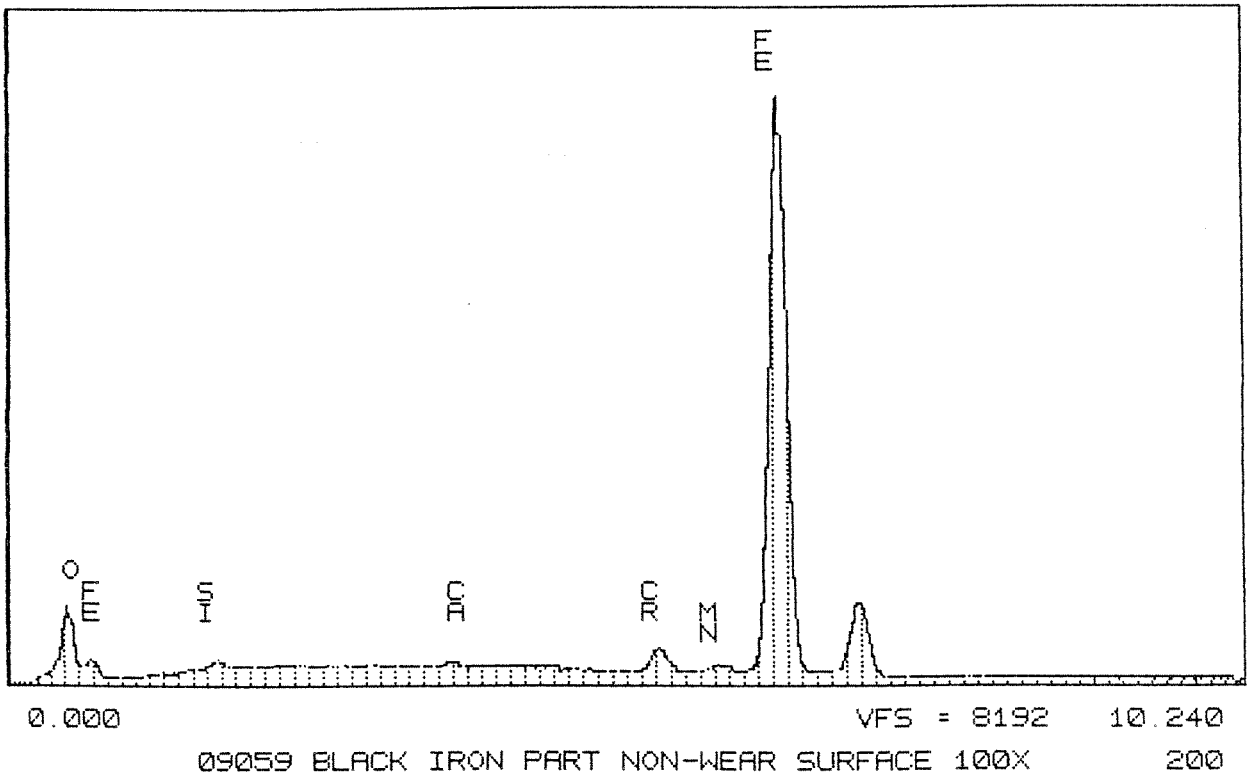
Falex Test 09059 Thrust washer
Black iron washer



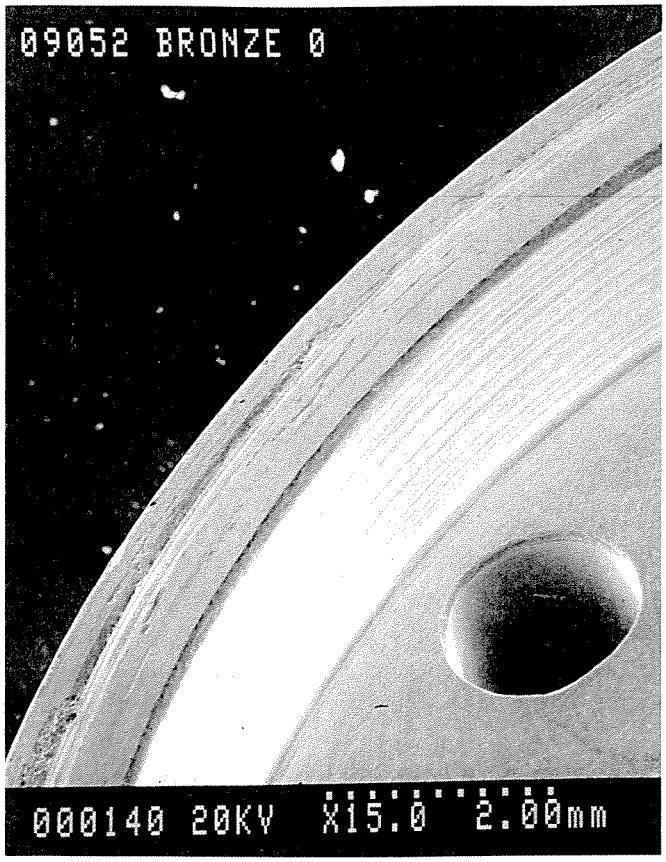


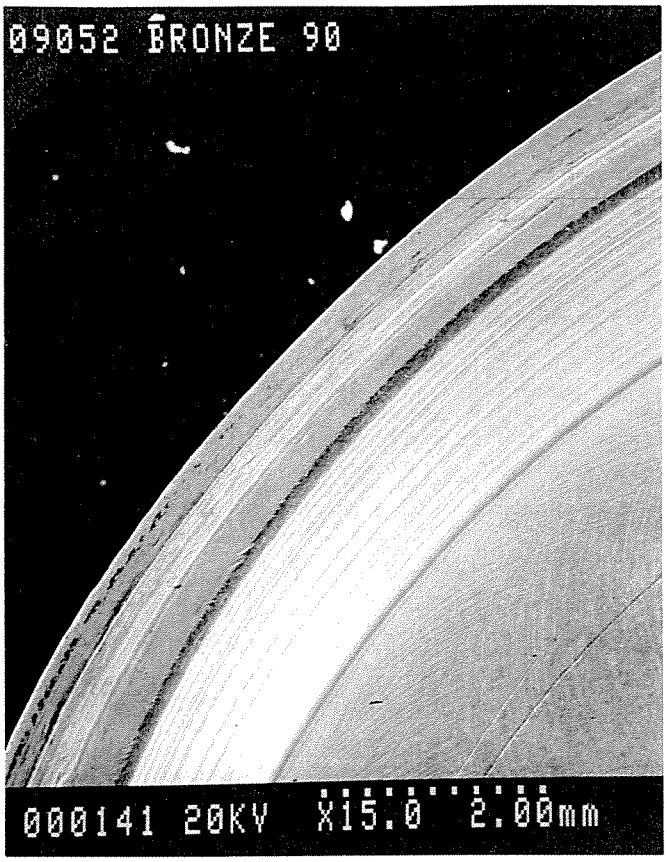
Non-wear bronze surface
Non-wear black iron surface

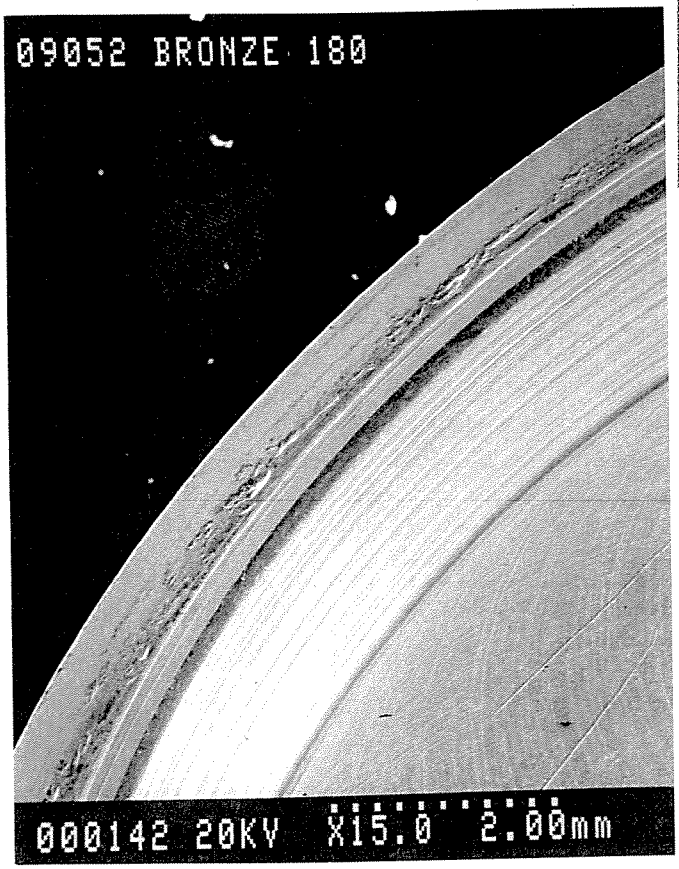


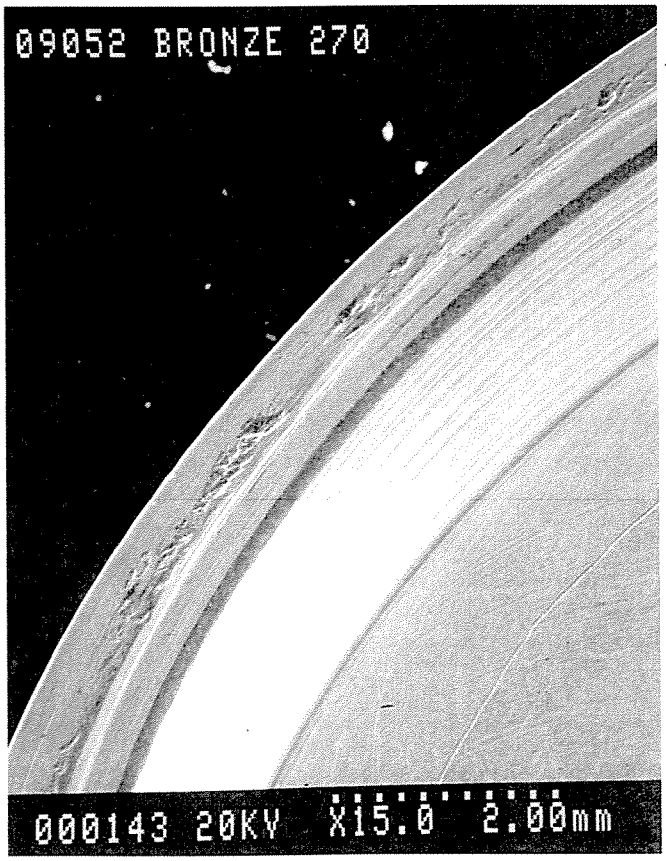


Falex Test 09052 Thrust washer
Bronze rim



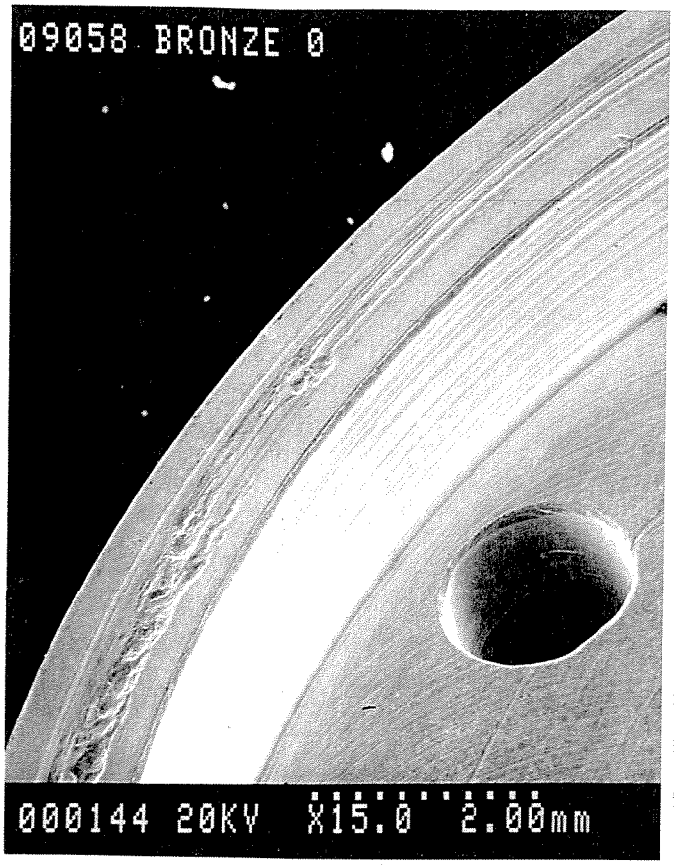


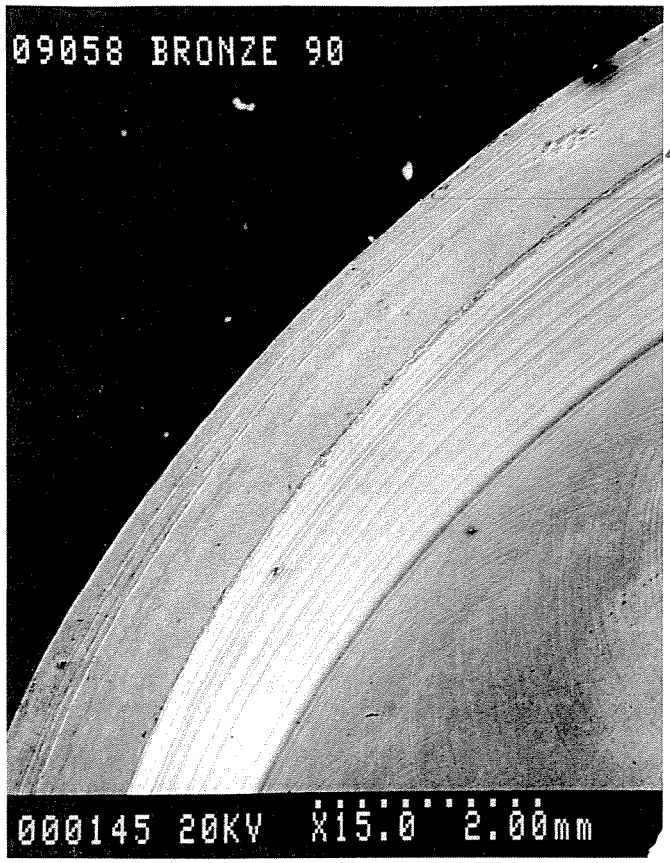


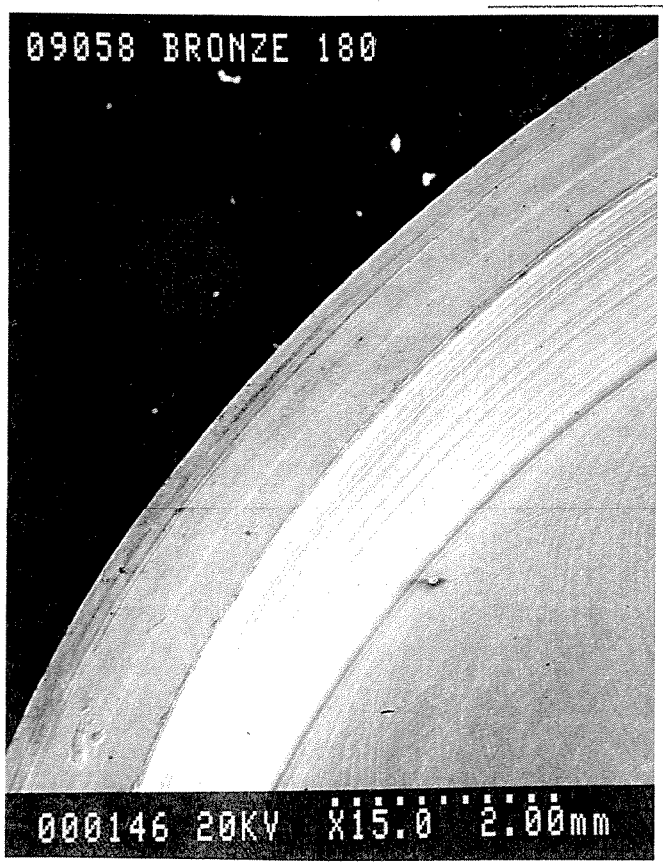


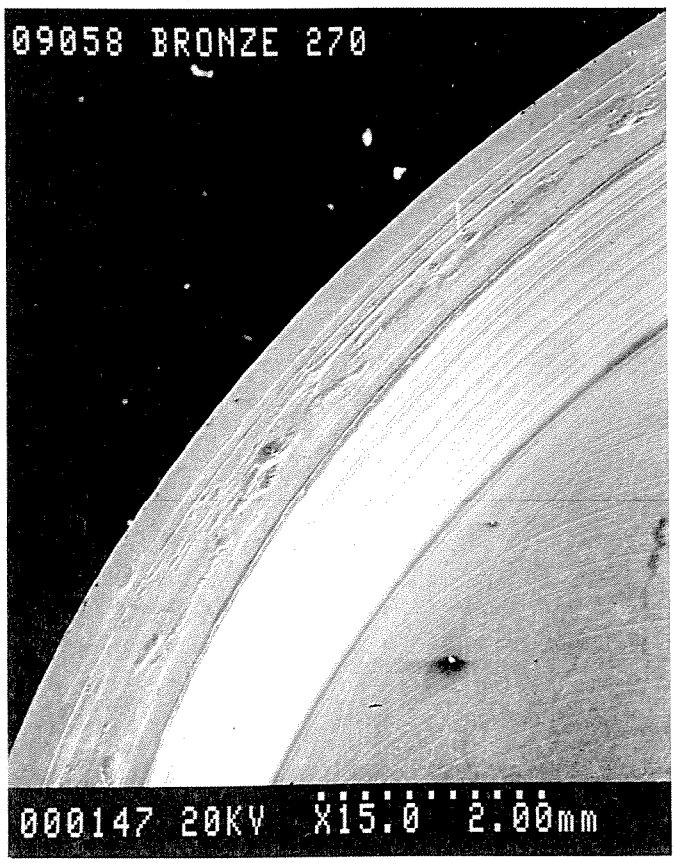
M29

Falex Test 09058 Thrust washer
Bronze rim

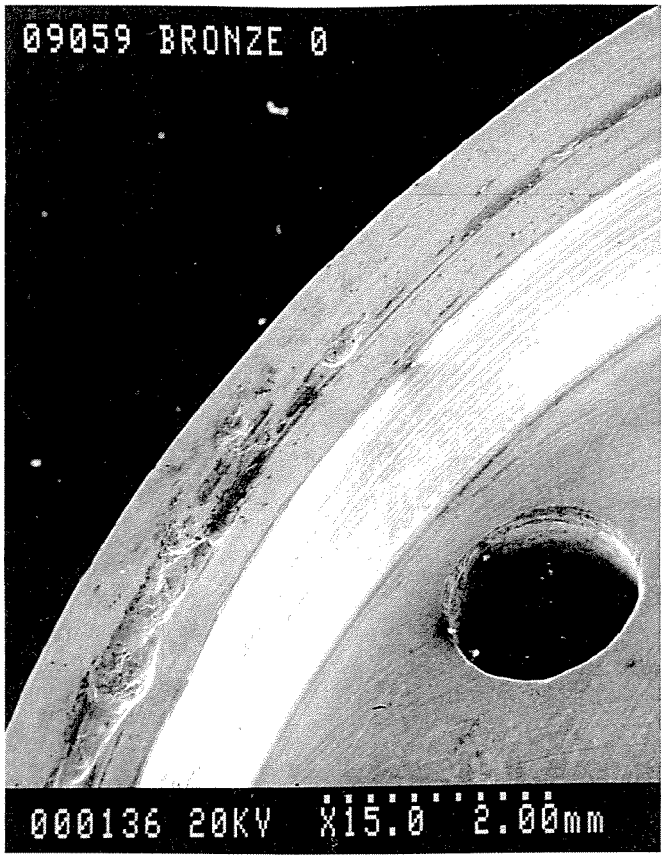


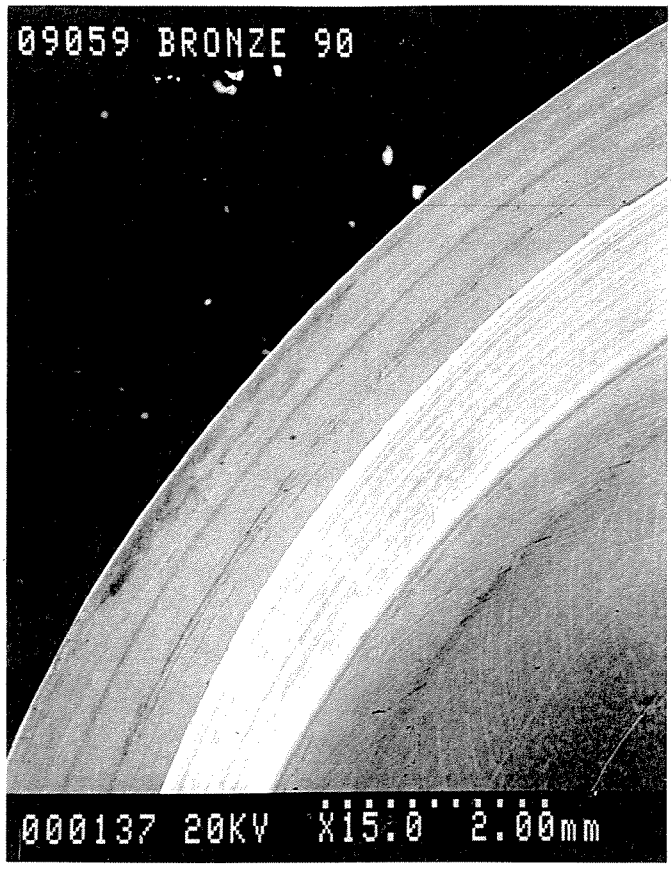


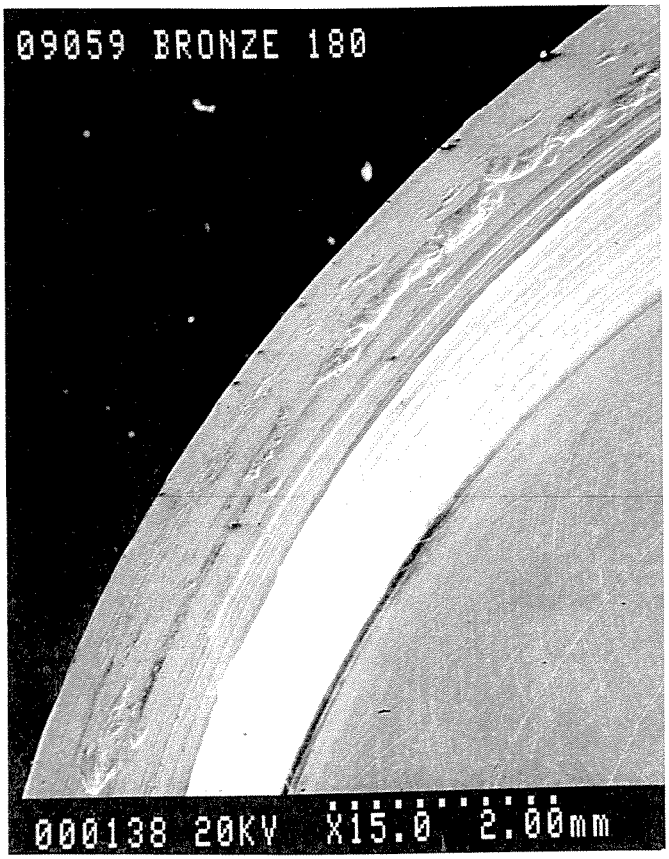


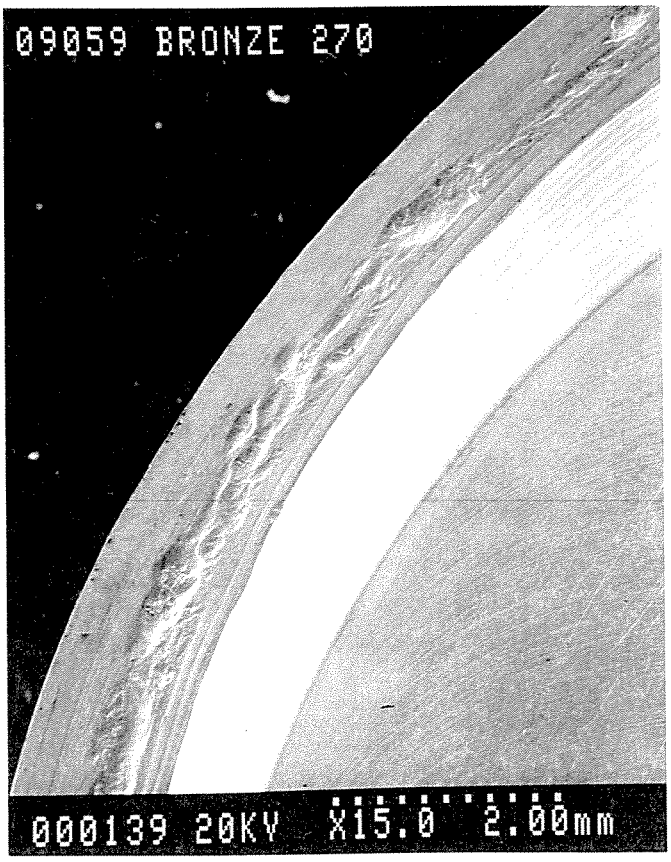


Falex Test 09059 Thrust washer
Bronze rim



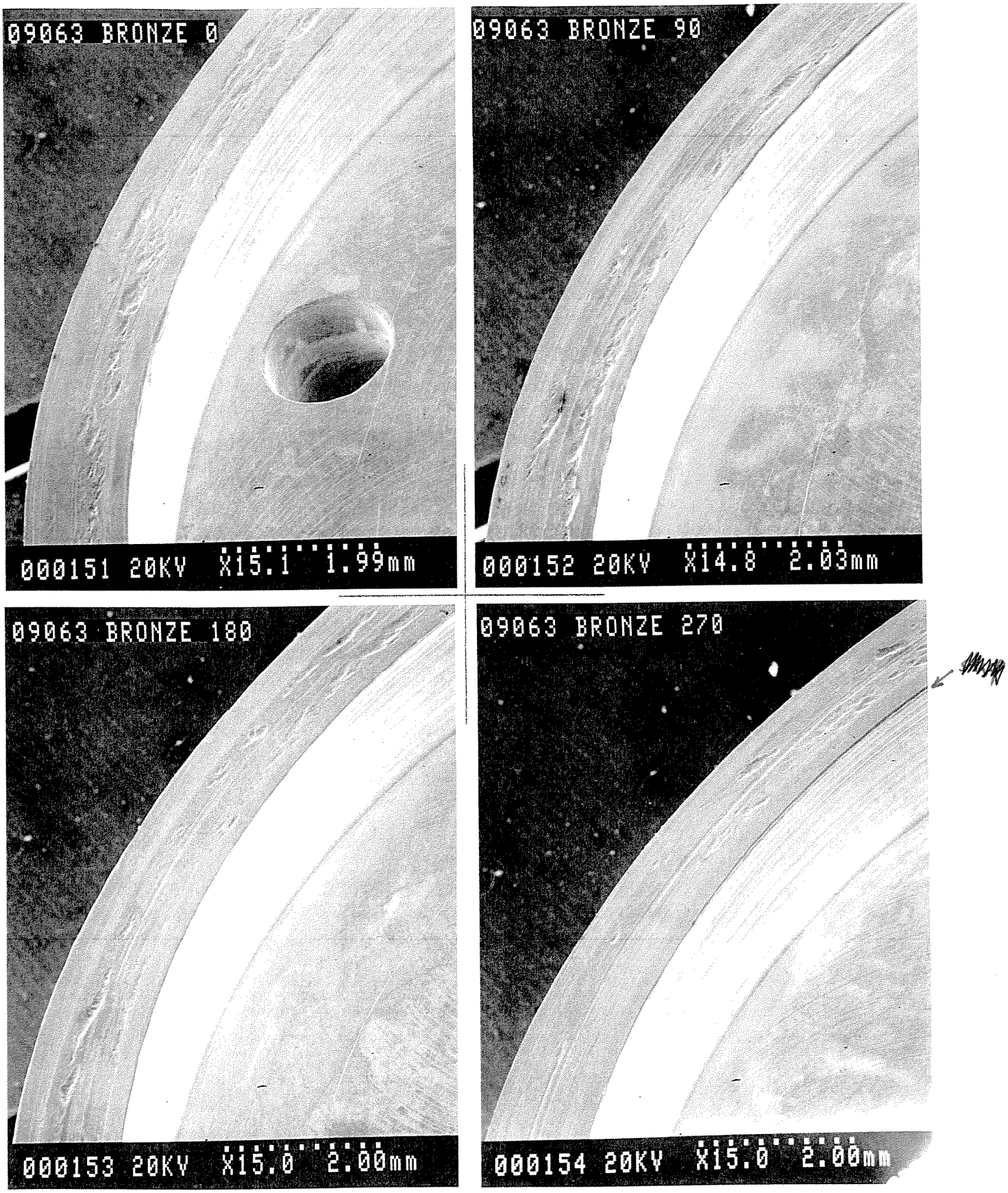






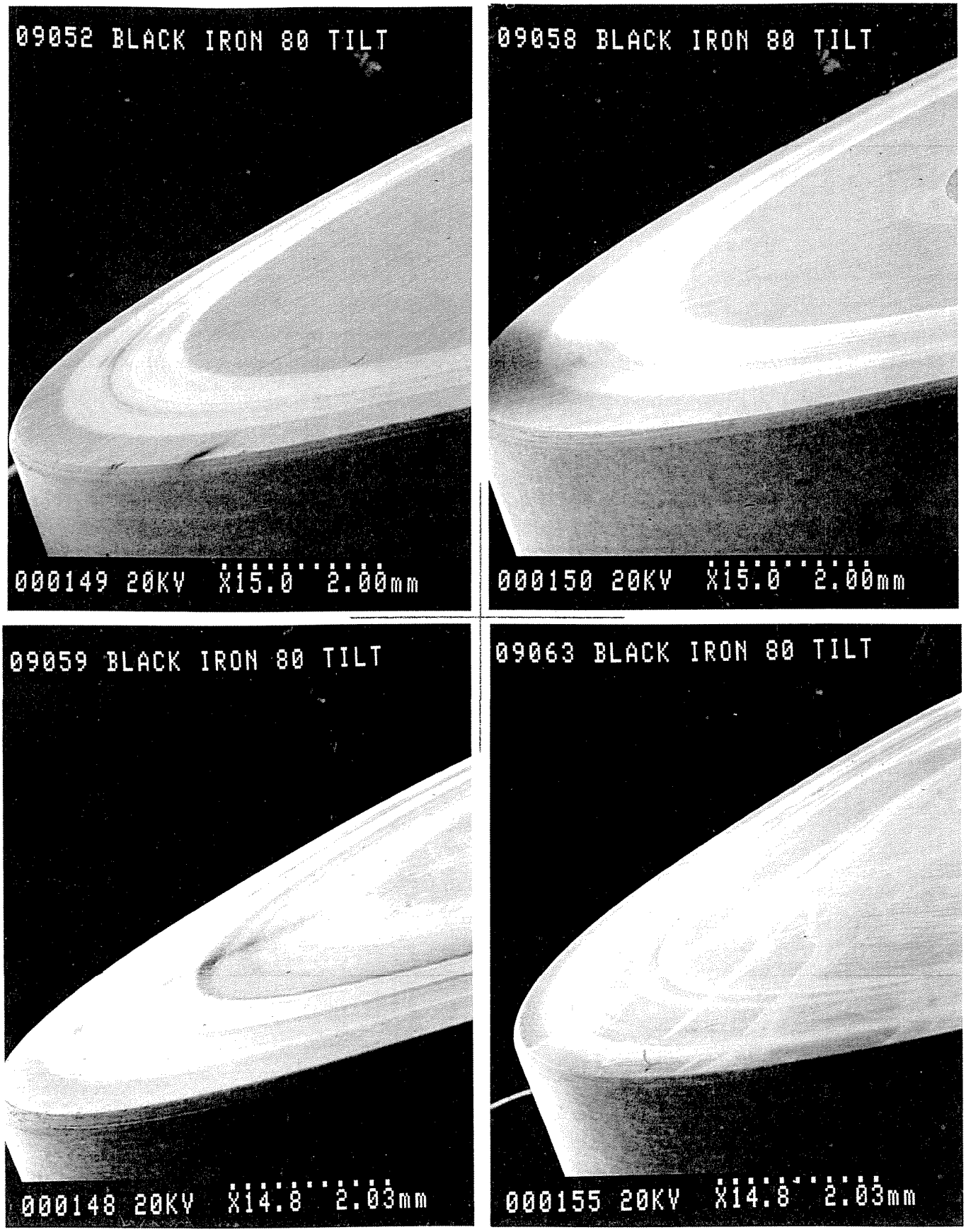
weathered A33

Falex Test 09063 Thrust washer
Bronze rim

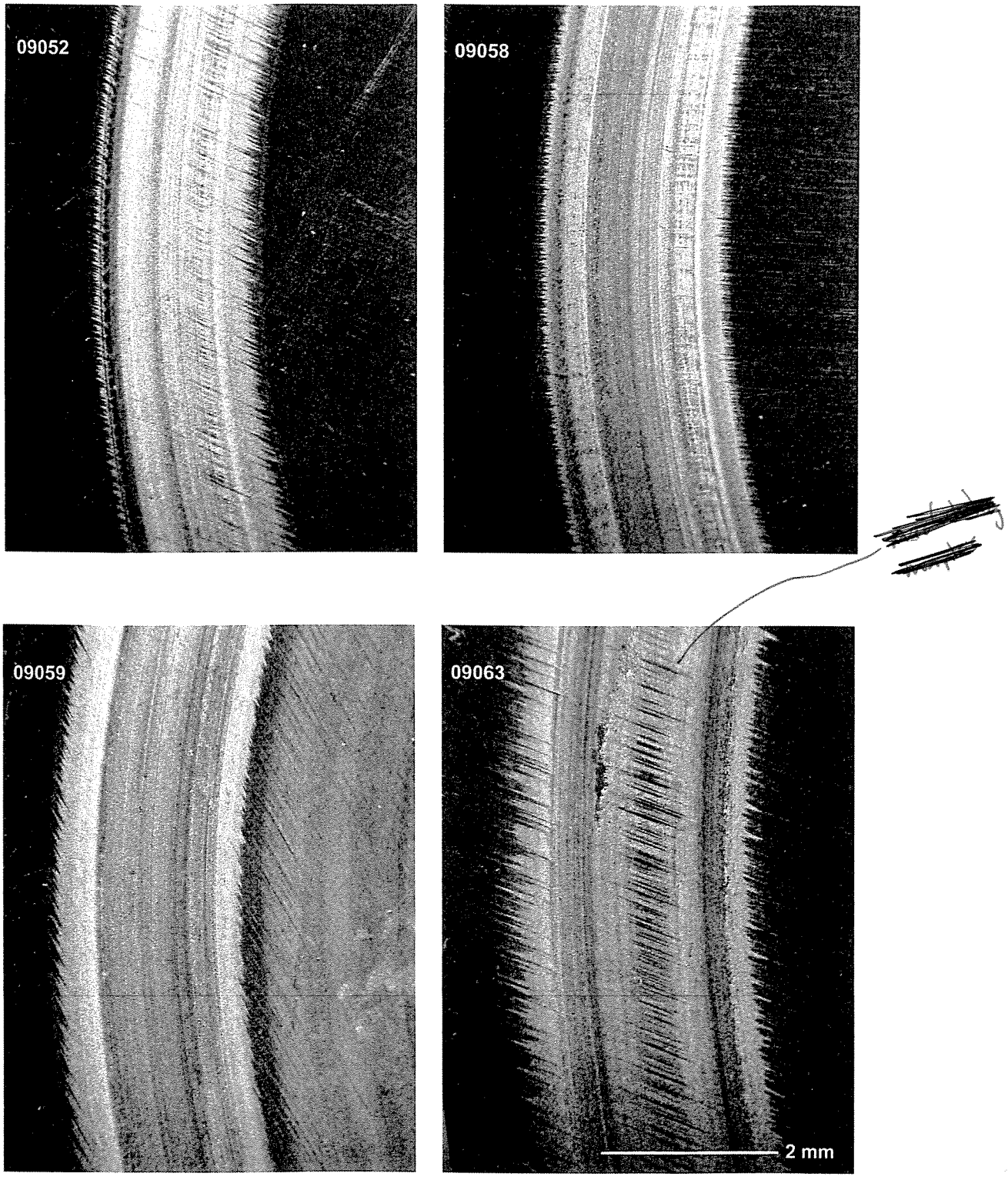


A33

Falex Tests 09052, 09058, 09059 and 09063 Thrust washer
Black iron washers – SEM photomicrographs



Falex Tests 09052, 09058, 09059 and 09063 Thrust washer
Black iron washers – Light photomicrographs



I am sure you can appreciate that this course of action has not been undertaken lightly, and may not be the most popular or easiest way for Alaska Airlines to proceed. I am convinced, however, that your personal involvement, and willingness to communicate, represents an opportunity for all of us to advance the investigation in ways that are beyond the ordinary.

Thank you again for your attention and assistance.

Sincerely,

[redacted]

Enclosure

EXECUTIVE SUMMARY

GREASE AND WEAR TESTING

Background

Early tests revealed that Aeroshell 33 grease failed the Fed Standard Method copper corrosion test. This fact, combined with the service history of Alaska MD-80 jackscrews after a changeover to Aeroshell 33 in January 1998, raised questions about the adequacy of Aeroshell 33, particularly in applications involving bronze or other copper alloys. (The MD-80 horizontal stabilizer gimbal nut is made of a bronze that consists of 80% copper.) It also raised questions about the role of Aeroshell 33 in the excessive wear and failure of the gimbal nut threads on Alaska Airlines Flight 261.

While the available knowledge of grease testing conducted as part of the Flight 261 accident investigation is limited, it is not clear that any testing was conducted using actual MD-80 jackscrew materials. It is also unclear whether any testing was done to replicate sliding wear at constant pressures representative of the in-service conditions experienced by the MD-80 jackscrew. (While the block-on-ring testing puts components at high initial pressures, the contact pressures decline quickly as wear progresses and do not accurately represent in-service conditions.)

Accordingly, outside counsel for Alaska Airlines arranged, in the context of litigation pending against Alaska Airlines, for independent testing of Aeroshell 33 grease and Mobilgrease 28 by a nationally-recognized lubricant testing laboratory.

In order to investigate the performance of Aeroshell 33 grease, and compare it to Mobilgrease 28, a test program was developed using standard methods and test equipment. This testing included both standard test materials and the actual materials used in the MD-80 jackscrew application.

The testing was conducted by Falex Corporation. This company is recognized in the wear testing community as the leader in the development of the wear test specifications for the American Society of Testing and Materials (ASTM), and is the developer and supplier of test equipment necessary to conduct the ASTM tests. Falex provides a comprehensive suite of objective wear testing services. This summary analyzes the results of the testing conducted by Falex.

Scope of Testing

Testing was conducted on fresh Aeroshell 33 grease, fresh Mobilgrease 28 and "weathered" Aeroshell 33 grease. The "weathered" grease was tested because observations indicated that Aeroshell 33 underwent a change in characteristics after exposure to moisture and copper alloys, resulting in the grease becoming dark reddish-

brown to black in color. The Aeroshell 33 grease was weathered by exposing it to moisture and copper.

Some of the tests explored the effects of certain environmental factors, including the presence of de-icing fluid, water, and a slightly elevated temperature.

Testing was performed with standard test materials specified by the ASTM (*steel on steel*) and with the materials actually used in the MD-80 jackscrew system (*steel on bronze*).

Findings

Wear testing was conducted using MD-80 jackscrew materials and a test method designed to simulate sliding contact, such as the MD-80 jackscrew application. These tests were conducted using pressures similar to the in-service condition of the MD-80 jackscrew as well as pressures much lower than those present in an MD-80 jackscrew. ***The test results showed that Aeroshell 33 had a wear rate that was 3 to 10 times greater than that exhibited by Mobilgrease 28 under the same test conditions***.

Details of Test Results

A set of wear tests were run to compare the greases under various conditions. Both standard test materials and actual MD-80 jackscrew materials were used. The following is a general description of the tests:

Block on Ring Test. (ASTM D-3704.) This test uses a lubricated block on which a ring is placed under load. The ring rotates back and forth in the same position on the block, causing wear. As the test samples wear, the area where the two parts contact one another becomes larger. As a result, the "contact pressures" between the test samples start at a fairly high level, but quickly transition to lower contact pressures.

Timken Test. (ASTM D-2509.) This is a sliding wear test similar to the block on ring test except that fresh grease is continuously introduced throughout the test. Each run is ten minutes. Pressure is increased for each run, and each run uses a fresh ring and face of the test block. This test determines the threshold pressure for onset of extreme contact wear or galling.

Pin on Disk Test. (ASTM G-99.) This test places a pin in contact with a flat rotating surface. This test determines the relationship between a load and the sliding velocity at which extreme wear or galling begins. Again, the change in wear is detected by a change in the friction coefficient.

Thrust Washer Test. (ASTM D-3702.) A flat disk is lubricated and a flat, rotating washer is pressed onto the disk. The washer presses onto the disc causing wear. The test is used to determine rate of wear and friction forces. The results provide a comparison of wear rates for various pressures and lubricants.

3 Ball Micro-Film Test. (Falex Multi-purpose number 6.) This test introduces the greases on steel balls under high pressures and compares the film strength and effectiveness of the greases.

Standard Tests Using Steel-on-Steel Contact

The *steel on steel* testing generally showed similar results with all three greases. The exception was the thrust washer test, where Aeroshell 33 grease demonstrated significantly more wear than Mobilgrease 28.

- The two fresh greases were essentially equal in the block on ring tests. Weathered Aeroshell 33 performed somewhat better than the other two fresh (unweathered) greases. As the weathered Aeroshell grease appeared to have "stiffened" during the weathering process, this may have allowed the grease to better stay in the contact region during the block on ring testing, reducing the amount of block wear.

- The Timken test determines the maximum load until the coefficient of friction rises while fresh grease is introduced to the contact area. In this test, Mobil 28 demonstrated a lower threshold transition load than the Aeroshell greases.

- Mobil 28 demonstrated a lower friction coefficient in the pin on disk test.

- Mobil 28 demonstrated the ability to withstand more contact pressure before torque increase in the thrust washer characterization testing, withstanding 10,500 psi as opposed to 8,750 psi for the Aeroshell 33.

Standard Tests using MD-80 Jackscrew Materials

Repeating the same standard tests using MD-80 jackscrew materials (*steel on bronze*), the Aeroshell 33 grease performed worse than Mobilgrease 28 in virtually every test. In general, the weathered Aeroshell 33 performed the worst, except in the block on ring test, where it was essentially equal to the fresh Aeroshell 33.

Tribology and
Petroleum Test
Equipment for
Over 70 Years

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GREASE EVALUATION STUDY

Submitted to:

Mr. Dane Jaques, Esq.

Dombroff & Gilmore
Washington, DC

DATE: February 14, 2002

Prepared by:
Brian M. Holtkamp,
Vice President, Testing Services

PROGRAM OVERVIEW

A test program was conducted to study the friction, wear, load-carrying and film strength characteristics of two greases. In addition, one of the greases was exposed to copper to create a "weathered" condition, which was then subjected to test conditions. Environmental test conditions included the addition of a de-icing agent, water, and temperature in various combinations to determine the effect on friction and wear properties.

Additionally, various loads levels were investigated using the thrust washer test geometry on the two submitted greases. This testing phase was conducted to determine the wear rate of the aluminum bronze when subjected to various load levels in the presence of Mobil 28 and Aeroshell 33 greases.

Overview:

The following test program report details the grease evaluation study performed by Falex Tribology Test Laboratory, Sugar Grove, IL. Two greases were investigated in this study. The submitted grease information follows:

Identification:	Quantity:	Falex Identification:
Mobilgrease 28 Batch: B22951-XI9L0	35 lb.	TL 4944
Mobilgrease 28 Batch: B18872-XI0J0	35 lb.	TL 4945
Mobilgrease 28 Batch: B18872-XI0J0	35 lb.	TL 4946
Mobilgrease 28 Batch: B16596-X3IG0	35 lb.	TL 4947
Aeroshell Grease 33 Batch: 98127ml/mp052101 Sequence # 55	35 lb.	TL-4948
Aeroshell Grease 33 Batch: 98127ml/mp052101 Sequence # 23	35 lb.	**TL-4949**
Aeroshell Grease 33 Batch: 98127ml/mp052101 Sequence # 31	35 lb.	**TL-4950**
Aeroshell Grease 33 Batch: 98127ml/mp052101 Sequence # 15	35 lb.	TL-4951
Aeroshell Grease 33 Batch: 98127ml/mp052101 Sequence # 69	35 lb.	TL-4952
Aeroshell Grease 33 Batch: 98127ml/mp052101 Sequence # 63	35 lb.	TL-4953
Aeroshell Grease 33 Batch: 98127ml/mp052101 Sequence # 48	35 lb.	TL-4954

Sample TL-4949 and TL-4950 Aeroshell 33 grease was exposed to copper in order to created a "weathered" condition. The process was conducted within the Falex Laboratory. Two 5-gallon stainless steel containers were used to heat six layers of grease and 0.012 inch diameter wire copper mesh to 100°C for 56 hours in a convection oven. (These two quantities will be referred to as "upper" and "lower" samples in this test report. These terms are used to describe their placement in the oven.) Distilled water was sprayed onto the copper mesh prior to adding grease. The grease was removed from the containers and returned to their original plastic containers, blended, and stored until used for testing.

Six grease samples were submitted to Phoenix Chemical Laboratory, Chicago, IL for chemical analysis. These consisted of three samples of each manufactured lot of Mobil 28, one sample of Aeroshell 33 and a sample from each container of weathered Aeroshell 33 grease.

Grease:	Falex Lab ID:	Phoenix Chemical Lab ID:
Mobil 28	TL- 4944	01 11 2 11
Mobil 28	TL- 4945	01 11 2 12
Mobil 28	TL- 4947	01 11 2 13
Aeroshell 33	TL- 4948	01 11 2 14
Aeroshell 33, weathered (lower)	TL- 4949	01 11 2 15
Aeroshell 33, weathered (upper)	TL- 4950	01 11 2 16

The analysis showed no lot variation for the Mobil grease supplied for this study. Elemental analysis on the Aeroshell grease showed an increase in copper for the weathered greases. Aeroshell 33 showed 3.3 parts per million (ppm) copper, while the lower weathered pan showed 2950 ppm and the upper pan showed 4620 ppm copper. This verified the weathering process, which was designed to introduce copper into the Aeroshell grease.

The complete report follows this report ("Chemical Analysis" section). All testing done in the Falex study used one batch of Mobil 28 grease (Falex ID #TL-4944), one batch of Aeroshell 33 grease (Falex ID #TL-4948) and the lower container of weathered Aeroshell 33 (Falex ID # TL- 4949).

The three greases were then tested under several conditions, with each test being conducted in duplicate. Five test methods were used to evaluate the greases. These include:

ASTM D3704 Standard Test Method for Wear Properties of Lubricating Greases Using the (Falex) Block on Ring Test Machine in Oscillating Motion

ASTM D2509 Standard Test Method for Measurement of Load-Carrying Capacity of Lubricating Grease (Timken Method)

ASTM G99 Standard Test Method for Wear Testing with a Pin-on-Disk apparatus

ASTM D3702 Standard Test Method for Wear Rate and Coefficient of Friction of Materials in Self-Lubricated Rubbing Contact Using a Thrust Washer Testing Machine

Three Ball Micro-film Test

The program is divided into five sections, or plans. Each section goal is detailed in the appropriate section. Following the test outline is a summary of test data gathered in the section. All data collected has been included as attachments to this report. Following the summary of each test phase, a final summary is presented which will allows a quick review of the program and conclusions drawn for the data collected. Additionally, images of worn test samples are included for additional information. Scanning Electron Microscope (SEM) images allow a closer image of the samples and provide further information on the wear processes involved with the tests conducted. Along with the SEM photos, elemental analysis was performed on the surfaces. This analysis allows a comparison of an unworn surface to a tested surface.

Test Plan:

Part A included standardized tests or procedures to establish the baseline for future tests with actual materials used in the field application (Part B). The standardized tests and materials were used to determine optimum test parameters when not specified by the test method.

The test conditions for each test configuration were:

Block on Ring Test Geometry:

Test Parameters:		*Standard Test Specimens:*	
Test Load:	630 or 360 or 180 lb.	Block:	O1 Steel
Test Speed:	87.5 cpm		27 - 33 Rc hardness
Motion:	Oscillatory		4 - 8 μ inch finish
Oscillation Angle:	90°	Ring:	SAE 4620 steel
Test Temperature:	Ambient conditions		58 - 63 Rc
Duration:	5,000 cycles		6 - 12 μ inch finish

Timken Test Geometry:

Test Parameters:		*Standard Test Specimens:*	
Test Load:	Various, starting at 30 lb.	Block:	Carburized steel
Test Speed:	800 rpm		58 - 62 Rc hardness
Test Duration:	10 minutes/ load stage		20 - 30 μ inch finish
Test Temperature:	38°C	Ring:	Carburized steel
			58 - 62 Rc hardness
			20 - 30 μ inch finish

Pin on Disk Geometry:

Test Parameters:		*Standard Test Specimens:*	
Test Load:	Various, increasing	Pin:	AISI E-52100 steel
Test Speed:	20 rpm		Grade 5 ball
Test Radius:	22 mm		0.5 inch diameter
Test Temperature:	Ambient conditions	Disk:	440C stainless steel
Test Duration:	approx. 75 minutes		48 – 52 Rc hardness
			12-14 μ inch finish

Thrust Washer Geometry:

Test Parameters:

Test Load:	Various, increasing
Test Speed:	5 rpm
Test Duration:	2 minutes/ load stage
Test Temperature:	Ambient conditions

Standard Test Specimens:

Rotating:	1018 steel
	14 – 18 Rc hardness
	15 – 18 μ inch finish
Stationary:	1018 steel
	14 – 18 Rc hardness
	15 – 18 μ inch finish

Three Ball Micro-film Geometry:

Test Parameters:

Test Load:	Various, increasing
Test Speed:	20 rpm
Test Duration:	5 minutes/ load stage
Test Temperature:	Ambient conditions

Standard Test Specimens:

Rotating:	440C stainless steel
	1 μ inch finish
	54-58 Rc hardness
Stationary:	440C stainless steel
	1 μ inch finish
	54-58 Rc hardness
Balls (3):	AISI E52100 steel
	Grade 5
	64-68 Rc hardness

A description of the test equipment used in this study can be found in the section titled "Test Equipment". This section describes, in detail, the test configuration for each of the methods conducted.

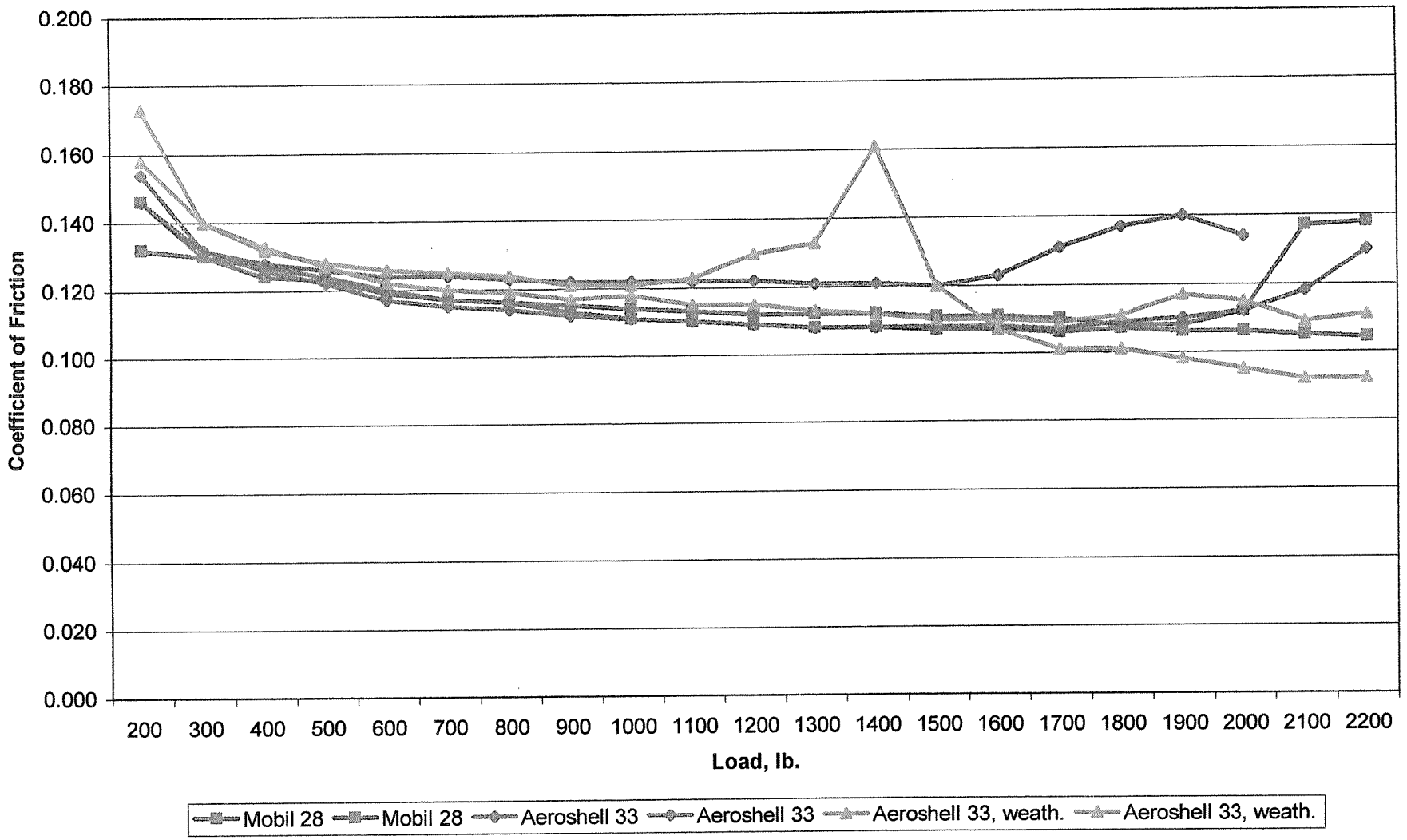
Summary of Part A:

Test Method:	Mobil 28	Aeroshell 33	Aeroshell 33, weathered
Block on Ring Test:			
Block Scar Width (mm)	2.5065	2.4150	1.5545
Final contact pressure (psi)	14,611	15,171	23,561
Timken Test:			
OK Load (lb)	18	30	30
Scar width at load (mm)	1.2015	1.211	1.5195
Final contact pressure (psi)	7,611	12,775	10,124
Pin on Disk Test:			
Final friction coefficient	0.123	0.141	0.135
Thrust Washer Test:			
Contact pressure (psi) at torque increase	10,500	8,750	8,000
Three Ball Microfilm Test:			
Friction, as load increases	Upward trending	Flat	Downward trend, high

Summary graphs for the Pin on Disk, Thrust washer, and Three Ball Micro-film tests are included for review to observe trends.

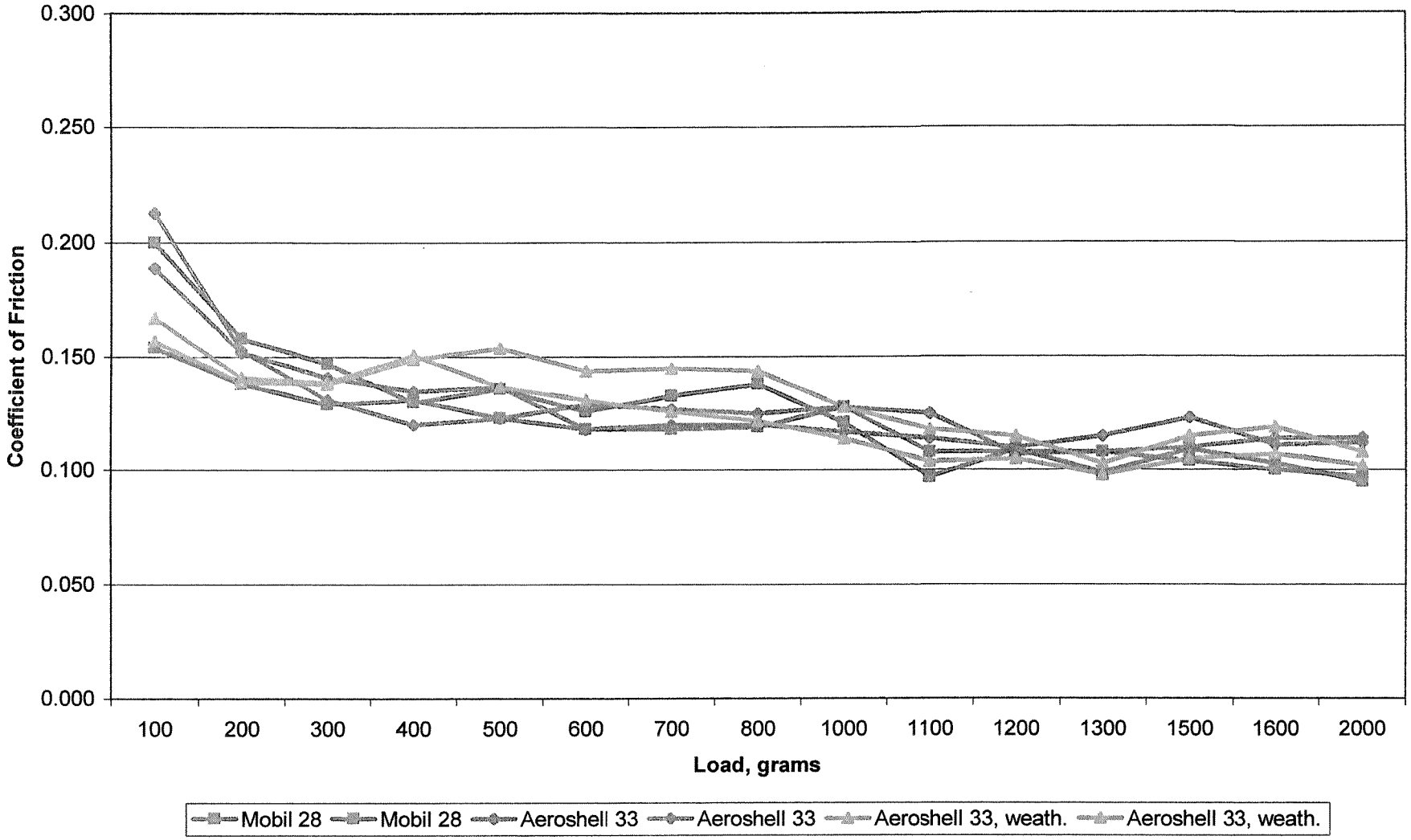
CoF vs Load

Steel vs steel, thrustwasher geometry



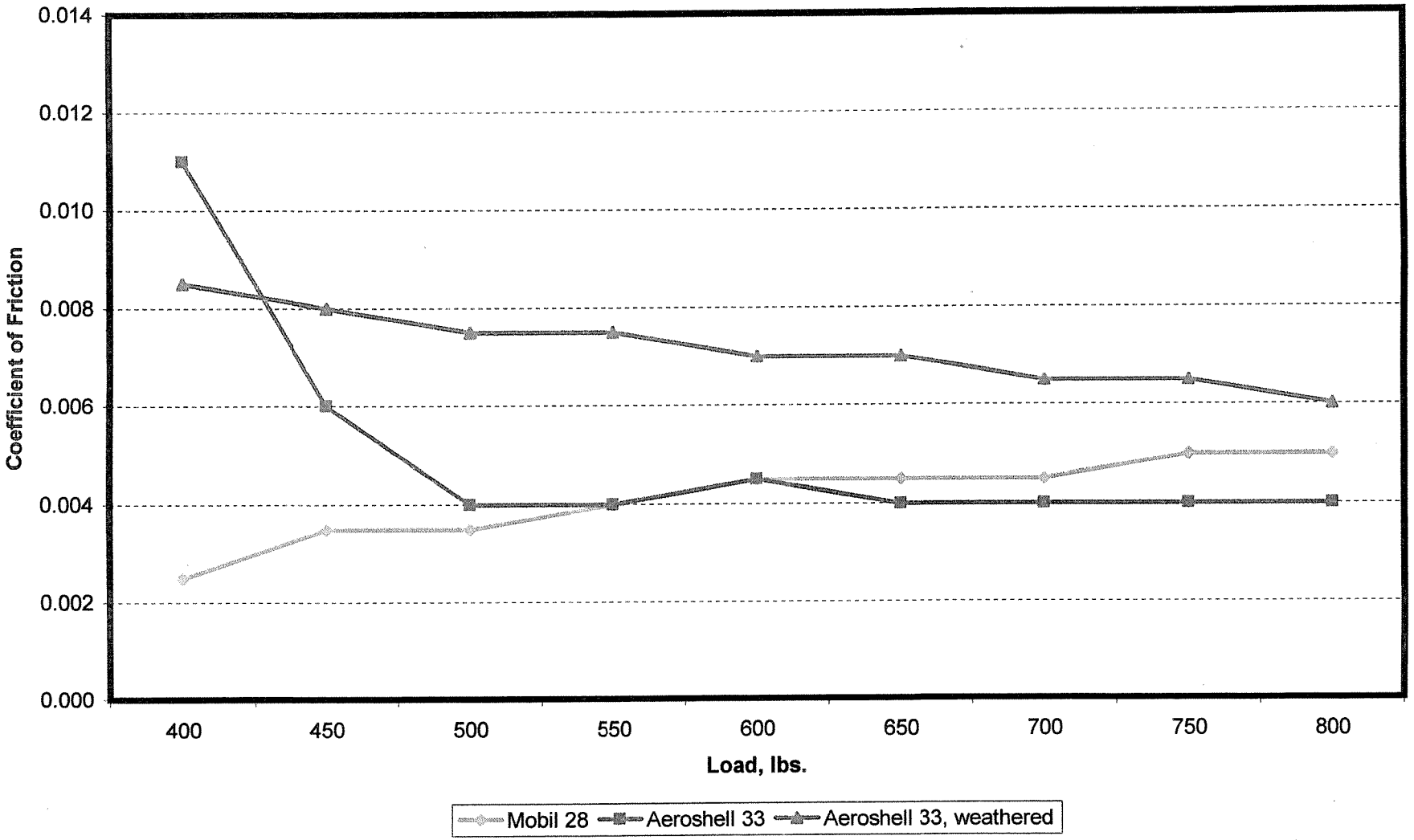
CoF vs Load

Steel vs steel, pin on disk geometry



CoF vs Load

440C vs. steel ball, 3 Ball Micro-film Geometry



Part B

Part B tests were identical to those conducted in Part A, using test specimens machined from supplied bronze material and oxide coated steel specimens. The bronze material was supplied by the client and machined by Falex Corporation into test pieces.

The following pieces were made from the submitted materials:

Material:	Identification:	Falex ID#:	Test pieces machined:
Bronze	AB05-01259-A	TL-5027	Block on Ring Test Block Timken Test Block
Bronze	AB05-01259-B	TL-5028	Thrust washer, rotating Pin on Disk, pin
Bronze	AB05-01259-C	TL-5029	3 Ball Micro-film, upper 3 Ball Micro-film, lower
Bronze	AB05-01259-D	TL-5030	Thrust washer, rotating

The steel components were supplied and machined by Falex Corporation. After machining, the bronze and steel test pieces were identified as listed below:

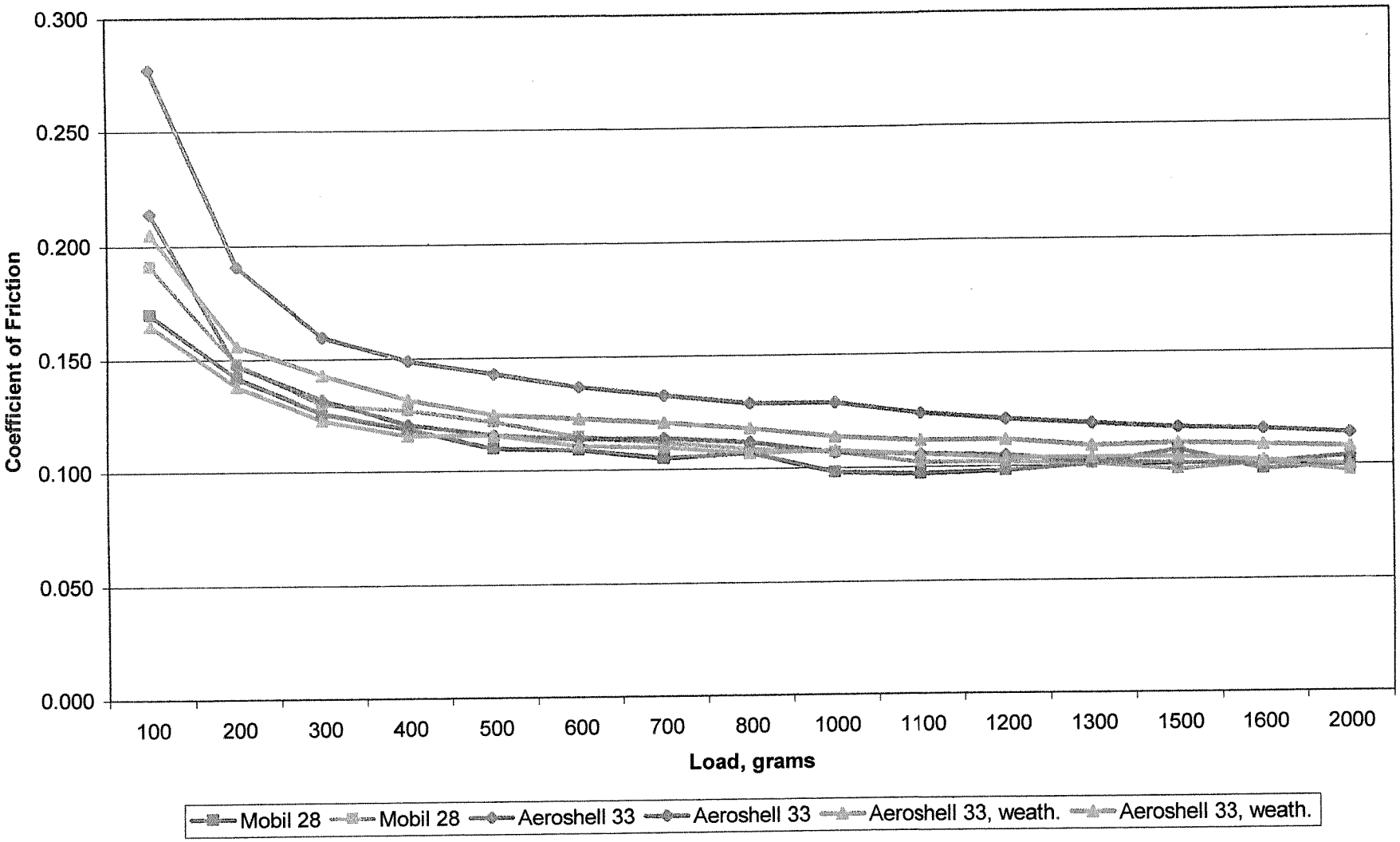
Material:	Description:	Falex ID:	Quantity:
Bronze	Block on Ring Test Block	TL-5060	31
Bronze	Timken Test Block	TL-5061	29
Bronze	Thrust washer, rotating	TL-5172	28
Bronze	Pin on Disk, pin	TL-5175	12
Bronze	3 Ball Micro-film, upper	TL-5174	13
Bronze	3 Ball Micro-film, lower	TL-5173	12
4140 steel	Test Ring	TL-5150	33
4140 steel	Thrust washer, lower	TL-5164	30
4140 steel	Pin on Disk, disk	TL-5165	23
4140 steel	Timken Test Ring	TL-5166	61

The finished steel specimens were then coated with a black oxide process per the client's requirements by HMQ Metal Finishing Group, LLC, Herkimer, NY.

In addition to conducting identical tests as determined in Part A, this part also investigated pressure conditions to determine deviations to wear and friction performance.

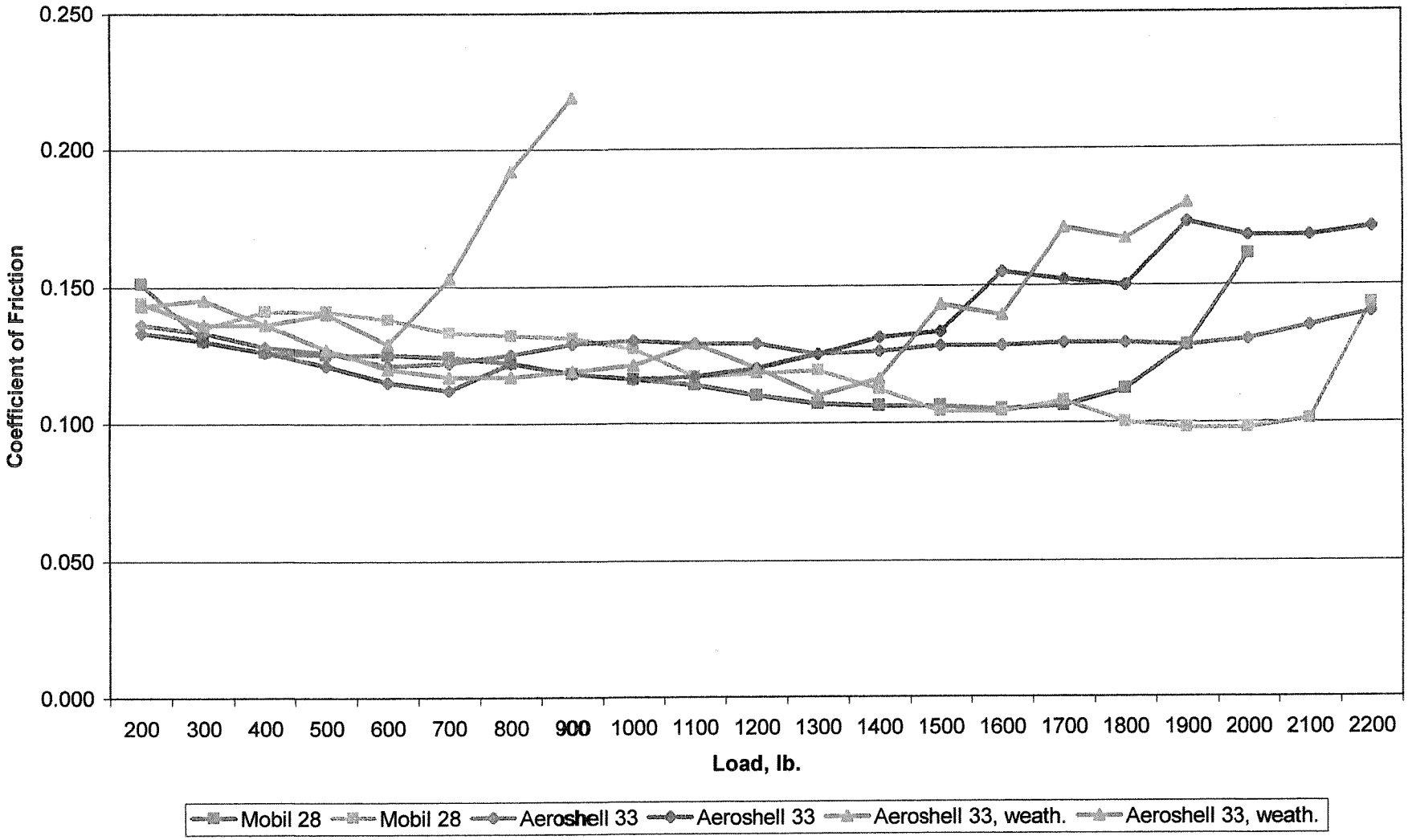
CoF vs Load

Bronze vs steel, pin on disk geometry



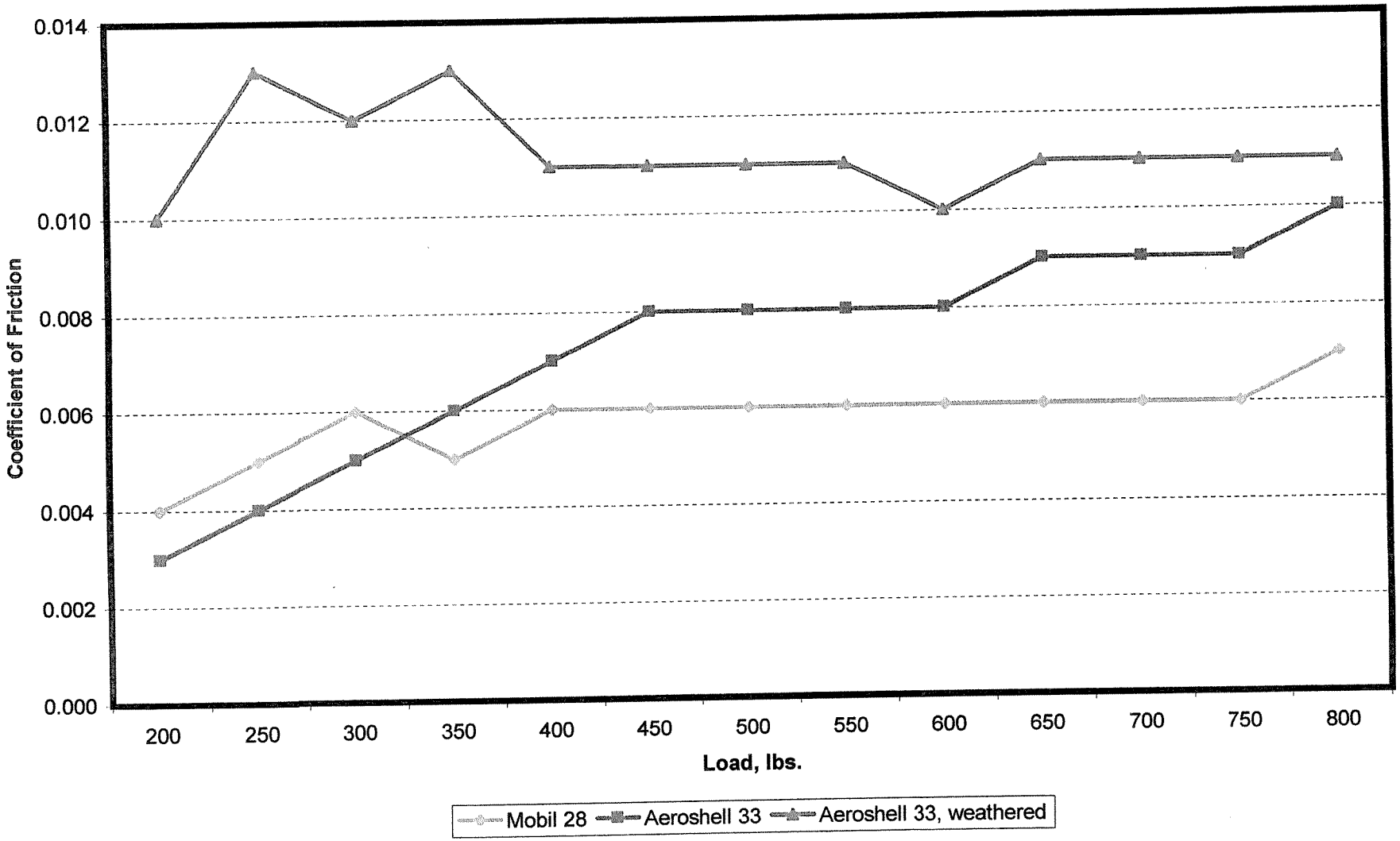
Cof vs Load

Bronze vs steel, thrustwasher geometry



CoF vs Load

Al Bronze vs. Oxide Coated Balls, 3 Ball Micro-film Geometry



Interim Test

Prior to starting Part B, an interim study was conducted using the block on ring configuration. Bronze test blocks were tested versus oxide coated standard steel test rings (SAE 4620 steel). This preliminary study was performed to investigate wear when de-icing fluid and a combination of de-icing fluid and water was applied during testing. The ARCO de-icing fluid was applied using a spray mist to deliver 2.5 ml per application. The fluid was applied prior to starting the test, and at 20-minute intervals thereafter. A total of 3 applications were performed for each test. This application technique was used for all tests performed with de-icing fluid. The last condition tested included introducing adding salt water to the test at the same intervals as the de-icer. 2.7 ml of salt water was added for this test condition.

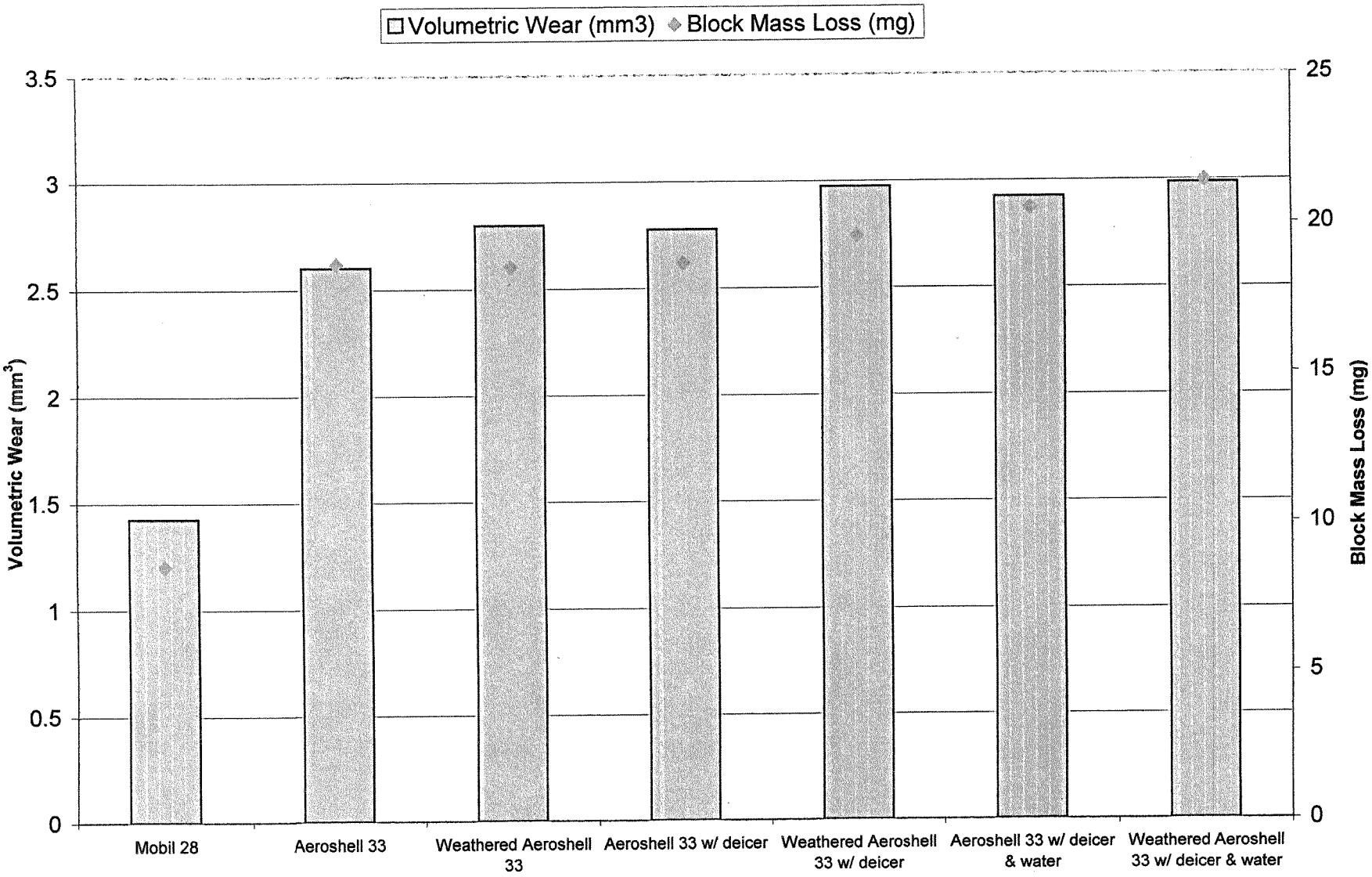
A summary graph showing the volumetric wear of the test block follows. ARCO de-icing fluid caused an increase in wear of approximately 6.5% to the Aeroshell 33 and Aeroshell 33 weathered grease. Introduction of salt water also caused an increase in wear, but to a lesser extent. A 5.3% increase in wear was seen with the Aeroshell 33 grease and 0.5% increase to the Aeroshell 33 weathered grease was experienced.

Summary of Part B:

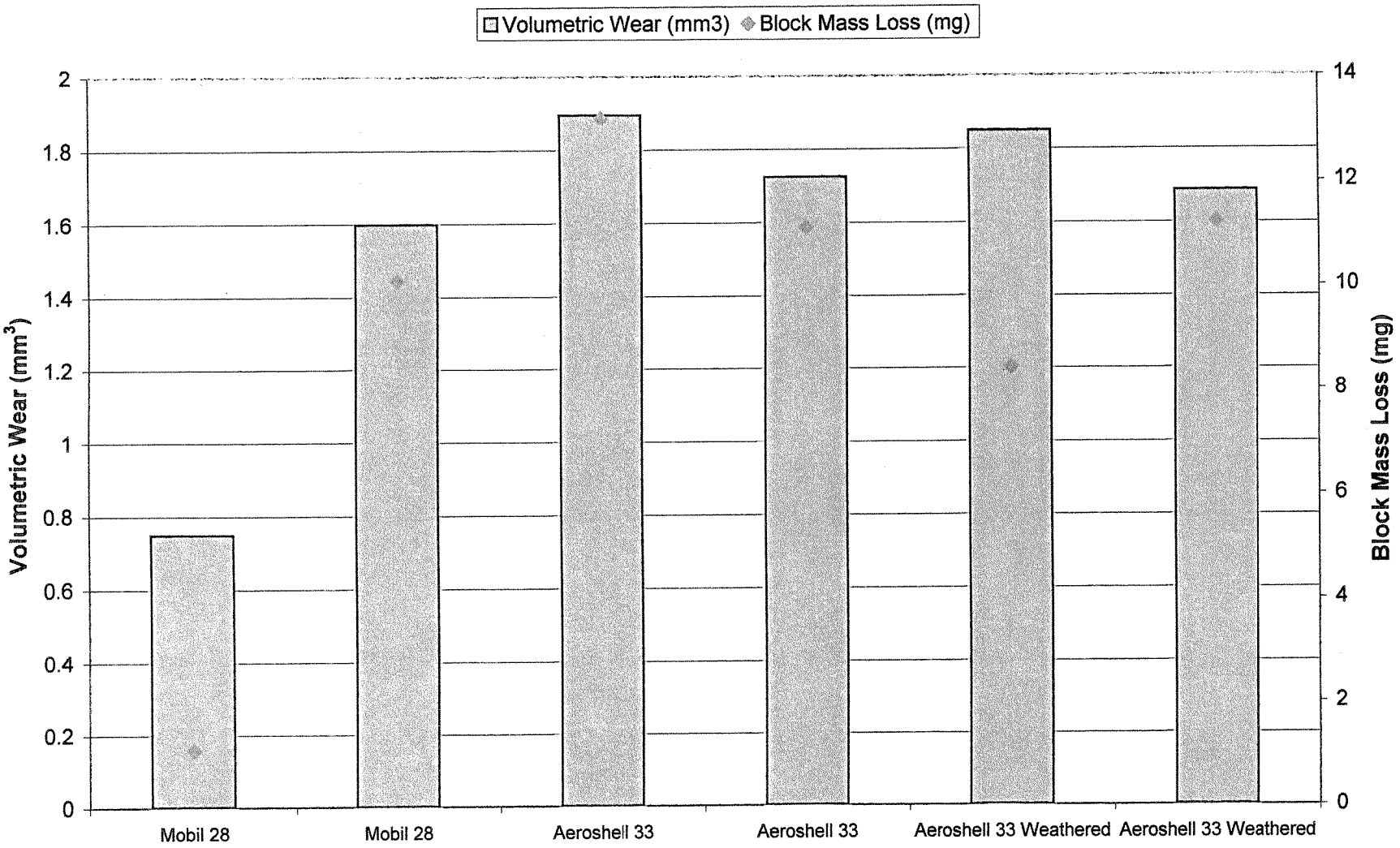
Test Method:	Mobil 28	Aeroshell 33	Aeroshell 33 weathered
Block on Ring Test:			
Block Scar Width (mm)	3.3300	3.9065	3.8745
Final contact pressure (psi)	11,159	9,366	9,442
Timken Test:			
Load (lb)	30	30	30
Scar width at load (mm)	3.9515	5.5775	5.2305
Pin on Disk Test:			
Final CoF	0.123	0.134	0.135
Thrust Washer Test:			
Contact pressure (psi) at torque increase	9,750	8,250	5,750
Three Ball Microfilm Test:			
Friction, as load increases	Level	Increasing	Level, high

Summary graphs for the Pin on Disk, Thrust washer, and Three Ball Micro-film tests are included for review to observe trends.

Interim Test Results
Block on Ring Geometry



Part B
Block on Ring Geometry
360 Lb. Load



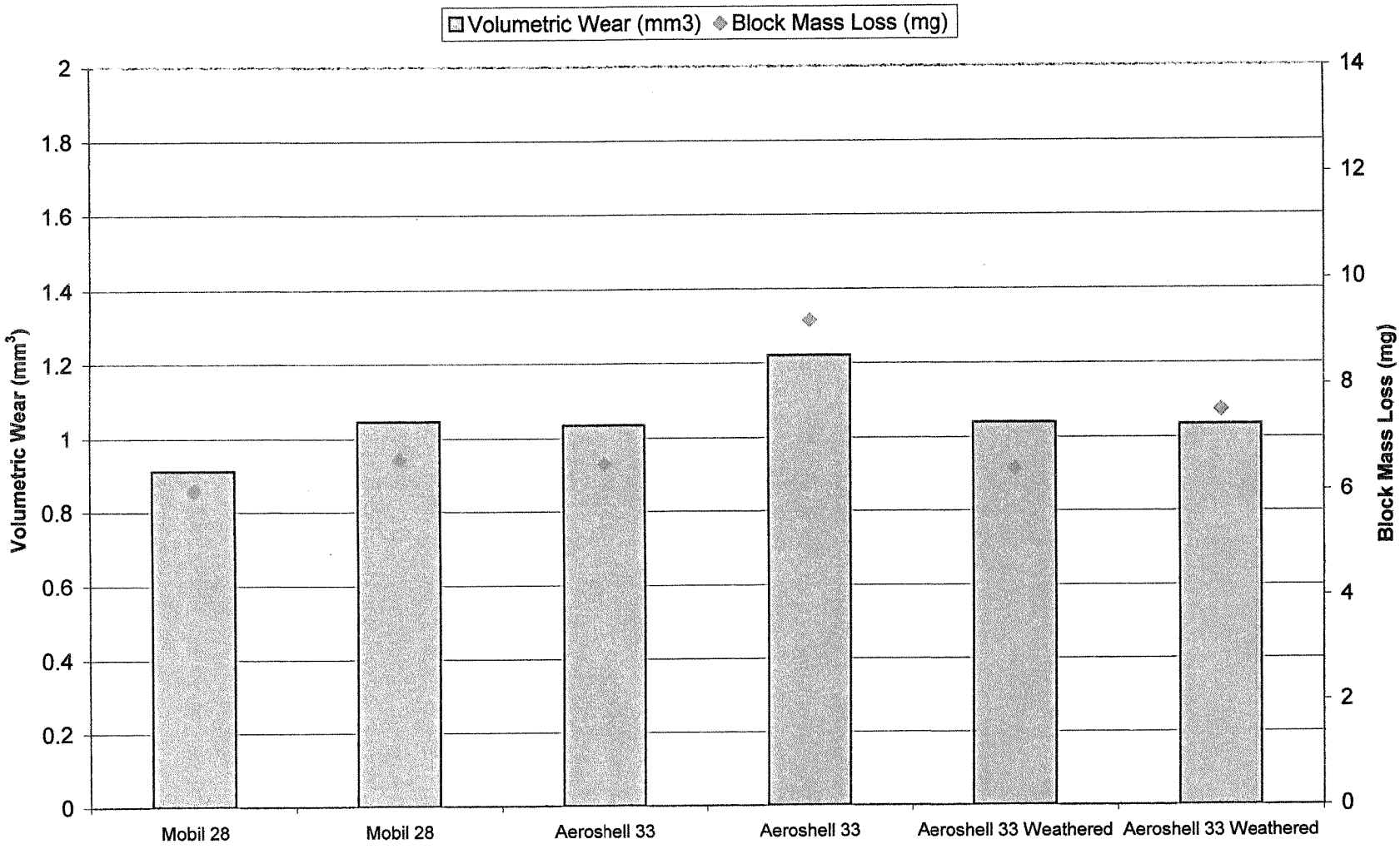
The block on ring test geometry and the thrust washer geometry were used further to study the effects of pressure differences on the performance of the greases.

Summary of Part B, pressure conditions

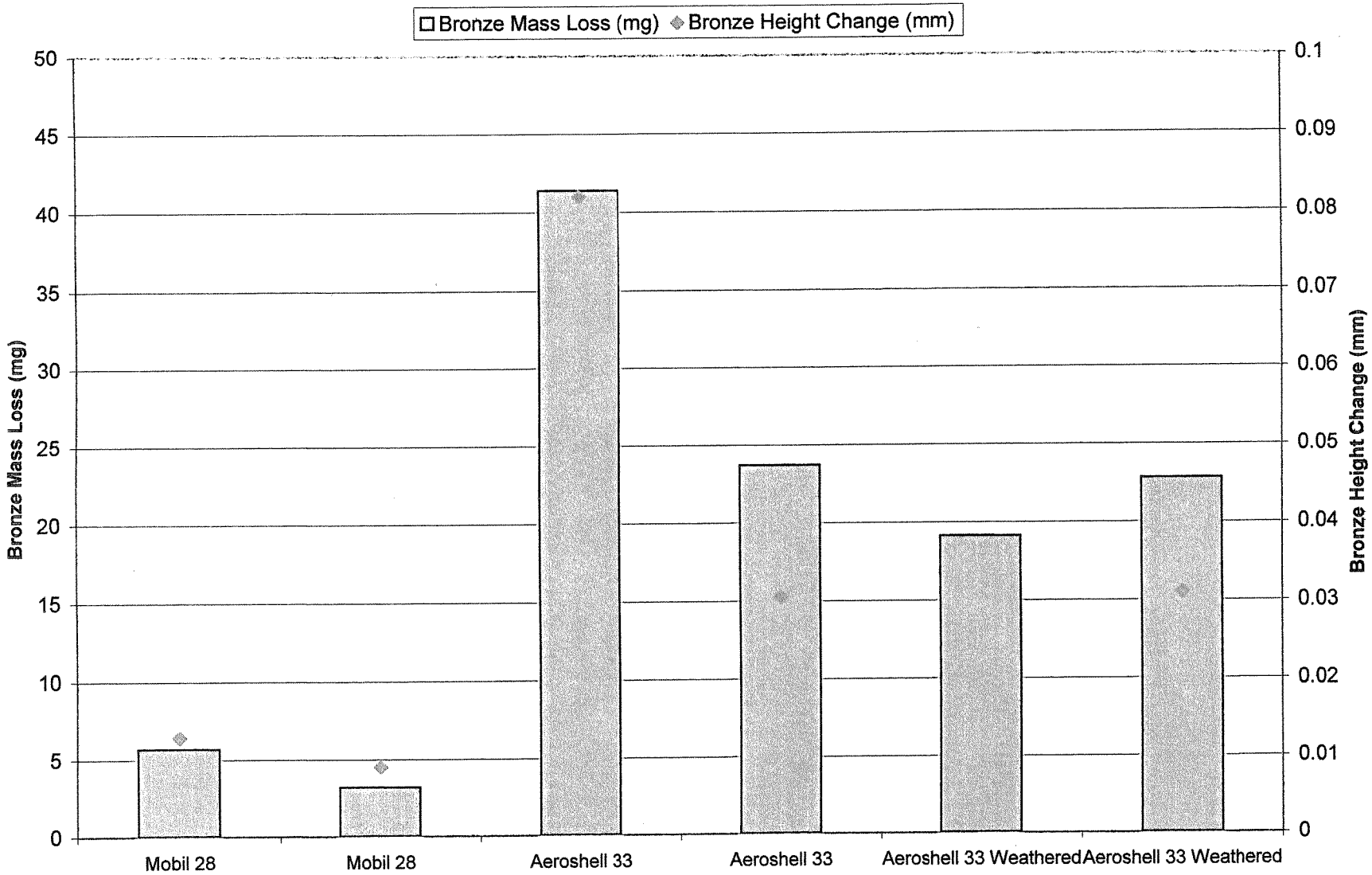
The block on ring tests were conducted at one-half the load of previous tests. The thrust washer tests were conducted at a constant load of 1520 pounds (7600 psi) for a 24-hour duration.

Test Method:	Mobil 28	Aeroshell 33	Aeroshell 33 weathered
Block on Ring Test:			
Block Scar Width (mm)	3.1815	3.080	3.245
Final contact pressure (psi)	5,751	5,954	5,636
Block on Ring Test **(2 mm/sec)**			
Block Scar Width (mm)	2.980	3.066	
Final contact pressure (psi)	6,137	5,965	
Thrust Washer Test:			
Bronze mass loss, mg	4.5	32.6	21.0
Steel mass loss, mg	1.8	1.9	1.5

Part B, Pressure Conditions
Block on Ring Geometry
180 Lb. Load



Part B, Pressure Conditions
Thrust Washer Geometry



Part C summary

	Block on Ring	Thrust Washer	3 Ball Micro-film
De-icer added:			
Mobil 28	3.946 mm scar 9,273 psi		See Chart
Aeroshell 33	3.881 mm scar 9,425 psi		
Aeroshell 33 weathered	3.9525 mm scar 9,262 psi	16.55 mg loss	See Chart
½ load condition: Aeroshell 33 weathered	3.153 mm scar 5,801 psi		
At 95°C			
Aeroshell 33 weathered	4.026 mm scar 9,085 psi		See Chart
At 95°C with water			
Mobil 28	3.2590 mm scar 11,138	12.3 mg loss	
Aeroshell 33	3.9115 mm scar 9,360	35.5 mg loss	
Aeroshell 33 weathered	4.0275 mm scar 9,082 psi	32.0 mg loss	

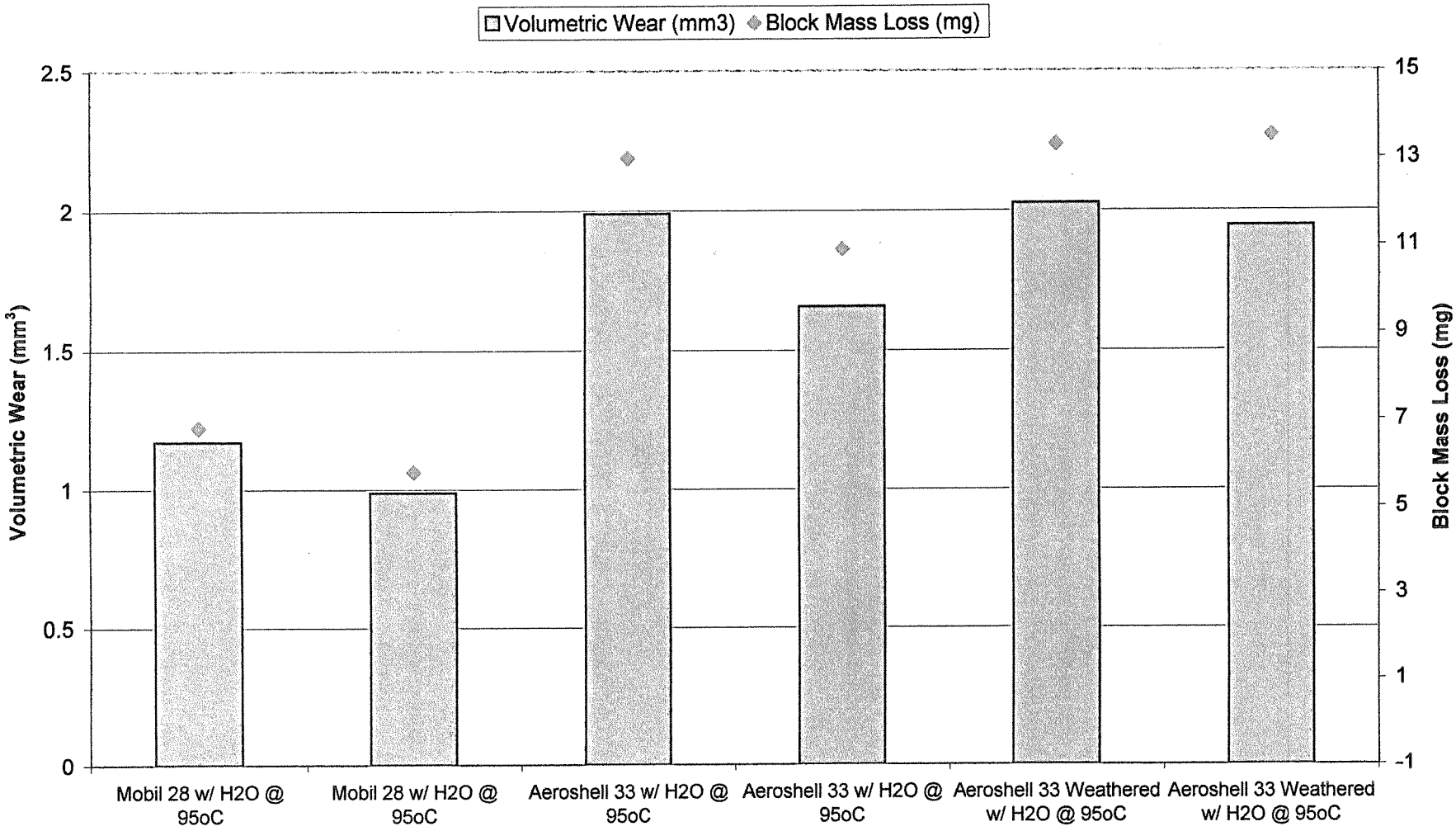
Tests were conducted to investigate the wear of the bronze component under various load levels when Mobil 28 and Aeroshell 33 were applied prior to the test. Tests were conducted using the same test parameters as the previous test phase:

Speed: 5 rpm (0.28 in/sec)
Duration: 24 hours
Temperature: 72F, ambient conditions
Lubricant: Mobil 28 or Aeroshell 33, 3 grams applied
Test Specimens:
Upper (rotating): Aluminum bronze
Lower (stationary): Oxide coated 4140 steel

The test load was reduced from the original test load of 1520 pounds. The load was reduced to 760, 380, 190, and finally, to 95 lb. The results can be seen in the summary graph on the next page.

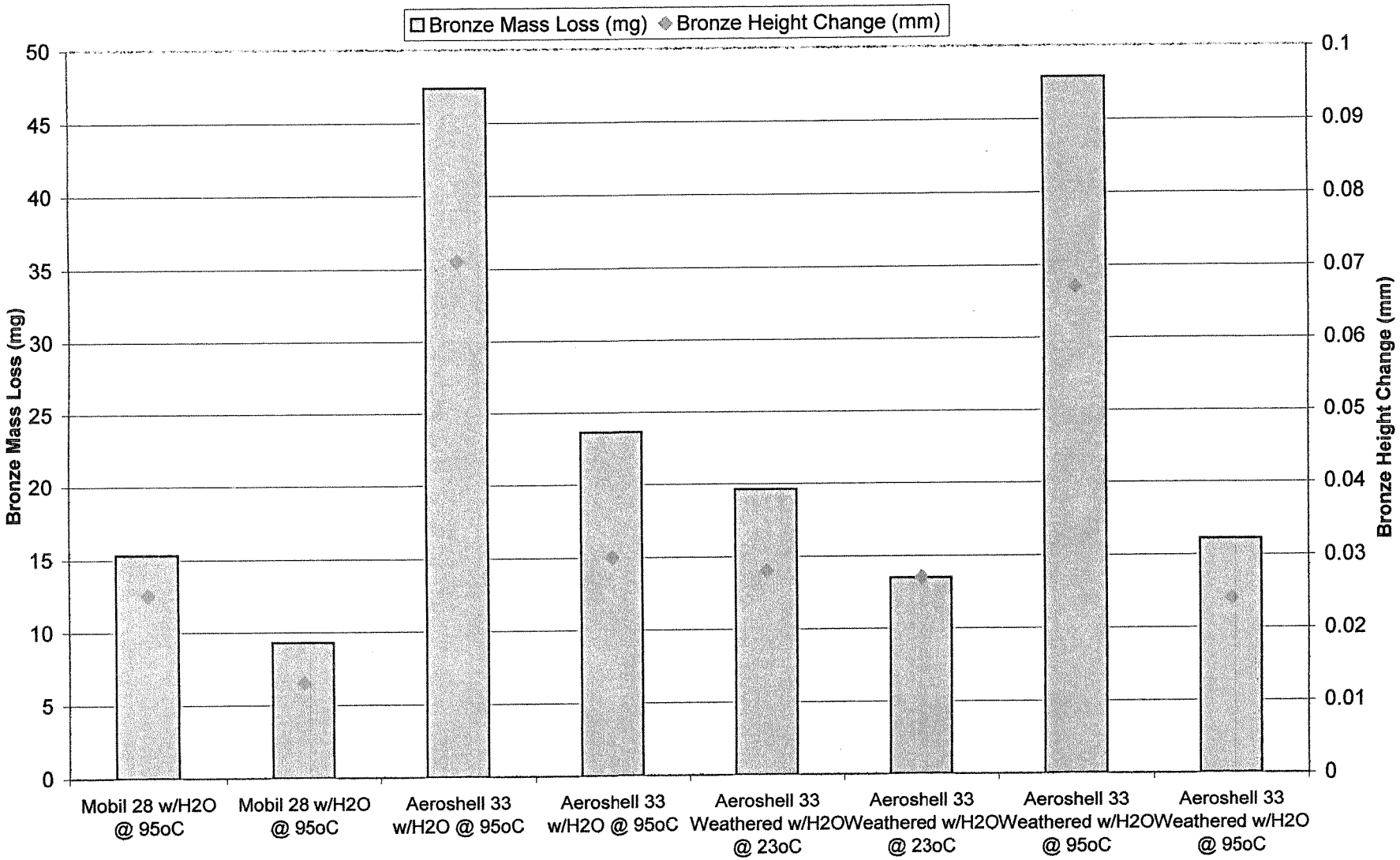
Due to the low wear at the 95 lb load stage, the test duration was extended an additional 24 hours. The data from this 48-hour test is not included with the summary graph. A separate graph showing the wear of the bronze test piece with the Aeroshell 33 grease and the Mobil 28 grease follows.

Part C
Block on Ring Geometry



Part C

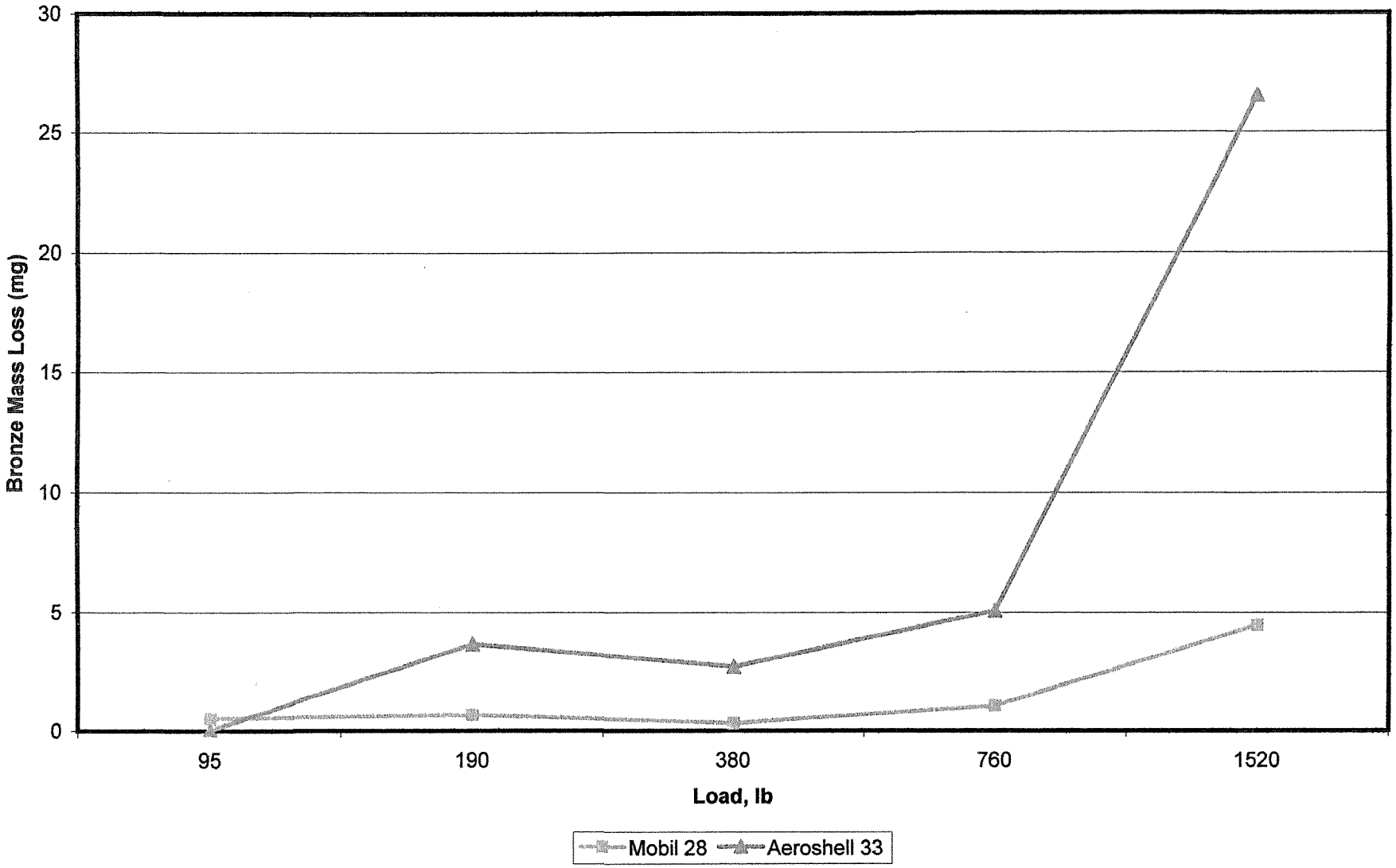
Thrust Washer Geometry



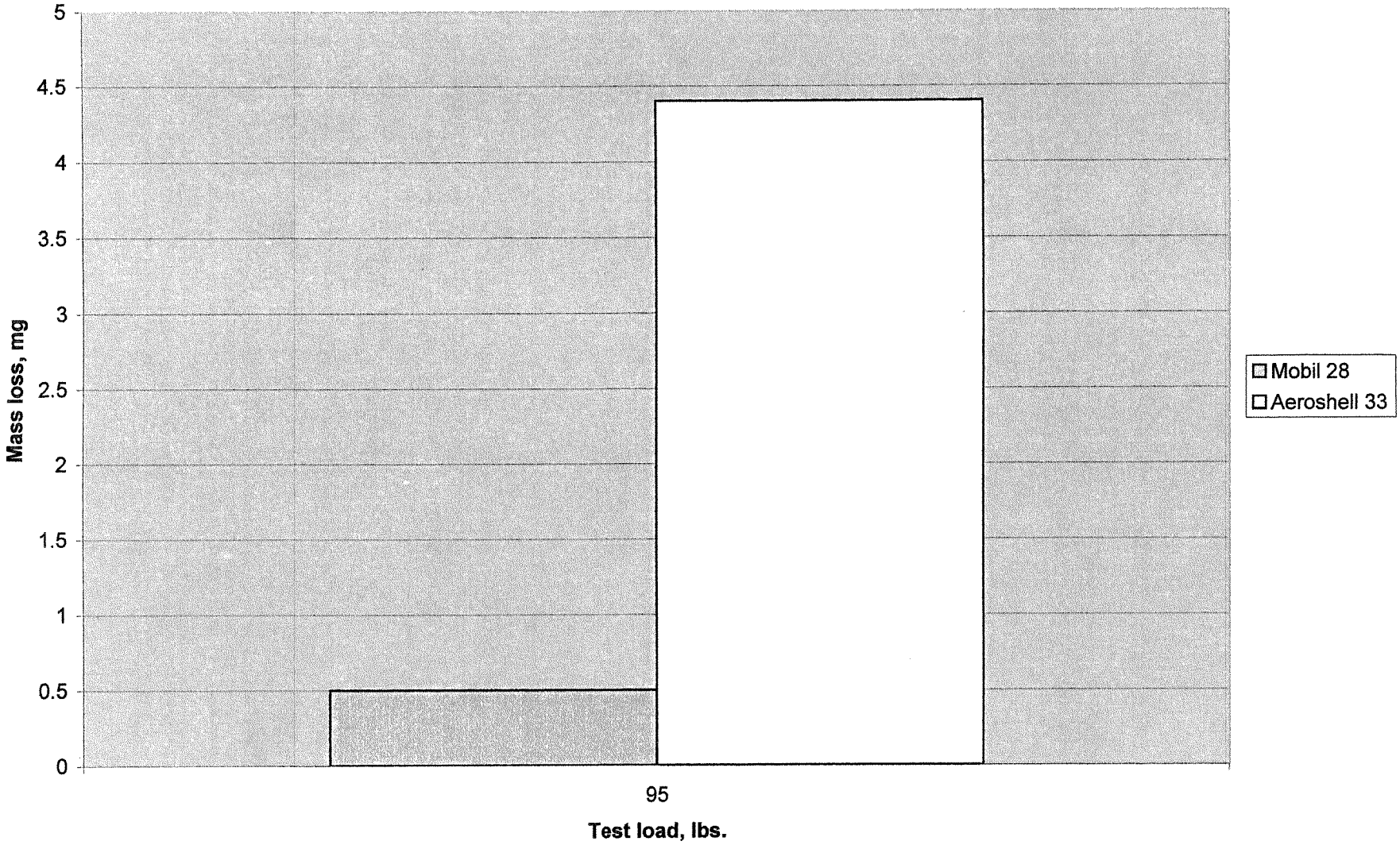
CoF vs Load

Al Bronze vs. Oxide Coated Balls, 3 Ball Micro-film geometry

Mass loss vs Load



Mass loss vs Load



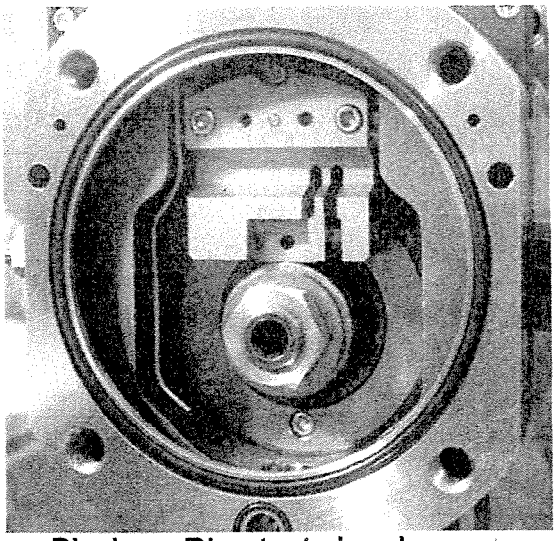
A description of the test equipment used in the study follows. This information provided for background information only. Some test configurations described were not part of the grease study.

Block on Ring Test Machine

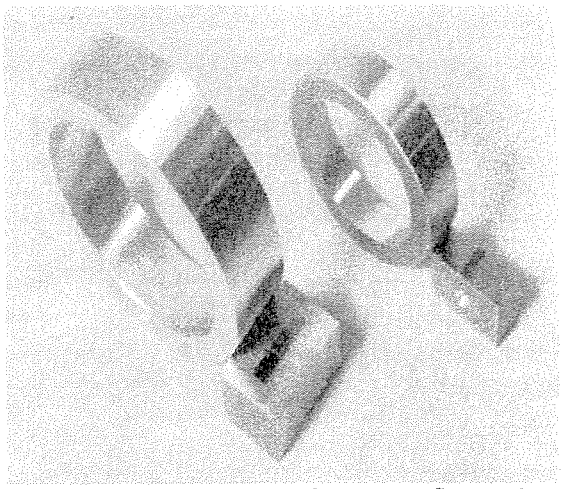
Applicable ASTM Test Methods:

- ASTM G77, "Ranking Resistance of Materials to Sliding Wear Using the Block-on-Ring Wear Test."
- ASTM D3704, "Wear Preventive Properties of Lubrication Greases Using the (Falex) Block on Ring Test Machine in Oscillating Motion."
- D2714, "Calibration and Operation of the Falex Block-on-Ring Friction and Wear Testing Machine."
- D2781, "Wear Life of Solid Film Lubricants in Oscillating Motion
- G137, "Ranking Resistance of Plastic Materials to Sliding Wear Using a Block-on-Ring Configuration."

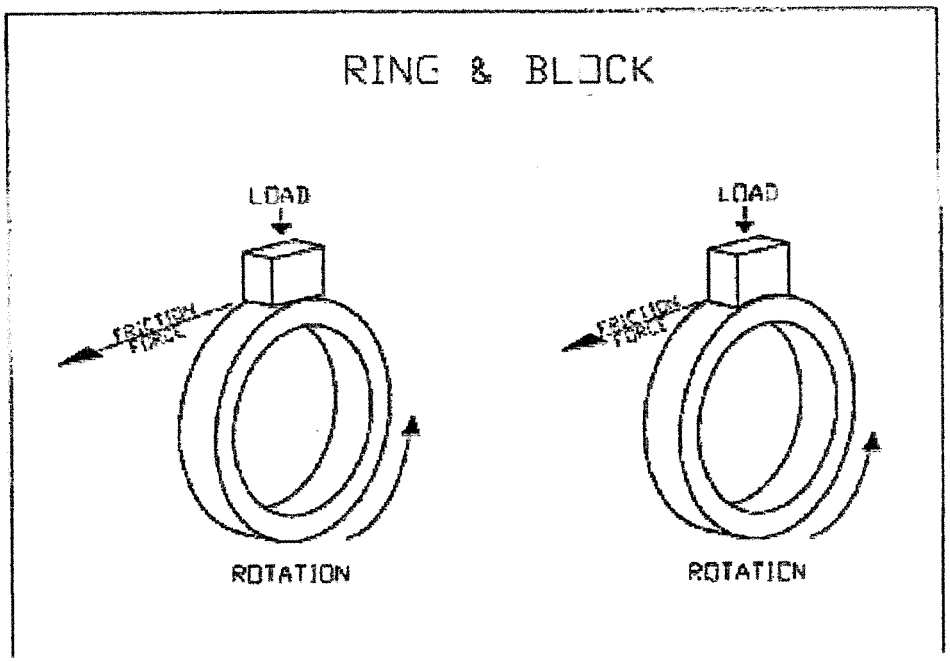
The Block-on-Ring test machine is a research tool primarily used to determine wear rates of materials in pure sliding motion. The tester is designed to accommodate different test fixtures to effect point, line, ellipsoid and area contact. The standard block-on-ring test uses a rectangular block on a rotating ring and starts as Hertzian line contact. As motion begins, a load carrying bearing surface forms, allowing the formation of anti-wear and/or EP films to form on the surface. The wear scar width is measured and reported at the end of the test. A table in ASTM G77 gives block scar volumes for measured wear scar widths. Oscillating drive mechanisms can be installed to effect reciprocating (back and forth) motion. This motion is used test methods for evaluating greases and bonded film lubricants. With increasing loads, monitoring the friction force of lubricants containing EP additives has shown good correlation with predicting load limits obtained from more sophisticated component tests. Area tests, which simulate journal-bearing applications, are affected on this test machine using the conforming or curved test block. This configuration is most effective when testing polymeric materials. When testing under area contact, it is advisable to perform an initial break-in to achieve complete contact between the mating surfaces. If complete contact is not achieved, limited contact will give higher than desired pressures on the contacting areas resulting in premature failure.



Block-on-Ring test chamber



Block on Ring Test piece configuration
Timken size (left); Falex size (right)



Block on Ring schematic Diagram

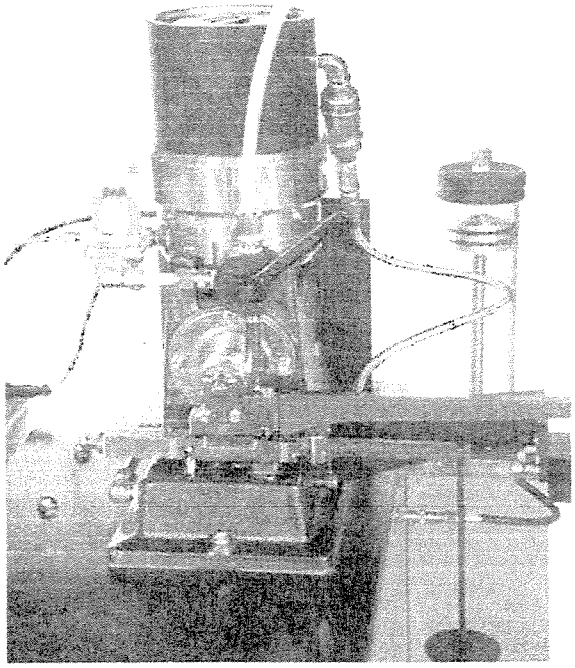
High Pressure (rectangular) block (left)
Low pressure (conformal) block (right)

Timken Test Machine

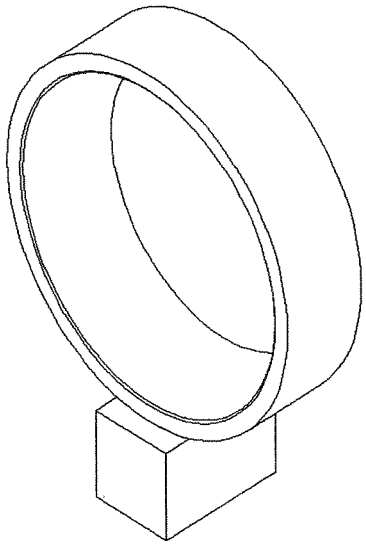
Applicable ASTM Test Methods:

- D2509, "Measurement of Load Carrying Capacity of Lubricating Grease"
- D2682, "Measurement of Extreme Pressure Properties of Lubricating Fluids"

The Timken Extreme Pressure (EP) Test Machine was developed in 1932 to measure load carrying capacity of EP lubricants for use in steel production. It is a block-on-ring type test and is called out in many specifications for oils and greases requiring extreme pressure properties or high levels of load carrying ability. This tester is designed to evaluate lubricants for low, medium and high levels of extreme pressure for lubricating greases [D2509] and fluids [D2782]. The test is carried out by running a series of 10-minute duration test runs at increasing test loads to the point where scoring or seizure occurs on the wear scar and is considered a failure. This failure mechanism is evidenced by lines that extend past the edge of the wear scar (scoring) or by jagged irregularities (scuffing). The tester is designed to provide friction data by balancing the lower friction arm with the upper load arm. Through the use of the equation listed below, the coefficient of friction is calculated.

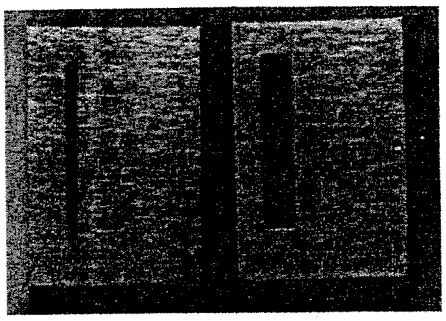


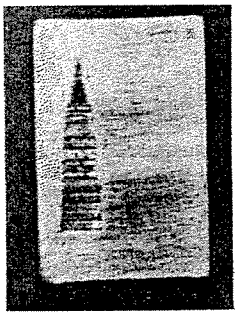
Timken Test Machine



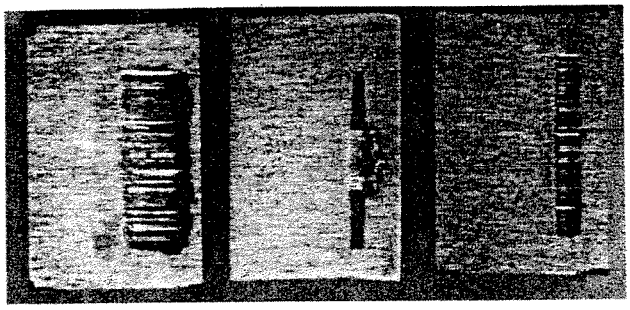
Timken Ring and Block configuration

Typical OK
No Scoring





Improper Setup



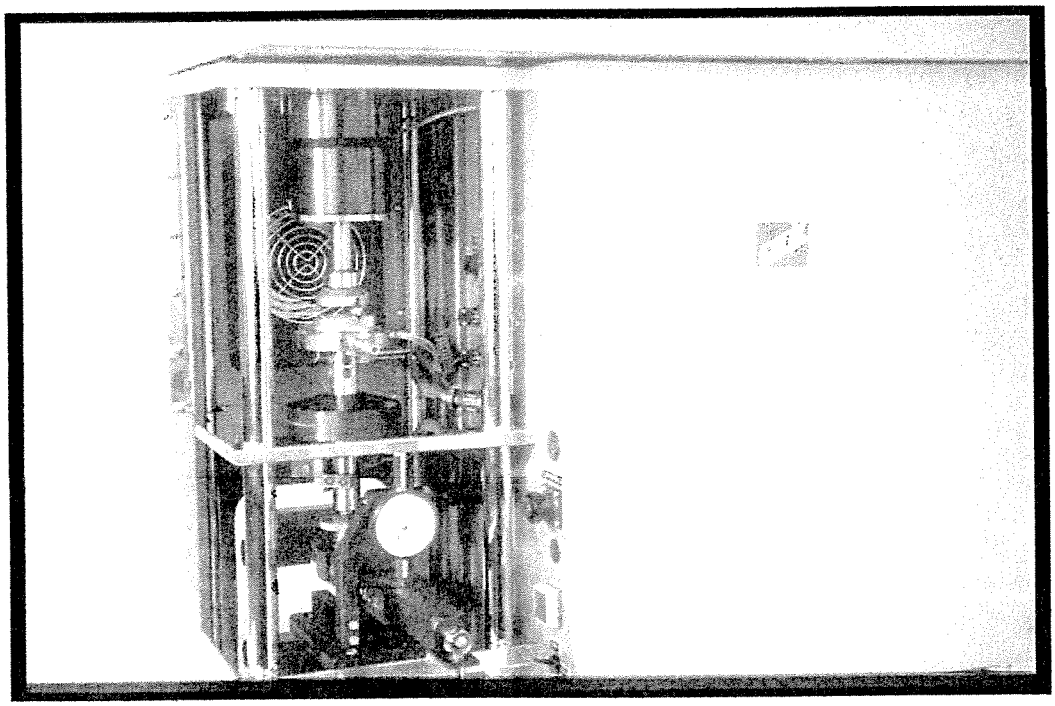
Scoring (failure)

Typical Timken test Wear Scars

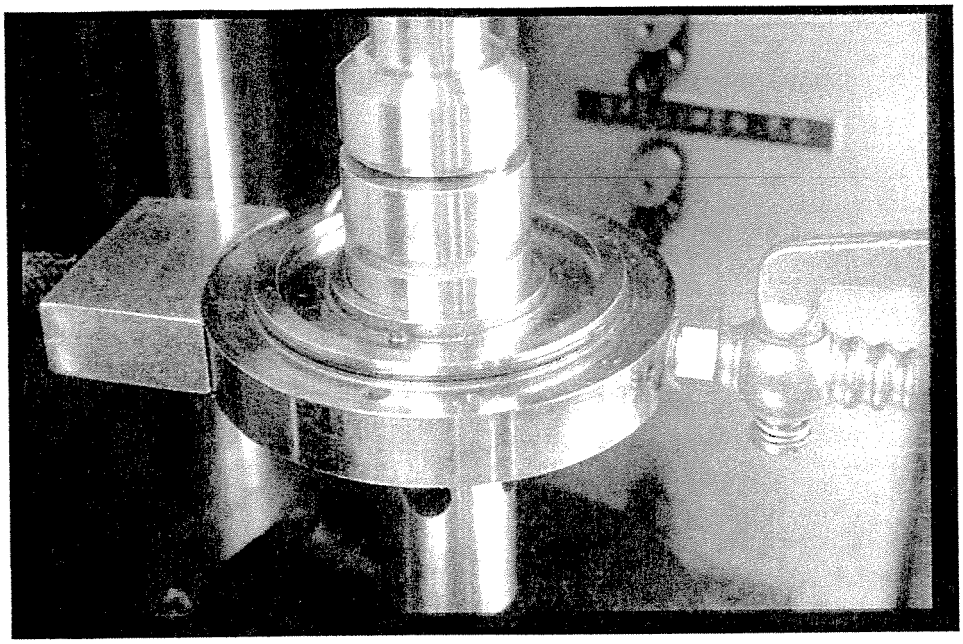
Multi-Specimen Test Machine

The Multi-Specimen test machine is designed to be a versatile tribology research test apparatus. It consists of two opposed, vertical test shafts. One rotates; the other is stationary. It is called Multi-Specimen because of the use of different adapters that can be placed between the opposing vertical shafts. These adapters are used to simulate many different tribological configurations. The Multi-Specimen can measure friction and wear under point, line and area contacts, in pure sliding, pure rolling, or combination roll/slide motion in unidirectional or oscillation studies. Because a lubricant is another parameter for the tribological system, virtually any of the adapters can accept a lubricant to determine its effect on friction and wear of the selected tribological system.

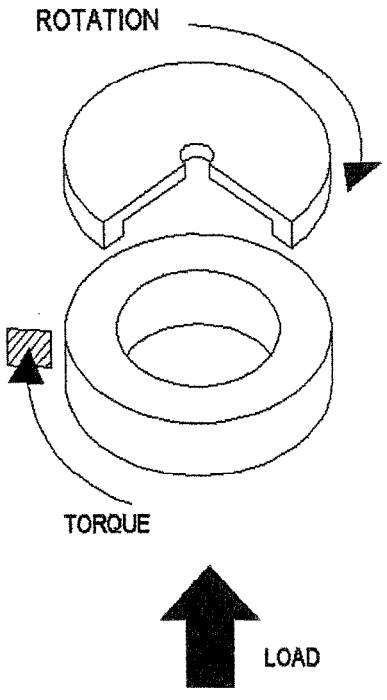
The most common adapter is the thrust washer. This adapter evaluates friction and wear properties of materials and lubricants under pure sliding motion and area contact. A break-in period is required to insure complete contact between the mating surfaces. This is verified visually. When using the thrust washer configuration for testing a lubricant for friction and wear properties, the lubricant is "squeezed" between the contacting surfaces, forcing excess lubricant out of the contact area. Only the residual lubricant remains in the contact zone. This is a good test for evaluating lubricants and lubricant chemistry in a starved lubrication system. A starved lubrication system is one where the lubricant is not replenished during the test.



Falex Multi-Specimen Test Machine



Thrust Washer test in testing position on the Falex Multi-Specimen Test Machine



Schematic Diagram of Thrust Washer Configuration

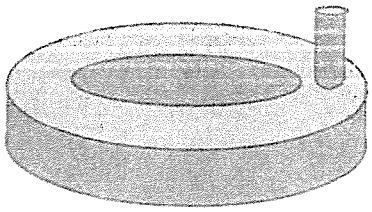
Pin on Disk Test Machine

Applicable ASTM Test Methods:

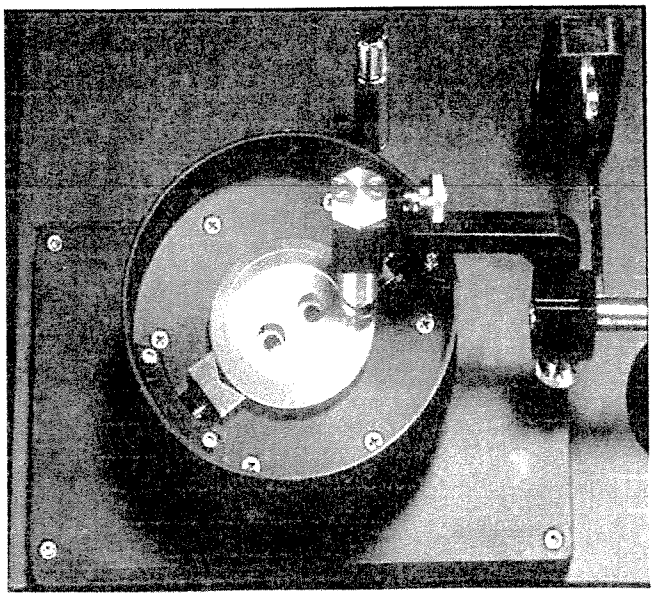
- ASTM G99, "Wear Testing with a Pin-on-Disk Apparatus."

Pin-on-Disk testing is the most commonly used wear test for determining comparative frictional properties and wear rates of material pairs in pure sliding motion. It consists of a rotating disk upon which is loaded a pin or ball. The pin can be radiused or flat. In the simplest version, the ball rotates over the same wear scar. Other mechanisms can be incorporated such that the pin or ball comes in contact with an untouched portion of the rotating disk. This results in a spiral type of wear track.

In wear evaluations, as wear progresses, material can be removed from the pin or ball and/or from the disk. Under some conditions, the material can be transferred from one piece to the other. Therefore, as with any wear test, both pieces should be examined for wear or material transfer. The pin or ball can be evaluated by measuring the diameter of the wear scar. Observations of material transfer should also be noted. The wear scar on the disk can be characterized by a profilometric trace across the surface to determine depth and width of the wear scar or by another surface characterization method.



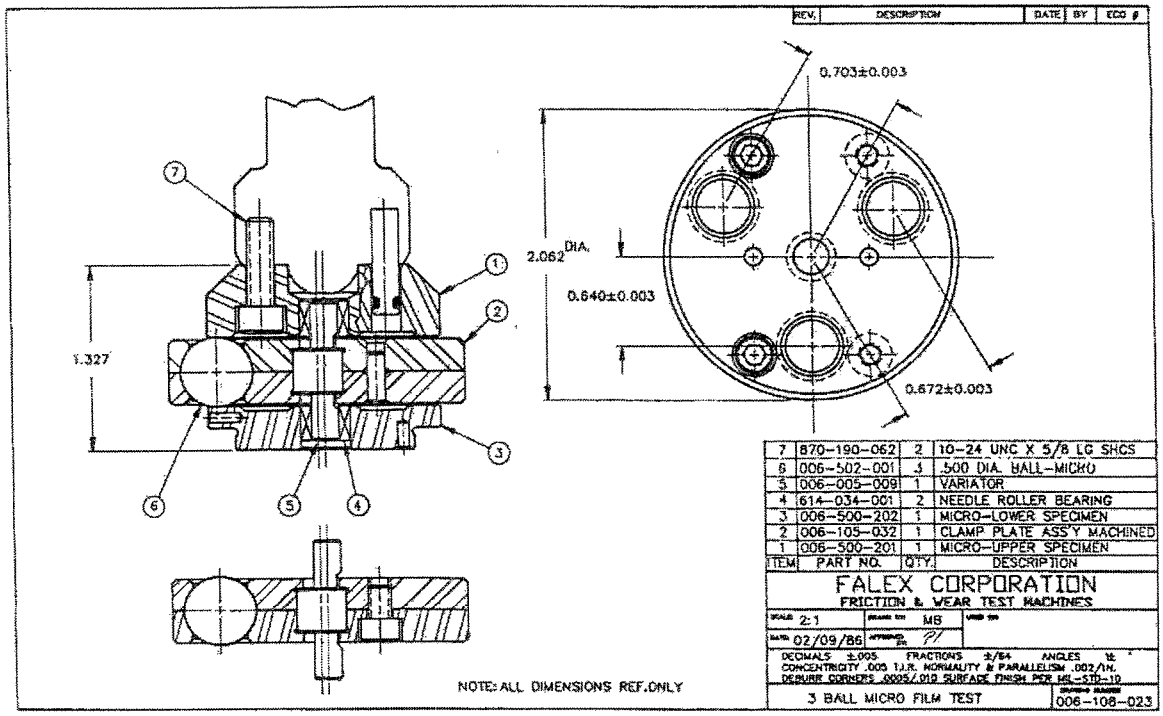
Pin-on-Disk schematic



Top view photo of Falex ISC Pin on Disk Test Machine used in the grease study.

Three Ball Micro Film Test

This test measures the film strength of lubricants and the threshold load value where the lubricant breaks down. The adapter holds three 1/2" test balls at three slightly different radii. It is attached to the upper shaft of the Multi-Specimen Test Machine. It is designed to roll and slide balls in a new track against the rotating upper and the stationary lower disk with each revolution to ensure full fluid film, up to the threshold limit. Threshold limit is indicated by a rise in the torque.



Assembly Drawing showing Three Ball Microfilm Adapter

Company:	**Dombroff & Gilmore**	Page:	9
Date:	10/19/01	Project #:	01-111
Technician:	M. Rapp		

Test Method:	ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine:	Falex Block on Ring Test Machine
Serial #:	800135004198

Testing Specimens:

Sample ID:	**Mobil 28**
Falex ID #:	4944
Block Type:	HP Test Block
Material:	Supplied Bronze, A
Finish (μin):	32
Hardness (BHN):	112-123
Falex ID #:	5060
Ring Type:	Falex S-25 w/ black oxide coating
Material:	SAE 4620 steel
Finish (μin):	22-28
Hardness (Rc):	58-63
Falex ID #:	5062

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	10/18/01
Test Number:	0107370

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3840	21.9861
Final	7.3754	21.9858
Loss	0.0086	0.0003

Block Scar Data

Measurement 1 (mm):	3.655
Measurement 2 (mm):	3.604
Measurement 3 (mm):	3.564
Average Scar (mm):	3.608
Standared Deviation:	0.037
Coefficient of Variation (%)	1.032
Volumetric Wear (mm^3):	1.4248
Final Pressure (psi):	10,138

Company:	**Dombroff & Gilmore**	Page:	10
Date:	10/19/01	Project #:	01-111
Technician:	M. Rapp		

Test Method:	ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine:	Falex Block on Ring Test Machine
Serial #:	800135004198

Testing Specimens:

Sample ID:	**Aeroshell 33**
Falex ID #:	4948
Block Type:	HP Test Block
Material:	Supplied Bronze, A
Finish (µin):	32
Hardness (BHN):	112-123
Falex ID #:	5060
Ring Type:	Falex S-25 w/ black oxide coating
Material:	SAE 4620 steel
Finish (µin):	22-28
Hardness (Rc):	58-63
Falex ID #:	5062

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	10/18/01
Test Number:	0107371

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.4173	22.2229
Final	7.3986	22.2229
Loss	0.0187	0.0000

Block Scar Data

Measurement 1 (mm):	4.418
Measurement 2 (mm):	4.405
Measurement 3 (mm):	4.401
Average Scar (mm):	4.408
Standared Deviation:	0.007
Coefficient of Variation (%)	0.165
Volumetric Wear (mm^3):	2.6031
Final Pressure (psi):	8,298

Company:	**Dombroff & Gilmore**	Page:	11
Date:	10/19/01	Project #:	01-111
Technician:	M. Rapp		

Test Method:	ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine:	Falex Block on Ring Test Machine
Serial #:	800135004198

Testing Specimens:

Sample ID:	**Weathered Aeroshell 33**
Falex ID #:	4949
Block Type:	HP Test Block
Material:	Supplied Bronze, A
Finish (µin):	32
Hardness (BHN):	112-123
Falex ID #:	5060
Ring Type:	Falex S-25 w/ black oxide coating
Material:	SAE 4620 steel
Finish (µin):	22-28
Hardness (Rc):	58-63
Falex ID #:	5062

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	10/18/01
Test Number:	0107372

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3936	22.2332
Final	7.3750	22.2339
Loss	0.0186	-0.0007

Block Scar Data

Measurement 1 (mm):	4.596
Measurement 2 (mm):	4.543
Measurement 3 (mm):	4.407
Average Scar (mm):	4.515
Standared Deviation:	0.080
Coefficient of Variation (%)	1.763
Volumetric Wear (mm^3):	2.7985
Final Pressure (psi):	8,100

Company:	**Dombroff & Gilmore**	Page:	12
Date:	10/19/01	Project #:	01-111
Technician:	M. Rapp		

Test Method:	ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine:	Falex Block on Ring Test Machine
Serial #:	800135004198

Testing Specimens:

Sample ID:	**Aeroshell 33**
Falex ID #:	4948
Block Type:	HP Test Block
Material:	Supplied Bronze, A
Finish (µin):	32
Hardness (BHN):	112-123
Falex ID #:	5060
Ring Type:	Falex S-25 w/ black oxide coating
Material:	SAE 4620 steel
Finish (µin):	22-28
Hardness (Rc):	58-63
Falex ID #:	5062

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	10/19/01
Test Number:	0107373

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.4054	22.2245
Final	7.3867	22.2243
Loss	0.0187	0.0002

Block Scar Data

Measurement 1 (mm):	4.506
Measurement 2 (mm):	4.503
Measurement 3 (mm):	4.501
Average Scar (mm):	4.503
Standared Deviation:	0.002
Coefficient of Variation (%)	0.046
Volumetric Wear (mm^3):	2.7762
Final Pressure (psi):	8,122

Comments:

2.5ml of Arco deicer (TL# 5063) was applied three times, at start of test, 20 minutes and 40 minutes.

Company:	**Dombroff & Gilmore**	Page:	13
Date:	10/19/01	Project #:	01-111
Technician:	M. Rapp		

Test Method:	ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine:	Falex Block on Ring Test Machine
Serial #:	800135004198

Testing Specimens:

Sample ID:	**Weathered Aeroshell 33**
Falex ID #:	4949
Block Type:	HP Test Block
Material:	Supplied Bronze, A
Finish (µin):	32
Hardness (BHN):	112-123
Falex ID #:	5060
Ring Type:	Falex S-25 w/ black oxide coating
Material:	SAE 4620 steel
Finish (µin):	22-28
Hardness (Rc):	58-63
Falex ID #:	5062

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	10/19/01
Test Number:	0107374

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.4118	22.1412
Final	7.3922	22.1421
Loss	0.0196	-0.0009

Block Scar Data

Measurement 1 (mm):	4.617
Measurement 2 (mm):	4.602
Measurement 3 (mm):	4.601
Average Scar (mm):	4.607
Standared Deviation:	0.007
Coefficient of Variation (%)	0.159
Volumetric Wear (mm^3):	2.9724
Final Pressure (psi):	7,940

Comments:

2.5ml of Arco deicer (TL# 5063) was applied three times, at start of test, 20 minutes and 40 minutes.

Company:	**Dombroff & Gilmore**	Page:	14
Date:	10/19/01	Project #:	01-111
Technician:	M. Rapp		

Test Method: ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine: Falex Block on Ring Test Machine
Serial #: 800135004198

Testing Specimens:

Sample ID: **Aeroshell 33**
Falex ID #: 4948

Block Type: HP Test Block
Material: Supplied Bronze, A
Finish (µin): 32
Hardness (BHN): 112-123
Falex ID #: 5060
Ring Type: Falex S-25 w/ black oxide coating
Material: SAE 4620 steel
Finish (µin): 22-28
Hardness (Rc): 58-63
Falex ID #: 5062

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	10/19/01
Test Number:	0107375

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3905	22.2746
Final	7.3700	22.2746
Loss	0.0205	0.0000

Block Scar Data

Measurement 1 (mm):	4.589
Measurement 2 (mm):	4.567
Measurement 3 (mm):	4.586
Average Scar (mm):	4.581
Standared Deviation:	0.010
Coefficient of Variation (%)	0.213
Volumetric Wear (mm^3):	2.9222
Final Pressure (psi):	7,985

Comments:

2.5ml of Arco deicer (TL# 5063) was applied three times, at start of test, 20 minutes and 40 minutes.

2.7ml of salt water (TL# 5065) was applied three times, at start of test, 20 minutes and 40 minutes.

Company:	**Dombroff & Gilmore**	Page:	15
Date:	10/20/01	Project #:	01-111
Technician:	M. Rapp		

Test Method: ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine: Falex Block on Ring Test Machine
Serial #: 800135004198

Testing Specimens:

Sample ID: **Weathered Aeroshell 33**
Falex ID #: 4949

Block Type: HP Test Block
Material: Supplied Bronze, A
Finish (µin): 32
Hardness (BHN): 112-123
Falex ID #: 5060
Ring Type: Falex S-25 w/ black oxide coating
Material: SAE 4620 steel
Finish (µin): 22-28
Hardness (Rc): 58-63
Falex ID #: 5062

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	10/20/01
Test Number:	0107377

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.3930	22.1571
Final	7.3716	22.1571
Loss	0.0214	0.0000

Block Scar Data

Measurement 1 (mm):	4.626
Measurement 2 (mm):	4.611
Measurement 3 (mm):	4.601
Average Scar (mm):	4.613
Standared Deviation:	0.010
Coefficient of Variation (%)	0.223
Volumetric Wear (mm^3):	2.9841
Final Pressure (psi):	7,929

Comments:

2.5ml of Arco deicer (TL# 5063) was applied three times, at start of test, 20 minutes and 40 minutes.

2.7ml of salt water (TL# 5065) was applied three times, at start of test, 20 minutes and 40 minutes.

Test block is from Test #0107374. Edge with double marking is this test.

Company:	***Dombroff & Gilmore***	Page:	1
Date:	01/28/02	Project #:	02-8
Technician	N. Pekoc		

Method:	Modified Thrust Washer
Machine:	Falex High Performance Multi-Specimen Test Machine, Computer Controlled Version
Serial #:	809C350011008, 009-091-105

TEST SPECIMENS:

Upper Material:	**C95500 Al Bronze**
Finish (μ in.):	32
Hardness (HRc):	112-123
Falex ID #:	5030
Lower Material:	**AISI 4140 Steel, black oxide coated**
Finish (μ in.):	32
Hardness (HRc):	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5306

TEST CONDITIONS:

Test Speed (rpm):	5
Temperature (°C):	Ambient
Duration (hr):	24
Test Load (lb):	Varies
Mean Test Radius (in):	0.531
Contact pressure (psi):	Varies

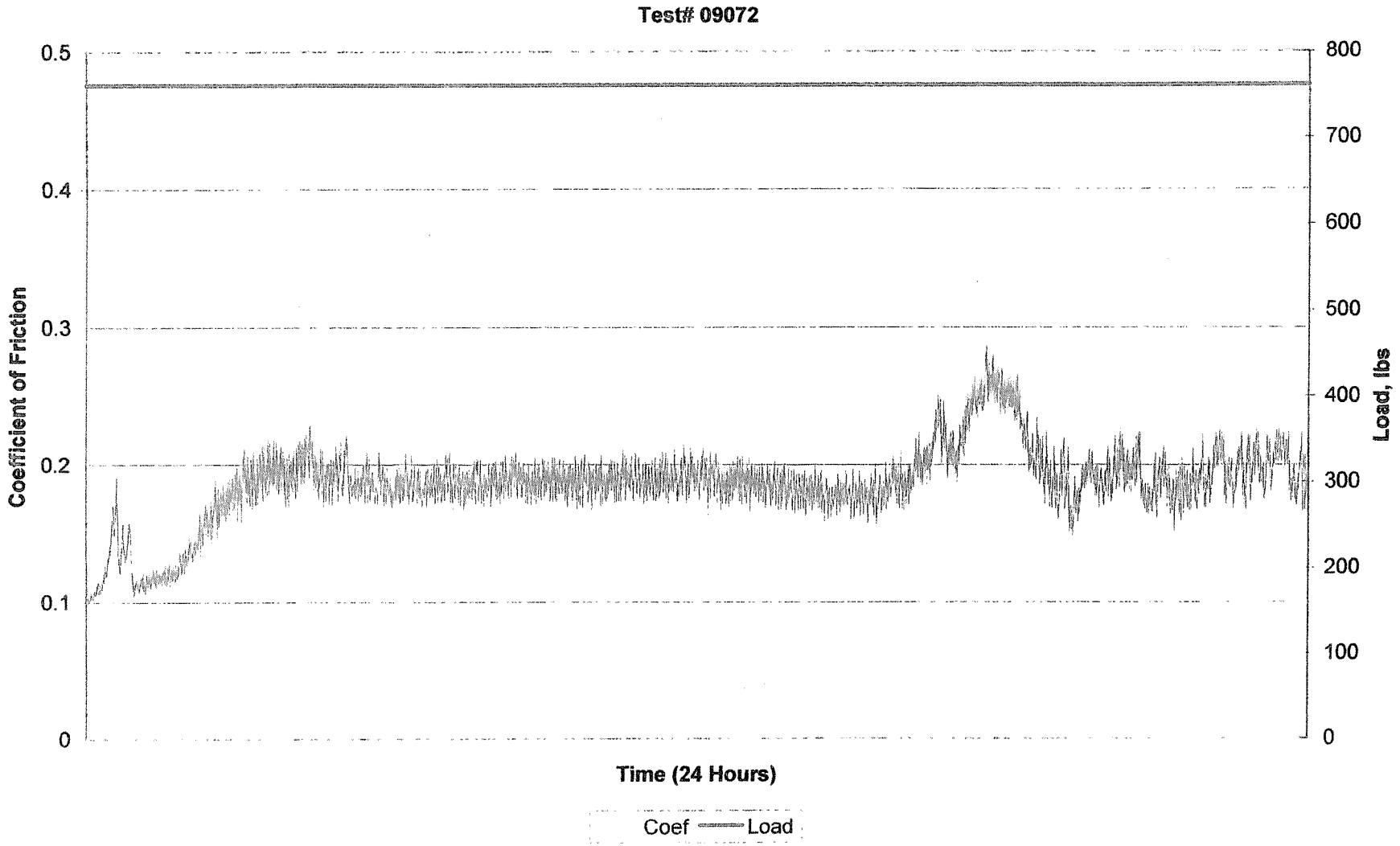
Test Results:

Test Date:	01/15/02	01/18/02	01/16/02
Test Number:	09072	9077	09074
Upper Falex ID #:	5030	5030	5030
Lower Falex ID #:	5306	5306	5306
Lubricant:	**Mobil 28**	**Mobil 28**	**Mobil 28**
Lubricant Falex ID #:	4944	4944	4944
SaveFile Name:	TDAT014-015	TDAT020-021	2dgwear01
Test Program Name:	DGTHWRT2	DGTHWRT2	D&GWEARTEST2
Load(Lb):	760	760	760
Mass Loss, Upper (mg):	1.6	1.0	0.5
Mass Loss, Lower (mg):	0.7	0.3	0.9
Bronze height change (mm):	0.0200	0.0035	0.0008

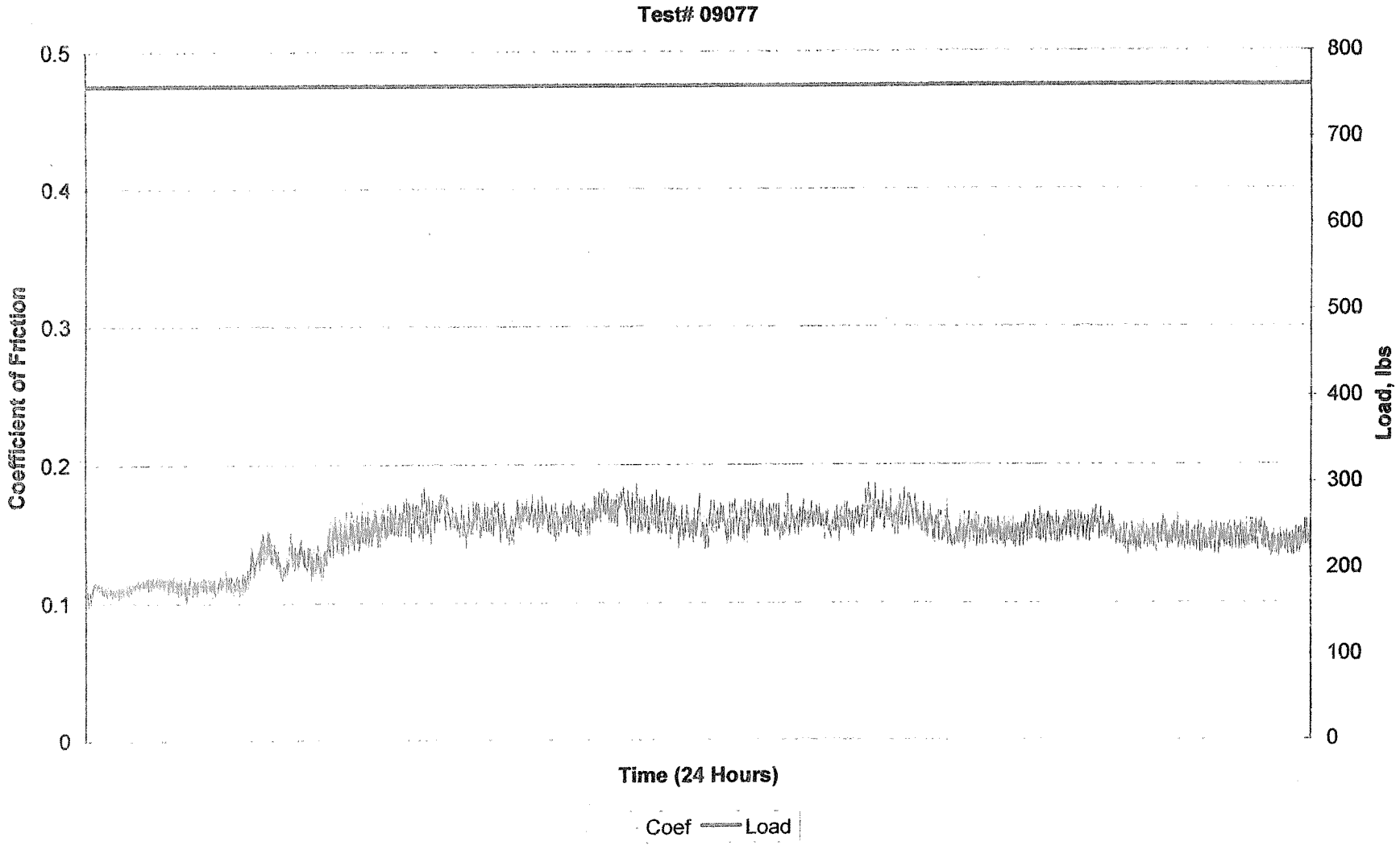
Comments: See Graphs for Torque, Friction Coefficient, Load, and Specimen Temperature trends.

Coefficient of Friction (CoF)
The dimensionless ratio of the friction force (FF) between the upper rotating material and the lower stationary material to the normal force (N) pressing these bodies together.

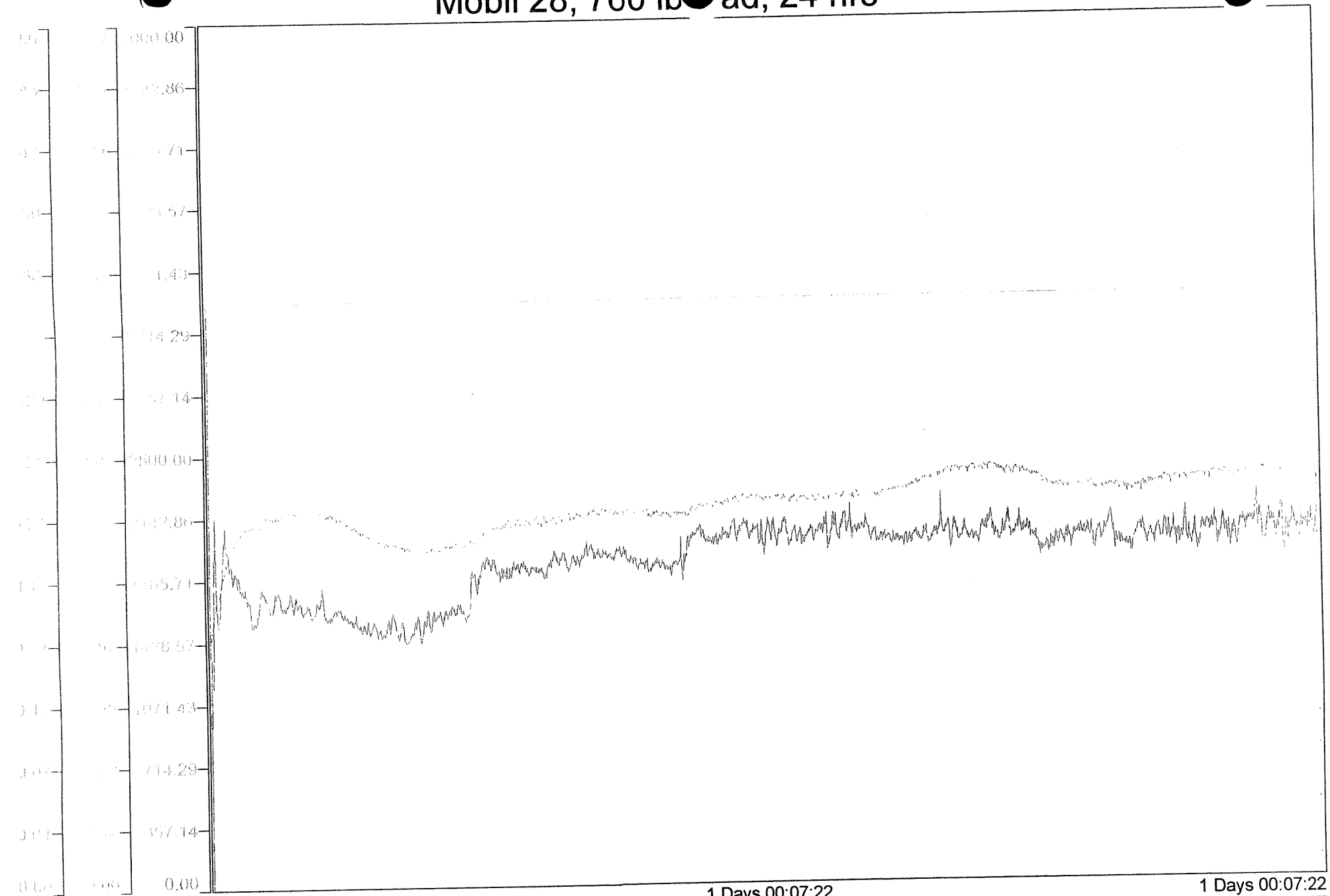
Mobil 28
Thrust Washer Geometry



Mobil 28
Thrust Washer Geometry



Mobil 28, 760 lb[illegible]ad, 24 hrs



Description	Batch Name	Scale Range	Eng. Units	1 Day 00:07:22
[illegible]ENT OF FRICTION	2dgwear01	0.00/0.50	Coef	No Data
[illegible]	2dgwear01	0.00/100.00	DEG.C	No Data
[illegible]	2dgwear01	0.00/5000.00	N	No Data

Company:	***Dombroff & Gilmore***	Page:	2
Date:	01/28/02	Project #:	02-8
Technician	N. Pekoc		

Method:	Modified Thrust Washer
Machine:	Falex High Performance Multi-Specimen Test Machine, Computer Controlled Version
Serial #:	809C350011008, 009-091-105

TEST SPECIMENS:

Upper Material:	**C95500 Al Bronze**
Finish (μ in.):	32
Hardness (HRc):	112-123
Falex ID #:	5030
Lower Material:	**AISI 4140 Steel, black oxide coated**
Finish (μ in.):	32
Hardness (HRc):	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5306

TEST CONDITIONS:

Test Speed (rpm):	5
Temperature (°C):	Ambient
Duration (hr):	24
Test Load (lb):	Varies
Mean Test Radius (in):	0.531
Contact pressure (psi):	Varies

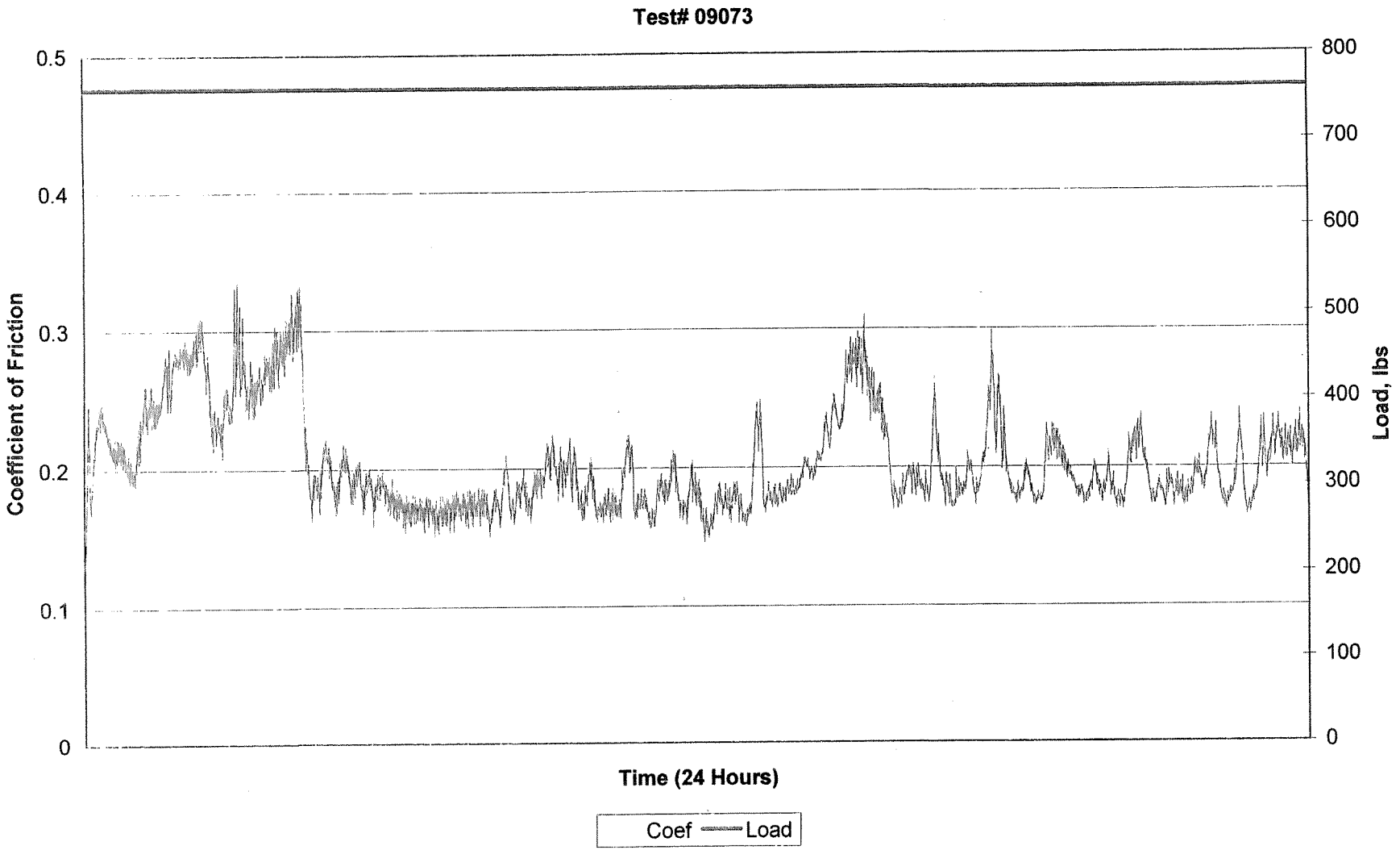
Test Results:

Test Date:	01/16/02	01/17/02	01/17/02	01/21/02
Test Number:	09073	09075	09076	09080
Upper Falex ID #:	5030	5030	5030	5030
Lower Falex ID #:	5306	5306	5306	5306
Lubricant:	**Aeroshell 33**	**Aeroshell 33**	**Aeroshell 33**	**Aeroshell 33**
Lubricant Falex ID #:	4948	4948	4948	4948
SaveFile Name:	TDAT016-017	TDAT018-019	2dgwear02	TDAT022-023
Test Program Name:	DGTHWRT2	DGTHWRT2	D&GWEARTEST3	DGTHWRT3
Load(Lb):	760	760	380	380
Mass Loss, Upper (mg):	4.8	5.3	3.9	1.3
Mass Loss, Lower (mg):	0.5	+0.3	0.6	1.8
Bronze height change (mm):	0.0085	0.0115	0.0060	0.0043

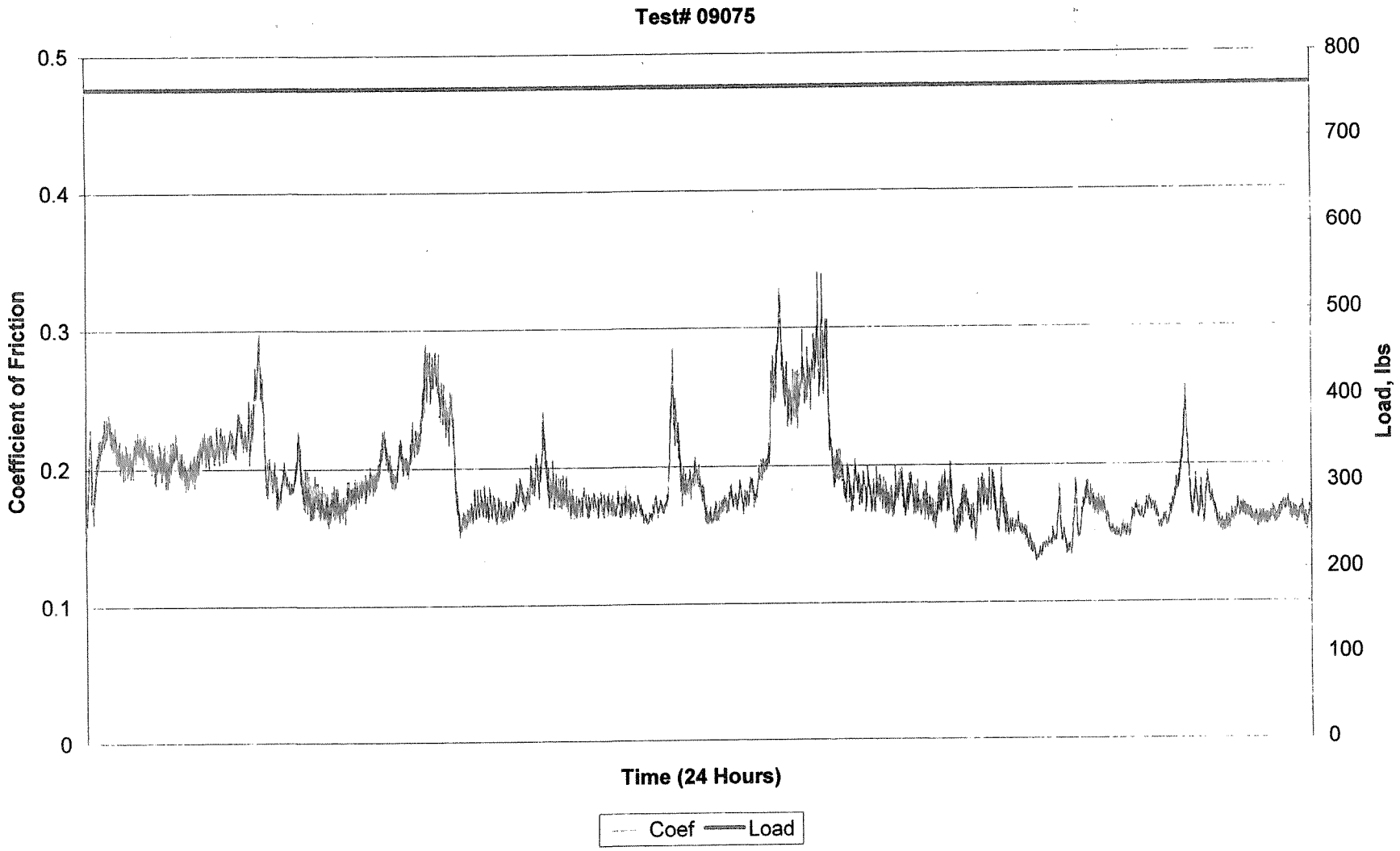
Comments: See Graphs for Torque, Friction Coefficient, Load, and Specimen Temperature trends.

Coefficient of Friction (CoF)
The dimensionless ratio of the friction force (FF) between the upper rotating material and the lower stationary material to the normal force (N) pressing these bodies together.

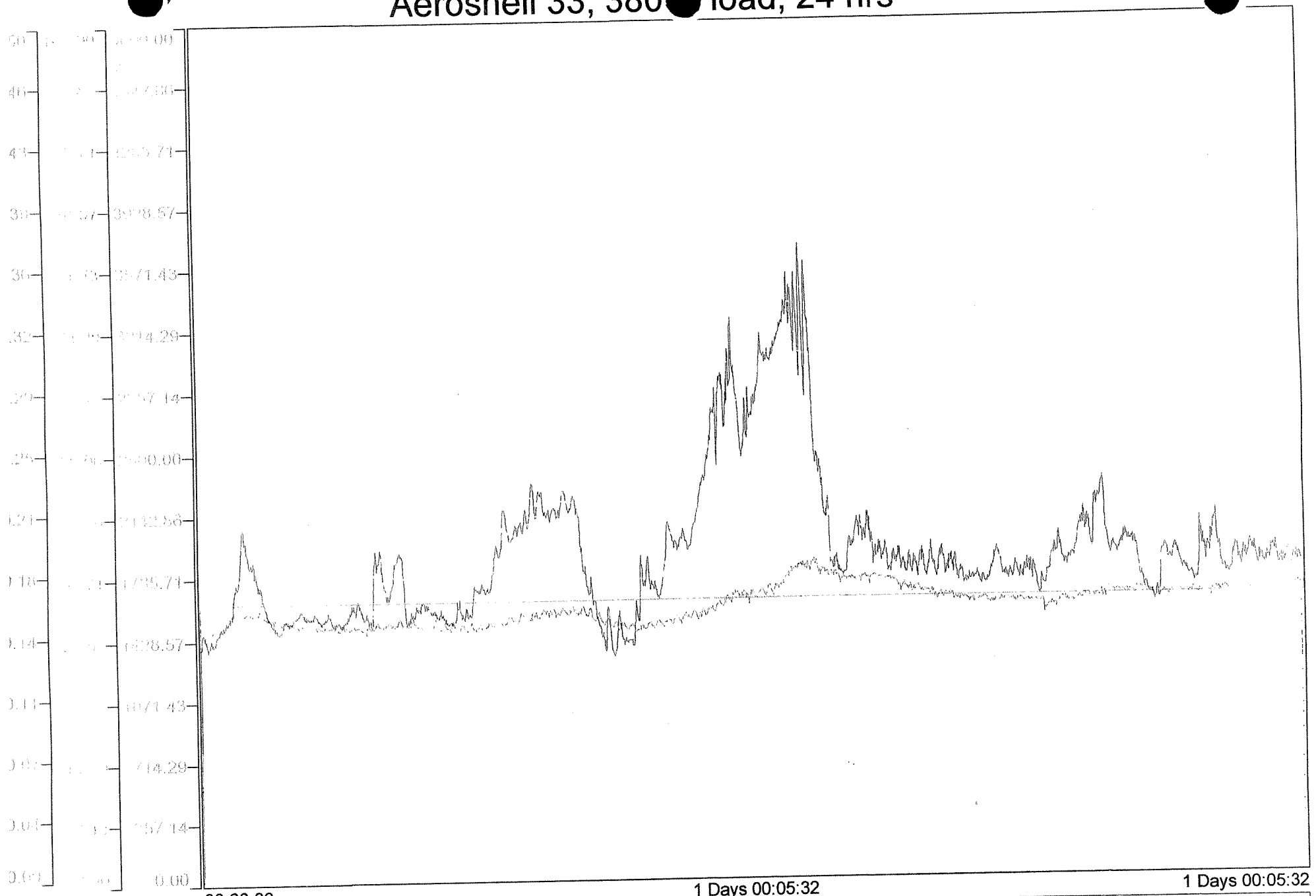
Aeroshell 33
Thrust Washer Geometry



Aeroshell 33
Thrust Washer Geometry

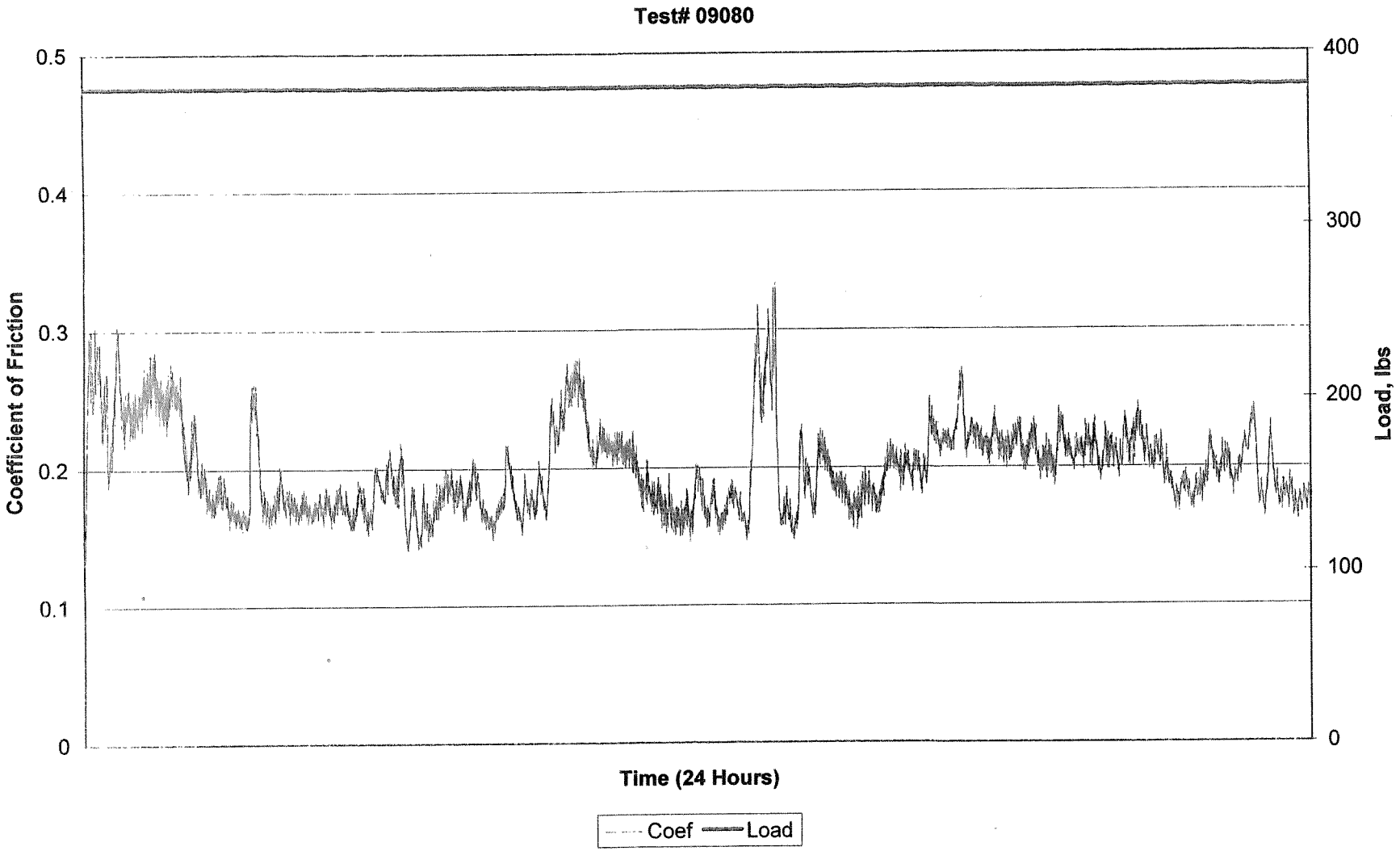


Aeroshell 33, 380 load, 24 hrs



Description	Batch Name	Scale Range	Eng. Units	1 Day 00:05:32
COEFFICIENT OF FRICTION	2dgwear02	0.00/0.50	Coef	***
[illegible] TEMP	2dgwear02	0.00/100.00	DEG.C	***
[illegible] LOAD	2dgwear02	0.00/5000.00	N	***

Aeroshell 33
Thrust Washer Geometry



Company:	***Dombroff & Gilmore***	Page:	3
Date:	01/28/02	Project #:	02-8
Technician	N. Pekoc		

Method:	Modified Thrust Washer
Machine:	Falex High Performance Multi-Specimen Test Machine, Computer Controlled Version
Serial #:	809C350011008, 009-091-105

TEST SPECIMENS:

Upper Material:	**C95500 Al Bronze**
Finish (μ in.):	32
Hardness (HRc):	112-123
Falex ID #:	5030
Lower Material:	**AISI 4140 Steel, black oxide coated**
Finish (μ in.):	32
Hardness (HRc):	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5306

TEST CONDITIONS:

Test Speed (rpm):	5
Temperature (°C):	Ambient
Duration (hr):	24
Test Load (lb):	Varies
Mean Test Radius (in):	0.531
Contact pressure (psi):	Varies

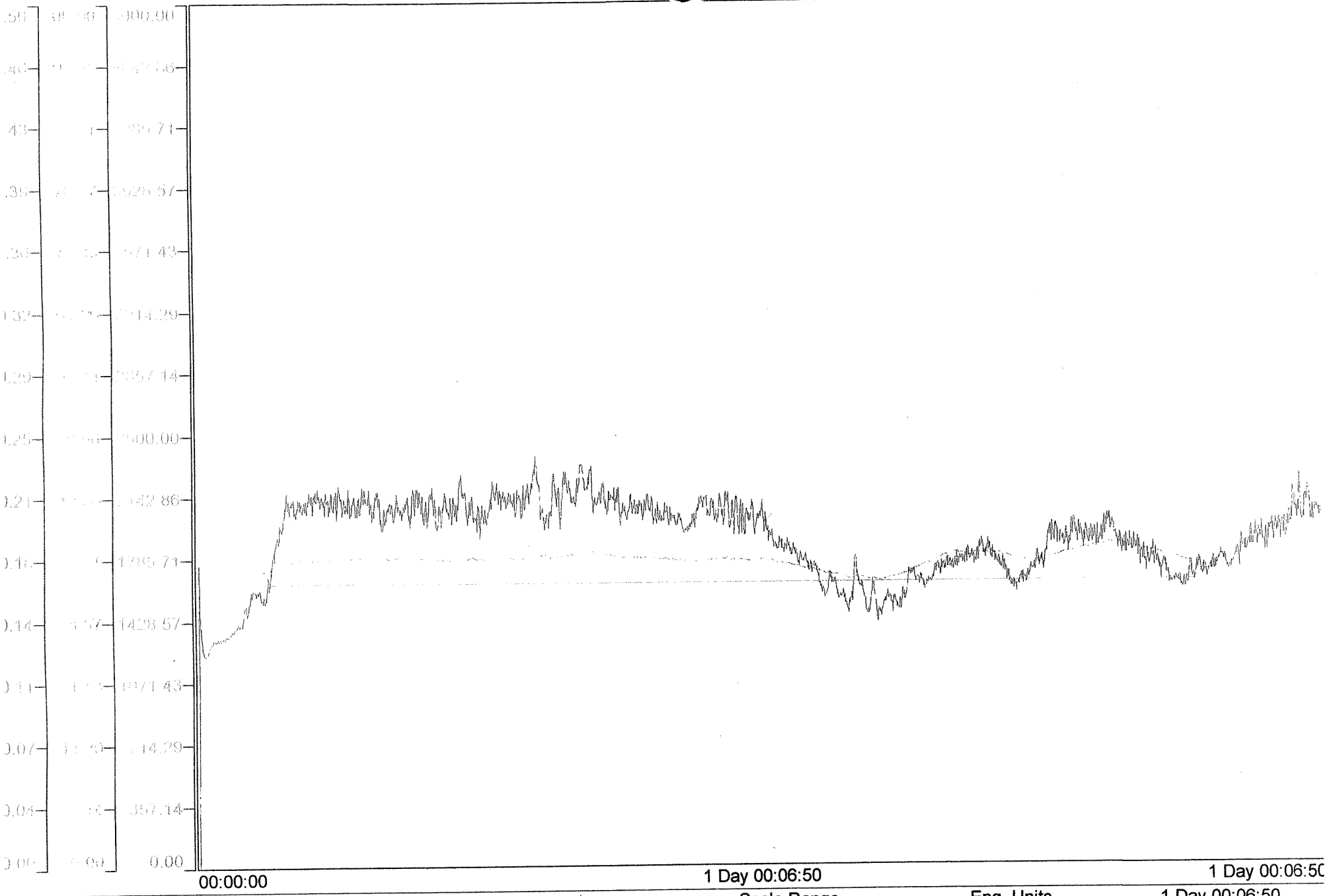
Test Results:

Test Date:	01/18/02	01/21/02	01/22/02	01/24/02
Test Number:	09078	09079	09082	09084
Upper Falex ID #:	5030	5030	5030	5030
Lower Falex ID #:	5306	5306	5306	5306
Lubricant:	**Mobil 28**	**Mobil 28**	**Aeroshell 33**	**Aeroshell 33**
Lubricant Falex ID #:	4944	4944	4948	4948
SaveFile Name:	2dgwear03	2dgwear04	TDAT024-025	2dgwear07
Test Program Name:	D&GWEARTEST3	D&GWEARTEST3	DGTHWRT4	D&GWEARTEST4
Load(Lb):	380	380	190	190
Mass Loss, Upper (mg):	0.5	0.1	2.8	4.5
Mass Loss, Lower (mg):	+0.1	N/A*	0.9	0.6
Bronze height change (mm):	0.0078	0.0093	0.0098	0.0118

Comments: See Graphs for Torque, Friction Coefficient, Load, and Specimen Temperature trends.
*Lower specimen was damaged on removal. Mass measurement is innaccurate.

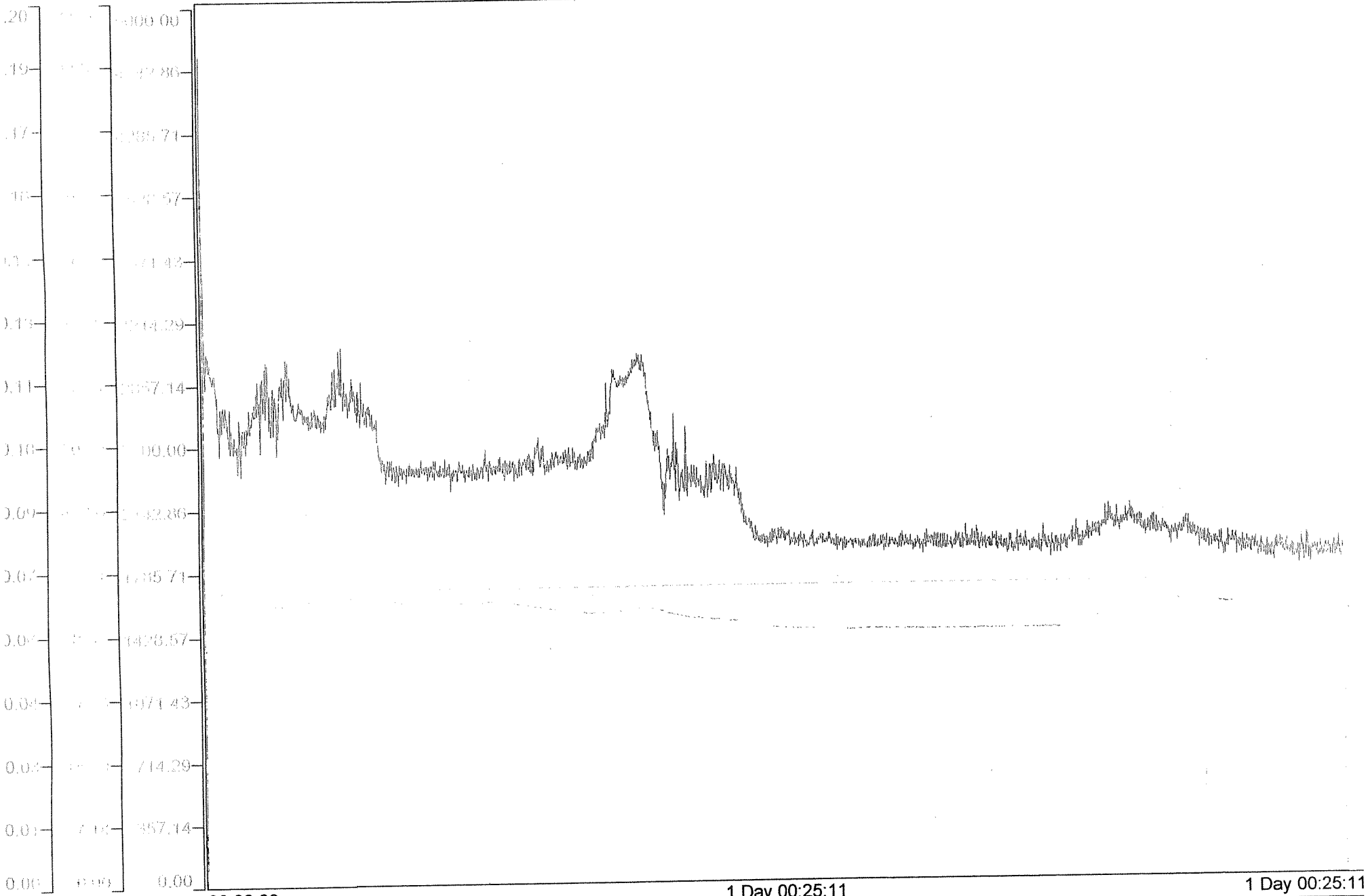
Coefficient of Friction (CoF)
The dimensionless ratio of the friction force (FF) between the upper rotating material and the lower stationary material to the normal force (N) pressing these bodies together.

Mobil 28, 380 lb load, 24 hrs.



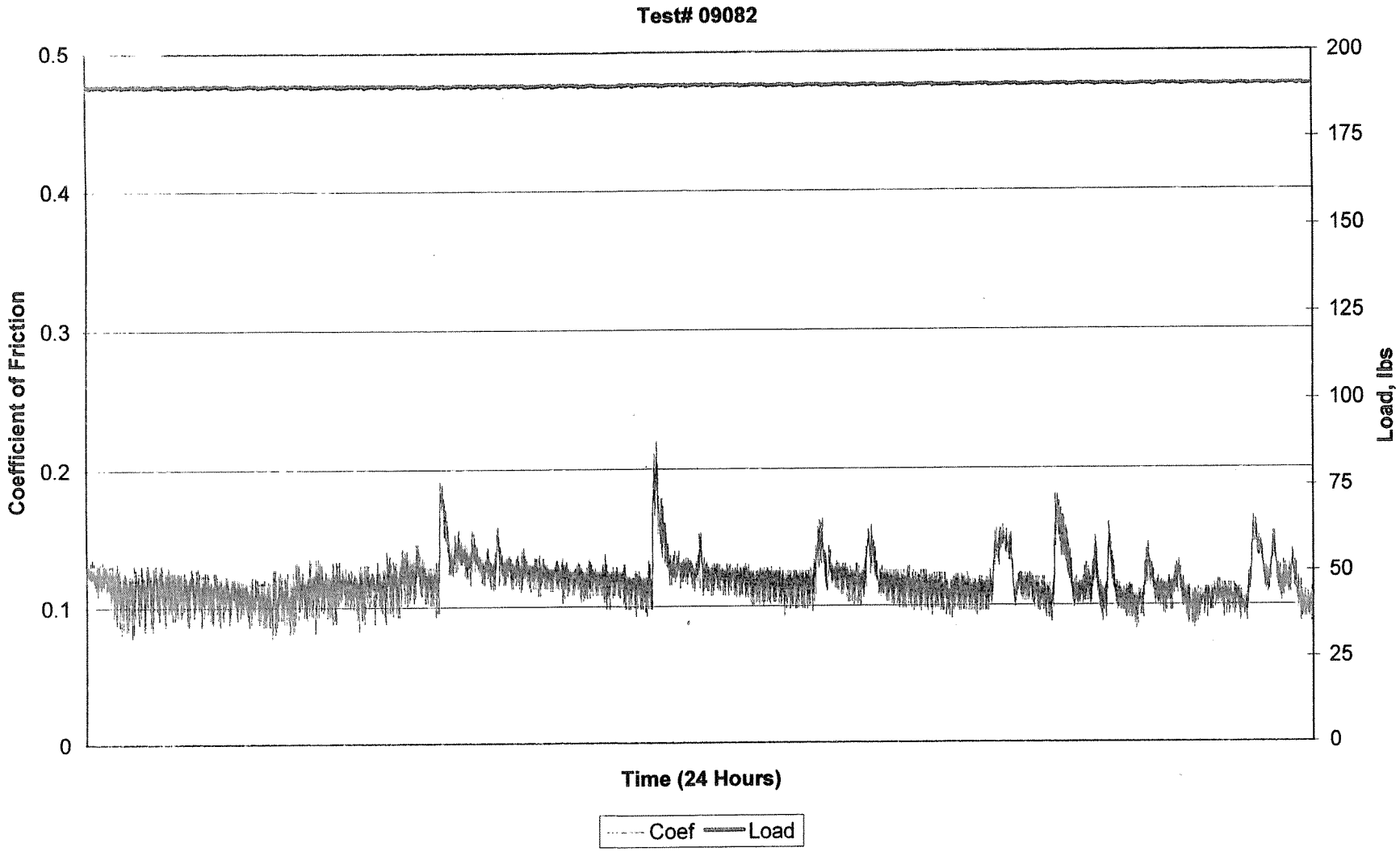
Description	Batch Name	Scale Range	Eng. Units	1 Day 00:06:50
COEFFICIENT OF FRICTION	2dgwear03	0.00/0.50	Coef	0.19
[illegible] TEMP	2dgwear03	0.00/100.00	DEG.C	33.36
[illegible] LOAD	2dgwear03	0.00/5000.00	N	0.00

Mobil 28, 380 lb load, 24 hrs.

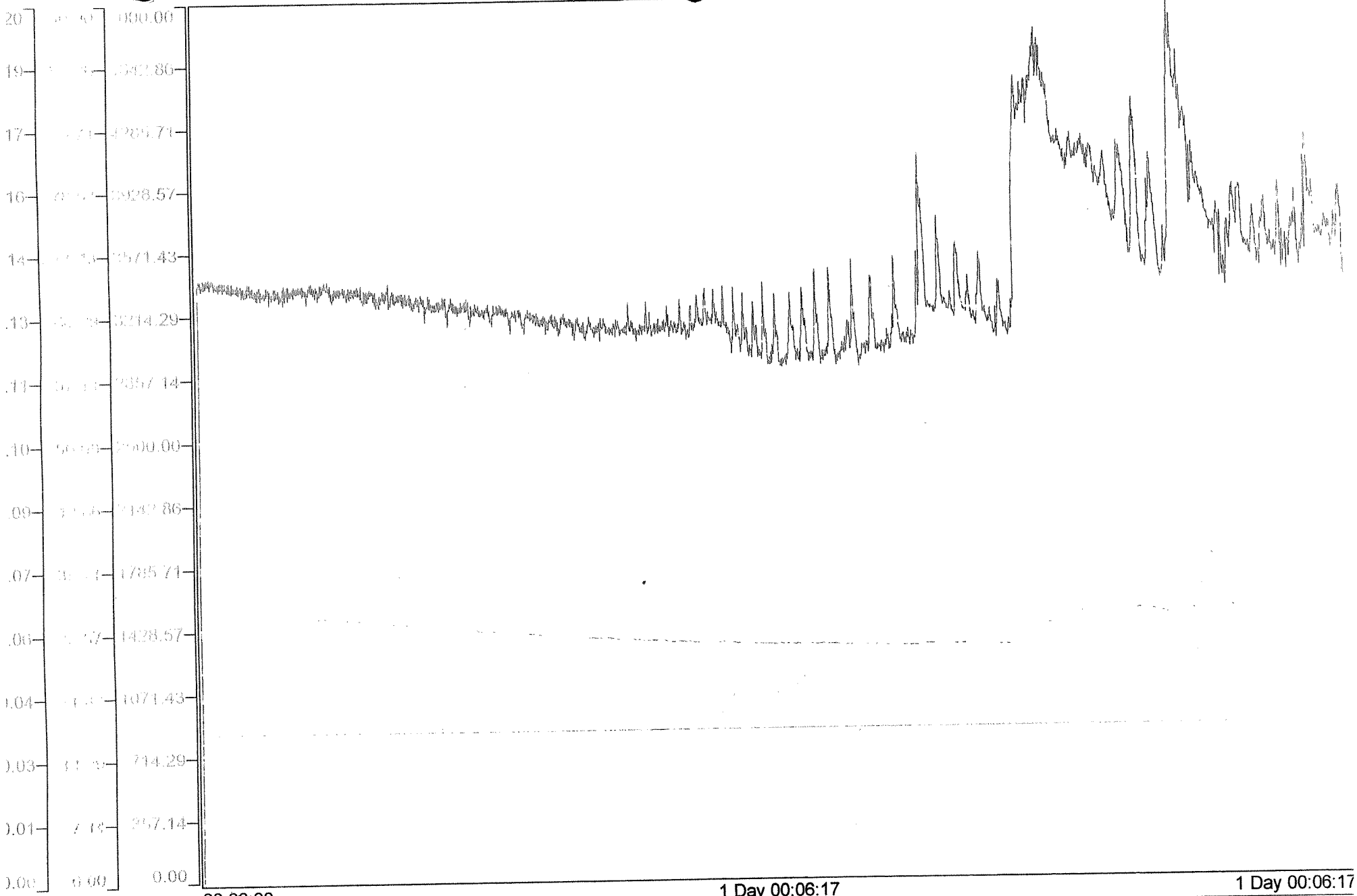


Description	Batch Name	Scale Range	Eng. Units	1 Day 00:25:11
COEFFICIENT OF FRICTION	2dgwear04	0.00/0.20	Coef	No Data
[illegible] TEMP.	2dgwear04	0.00/100.00	DEG.C	No Data
[illegible]	2dgwear04	0.00/5000.00	N	No Data

Aeroshell 33
Thrust Washer Geometry



Aeroshell 33, 190 load, 24 hrs



Description	Batch Name	Scale Range	Eng. Units	1 Day 00:06:17
COEFFICIENT OF FRICTION	2dgwear07	0.00/0.20	Coef	0.15
INLET AIR TEMP.	2dgwear07	0.00/100.00	DEG.C	30.51
[illegible] LOAD	2dgwear07	0.00/5000.00	N	0.00

Company:	***Dombroff & Gilmore***	Page:	4
Date:	01/28/02	Project #:	02-8
Technician	N. Pekoc		

Method:	Modified Thrust Washer
Machine:	Falex High Performance Multi-Specimen Test Machine, Computer Controlled Version
Serial #:	809C350011008, 009-091-105

TEST SPECIMENS:

Upper Material:	**C95500 Al Bronze**
Finish (μ in.):	32
Hardness (HRc):	112-123
Falex ID #:	5030
Lower Material:	**AISI 4140 Steel, black oxide coated**
Finish (μ in.):	32
Hardness (HRc):	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5306

TEST CONDITIONS:

Test Speed (rpm):	5
Temperature (°C):	Ambient
Duration (hr):	24
Test Load (lb):	Varies
Mean Test Radius (in):	0.531
Contact pressure (psi):	Varies

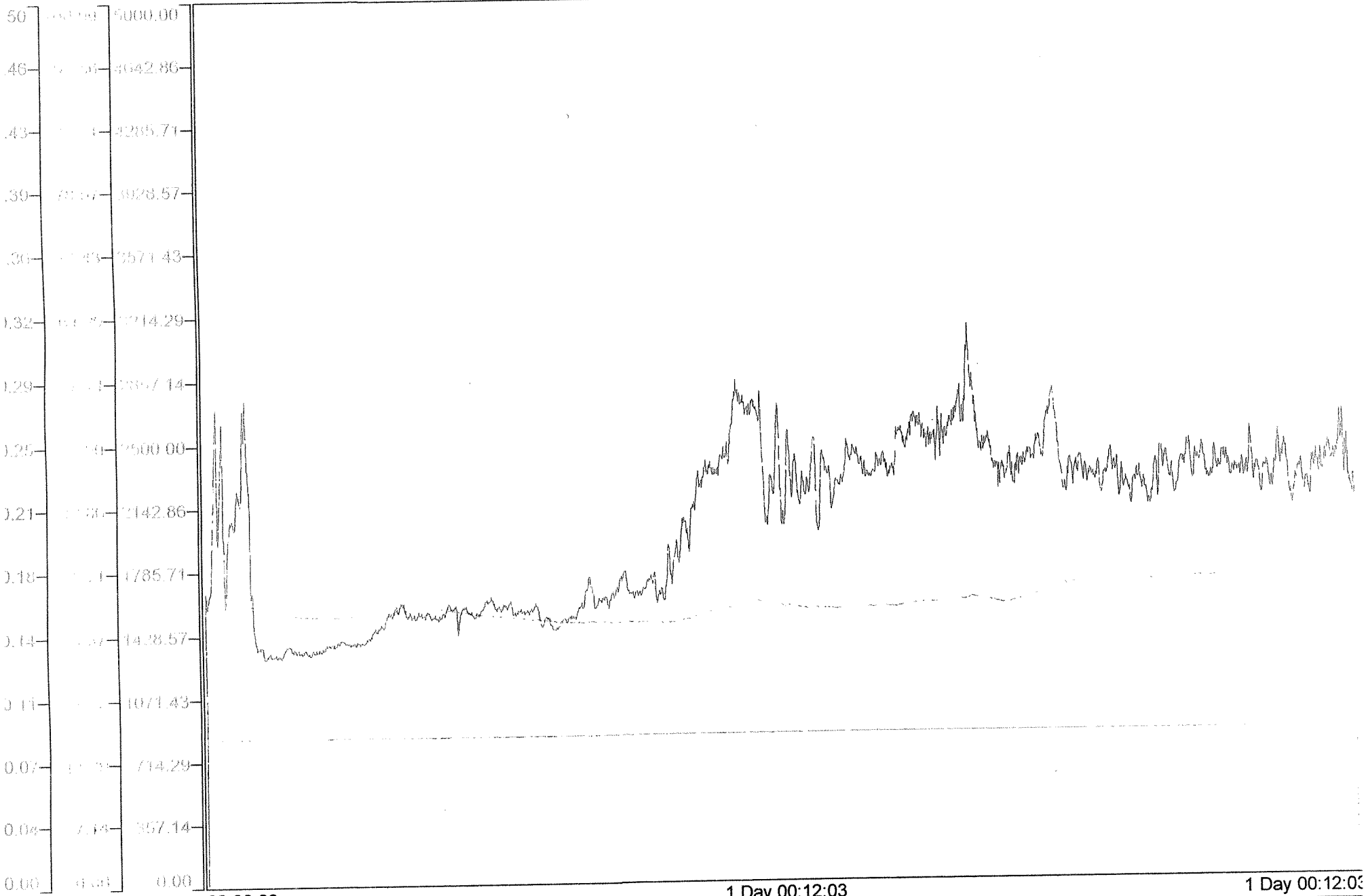
Test Results:

Test Date:	01/22/02	01/23/02	02/01/02
Test Number:	09081	09083	09085
Upper Falex ID #:	5030	5030	5030
Lower Falex ID #:	5306	5306	5306
Lubricant:	**Mobil 28**	**Mobil 28**	**Aeroshell 33**
Lubricant Falex ID #:	4944	4944	4948
SaveFile Name:	2dgwear05	2dgwear06	2dgwear08
Test Program Name:	D&GWEARTEST4	D&GWEARTEST4	D&GWEARTEST3
Load(Lb):	190	190	380
Mass Loss, Upper (mg):	0.7	0.6	2.9
Mass Loss, Lower (mg):	0.7	0.7	0.4
Bronze height change (mm):	0.0083	0.0080	0.0100

Comments: See Graphs for Torque, Friction Coefficient, Load, and Specimen Temperature trends.

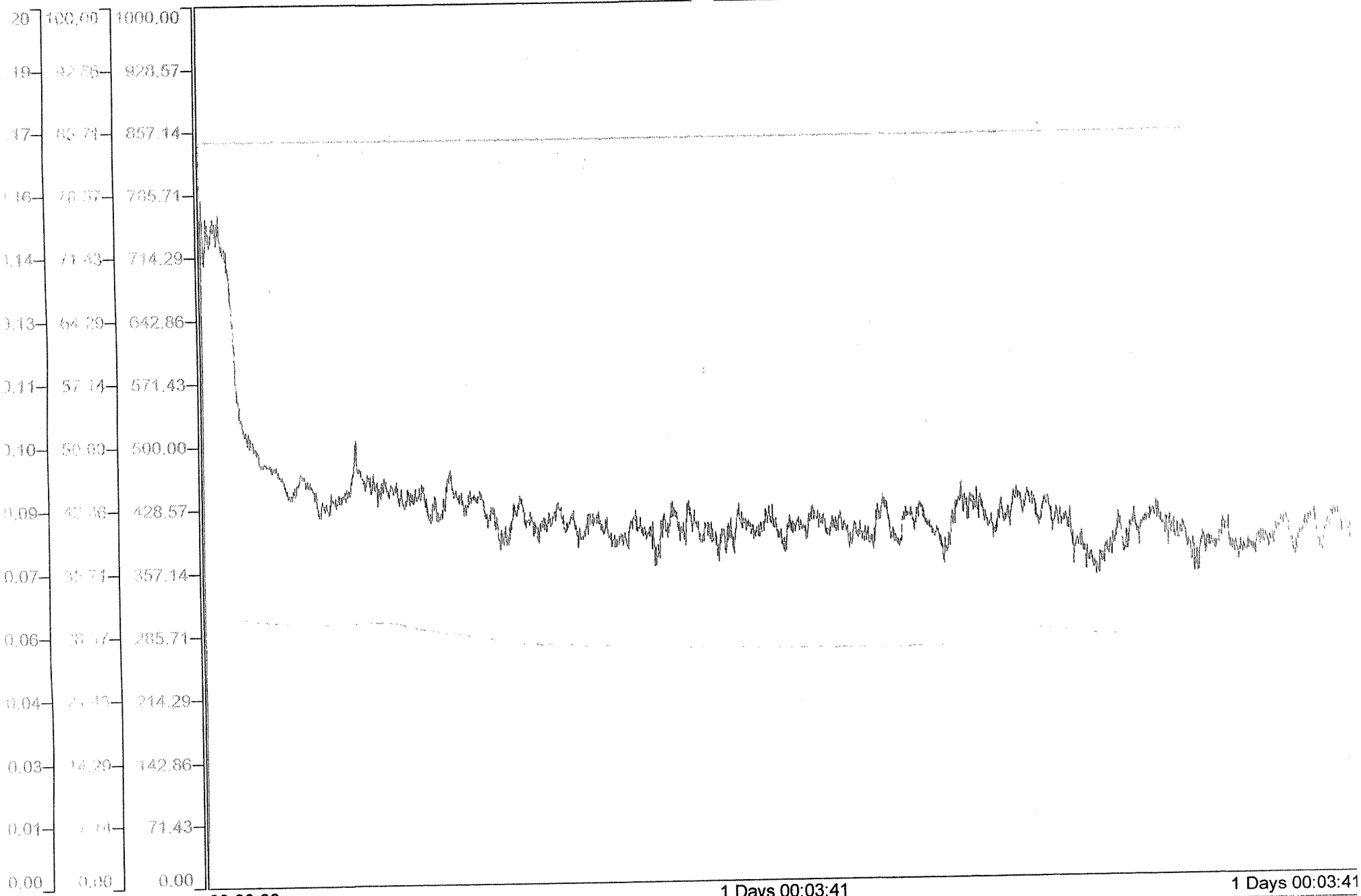
Coefficient of Friction (CoF)
The dimensionless ratio of the friction force (FF) between the upper rotating material and the lower stationary material to the normal force (N) pressing these bodies together.

Mobil 28, 190 l[illegible]oad, 24 hrs



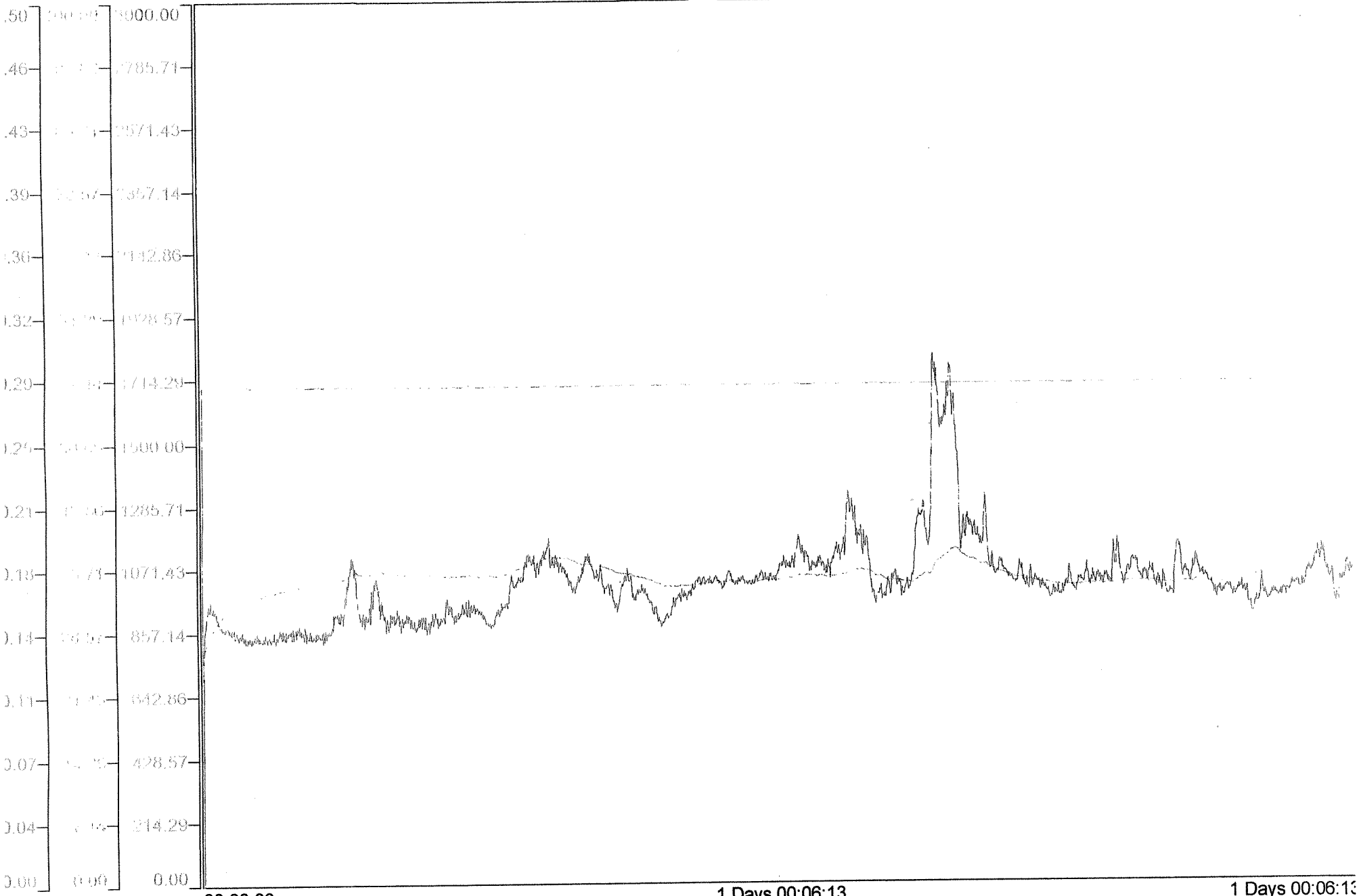
Description	Batch Name	Scale Range	Eng. Units	1 Day 00:12:03
COEFFICIENT OF FRICTION	2dgwear05	0.00/0.50	Coef	0.21
[illegible] TEMP	2dgwear05	0.00/100.00	DEG.C	31.95
[illegible] LOAD	2dgwear05	0.00/5000.00	N	0.00

Mobil 28, 190 l[illegible]oad, 24 hrs



Description	Batch Name	Scale Range	Eng. Units	1 Day 00:03:41
COEFFICIENT OF FRICTION	2dgwear06	0.00/0.20	Coef	No Data
[illegible]TEMP.	2dgwear06	0.00/100.00	DEG.C	No Data
[illegible]LOAD	2dgwear06	0.00/1000.00	N	No Data

Aeroshell 33, [redacted] lb, 24hrs



Description	Batch Name	Scale Range	Eng. Units	1 Day 00:06:13
COEFFICIENT OF FRICTION	2dgwear08	0.00/0.50	Coef	0.20
[illegible] TEMP.	2dgwear08	0.00/100.00	DEG.C	34.26
[illegible] LOAD	2dgwear08	0.00/3000.00	N	0.00

Company:	***Dombroff & Gilmore***	Page:	6
Date:	02/08/02	Project #:	02-8
Technician	N. Pekoc		

Method:	Modified Thrust Washer
Machine:	Falex High Performance Multi-Specimen Test Machine, Computer Controlled Version
Serial #:	809C350011008, 009-091-105

TEST SPECIMENS:

Upper Material:	**C95500 Al Bronze**
Finish (μ in.):	32
Hardness (HRc):	112-123
Falex ID #:	5030
Lower Material:	**AISI 4140 Steel, black oxide coated**
Finish (μ in.):	32
Hardness (HRc):	Nitride, case depth .003-.005 Core strength 160-180 KSI
Falex ID #:	5306

TEST CONDITIONS:

Test Speed (rpm):	5
Temperature (°C):	Ambient
Duration (hr):	Varies
Test Load (lb):	Varies
Mean Test Radius (in):	0.531
Contact pressure (psi):	Varies

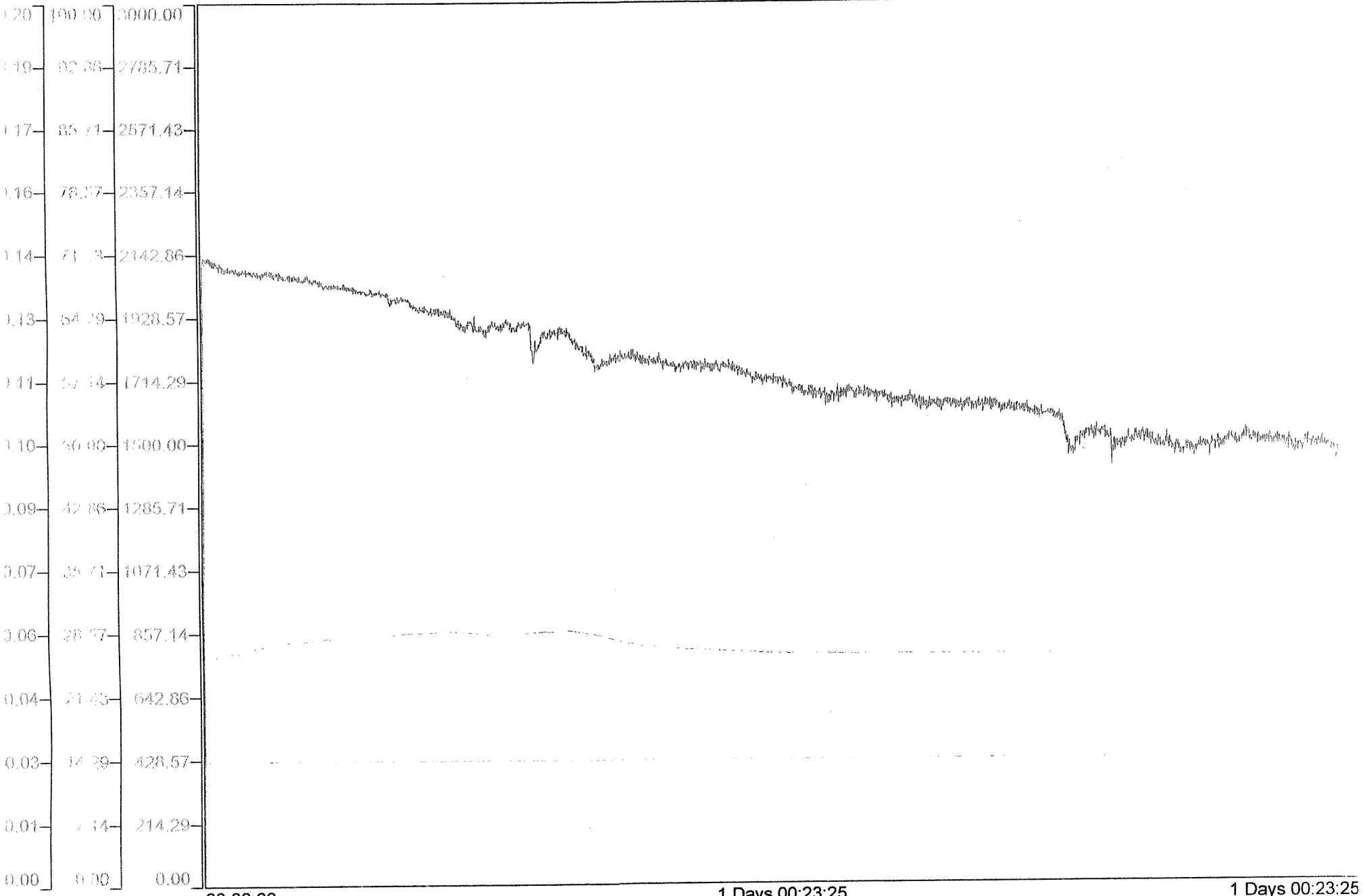
Test Results:

Test Date:	02/04/02	02/05/02	02/04/02	02/05/02
Test Number:	09086	0606424	0606423	09087
Upper Falex ID #:	5030	5030	5030	5030
Lower Falex ID #:	5306	5306	5306	5306
Lubricant:	**Aeroshell 33**	**Aeroshell 33**	**Mobil 28**	**Mobil 28**
Lubricant Falex ID #:	4948	4948	4944	4944
Duration:	24	48	24	48
SaveFile Name:	2dgwear09	2dgwear12	2dgwear10	2dgwear11
Test Program Name:	D&GWEARTEST5	DGTHWRT5	DGTHWRT5	DGWEARTEST5
Load(Lb):	95	95	95	95
Mass Loss, Upper (mg):	0.0	4.4	0.5	0.5
Mass Loss, Lower (mg):	2.2	1.5	0.6	1.0
Bronze height change (mm):	0.0053	0.0070	0.0033	0.0010

Comments: See Graphs for Torque, Friction Coefficient, Load, and Specimen Temperature trends.

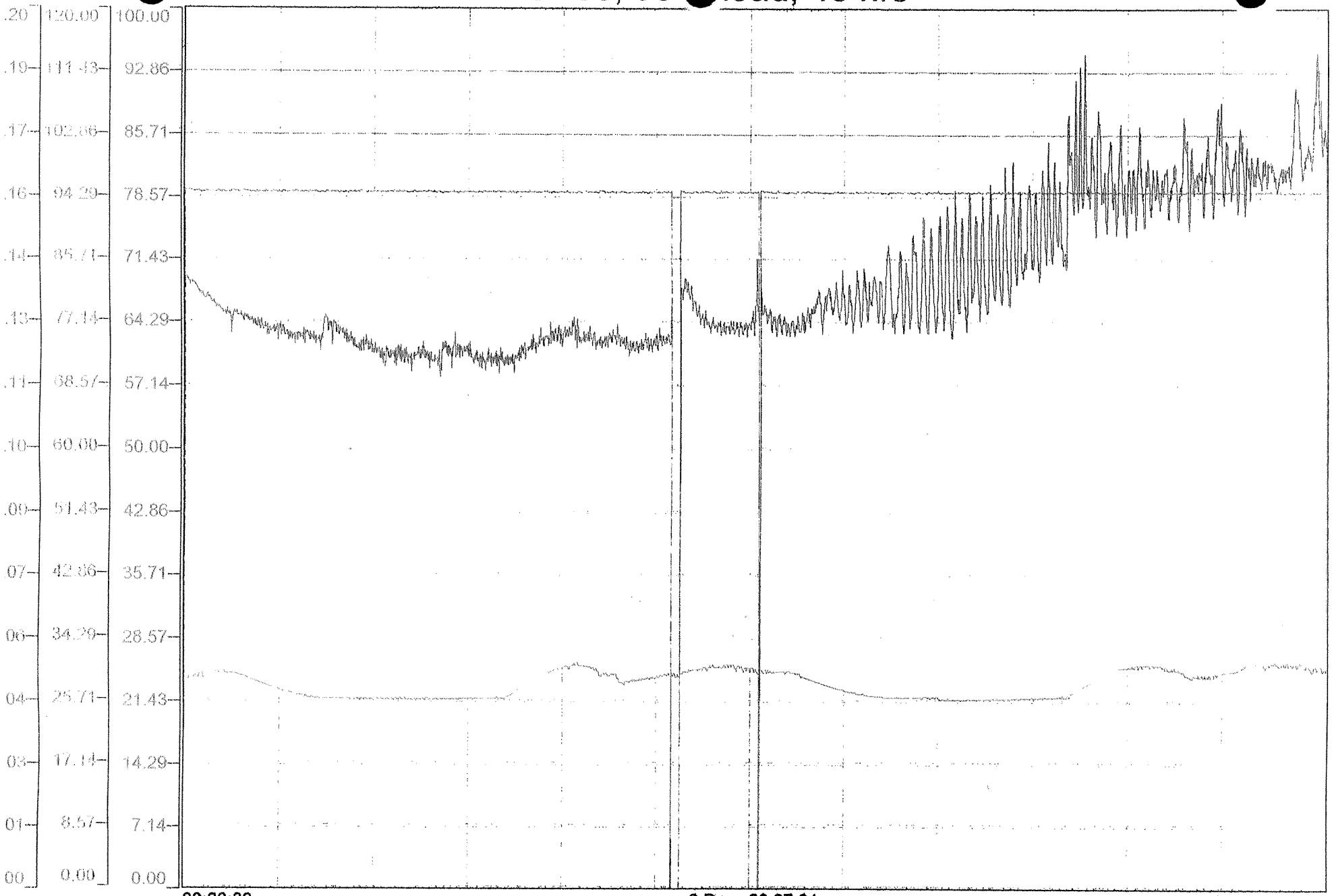
Coefficient of Friction (CoF)
The dimensionless ratio of the friction force (FF) between the upper rotating material and the lower stationary material to the normal force (N) pressing these bodies together.

Aeroshell 33, 95 load, 24 hrs



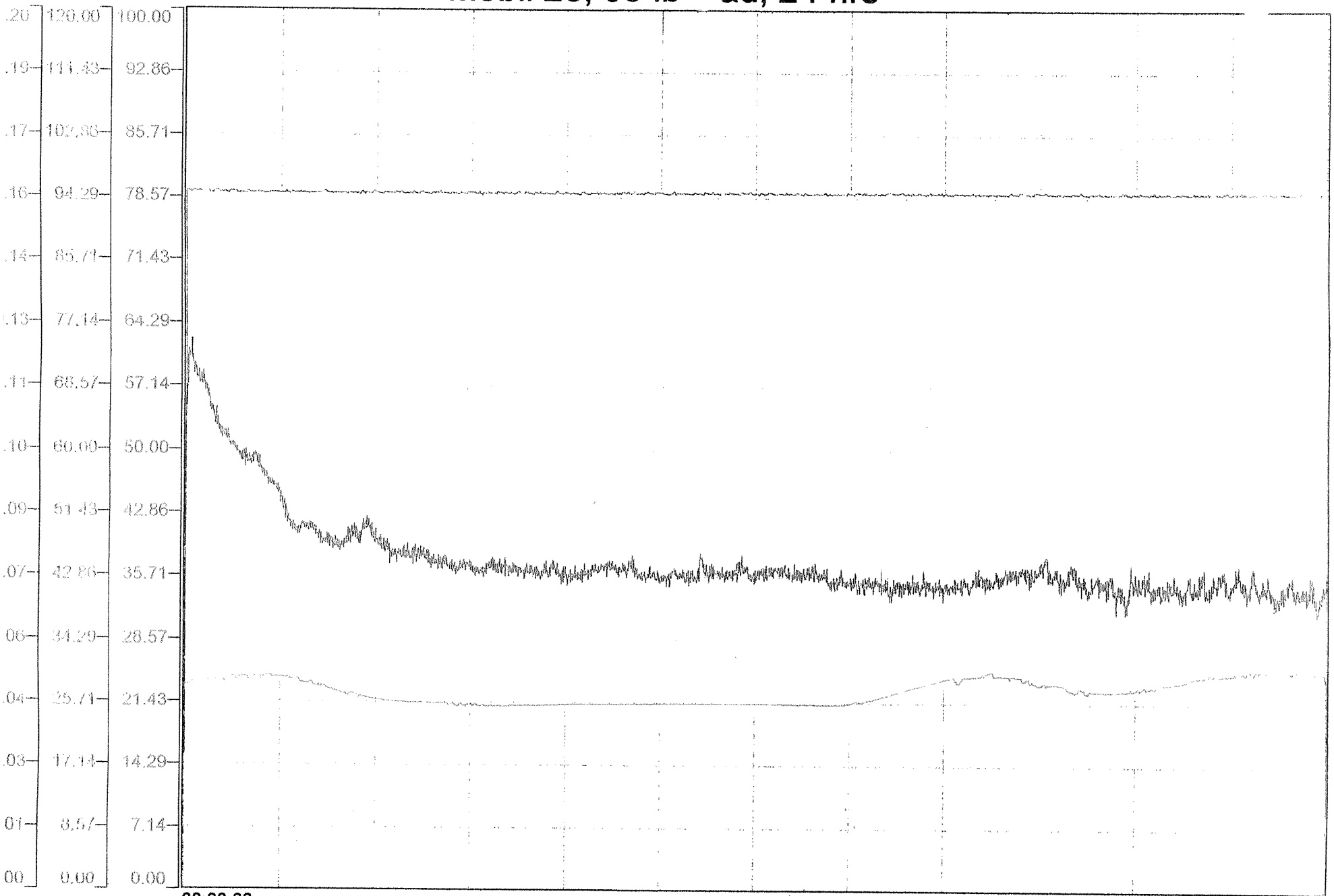
Description	Batch Name	Scale Range	Eng. Units	1 Day 00:23:25
COEFFICIENT OF FRICTION	2dgwear09	0.00/0.20	Coef	No Data
INTERFACE TEMP.	2dgwear09	0.00/100.00	DEG.C	No Data
SPECIMEN LOAD	2dgwear09	0.00/3000.00	N	No Data

Aeroshell 33, 95 [illegible]load, 48 hrs



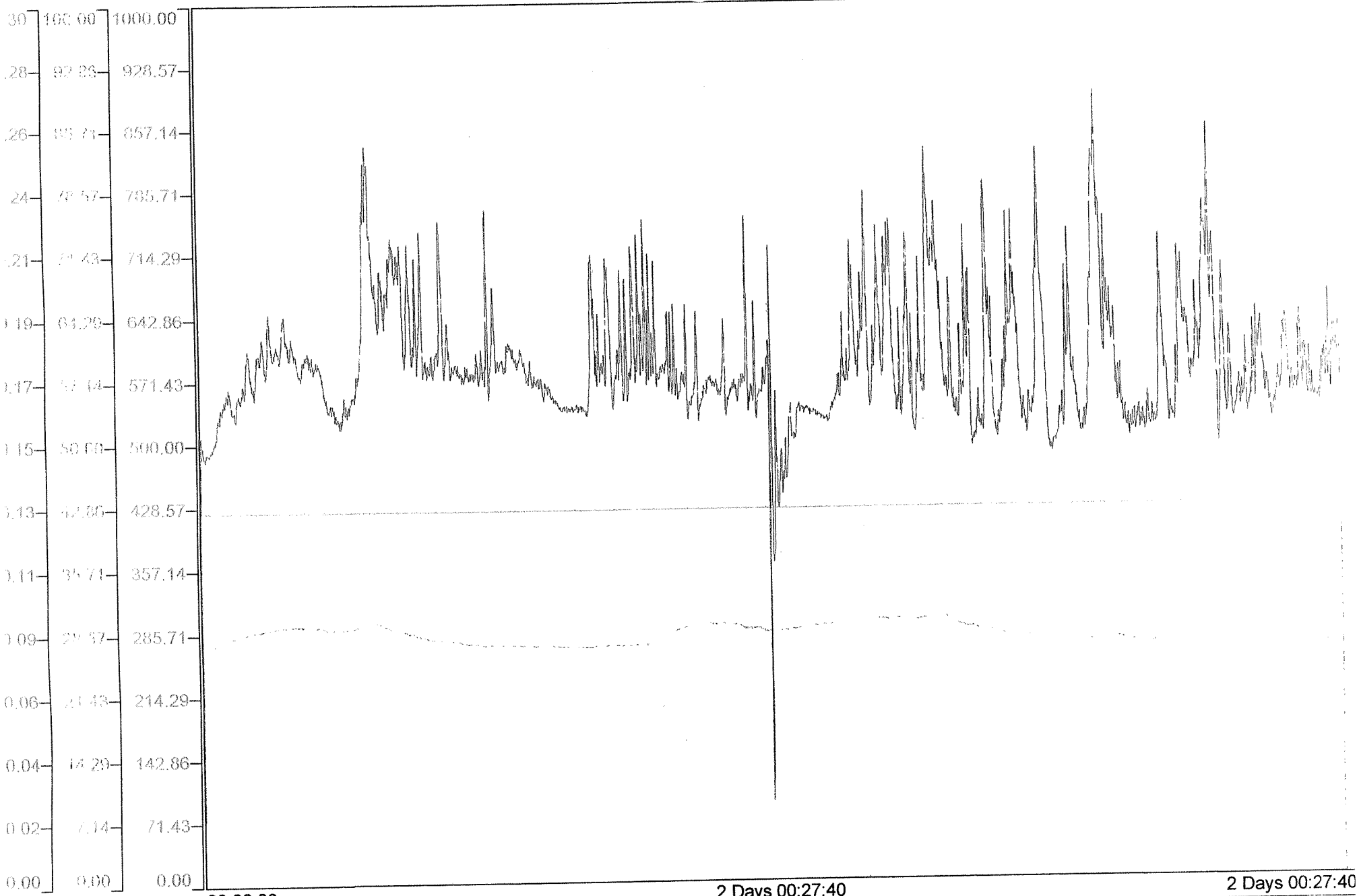
escription	Batch Name	Scale Range	Sample Freq.	Eng. Units	2 Days 00:27:04
OIL - FRICT	2dgwear12	0.00/0.20	00:00:01		No Data
DAD	2dgwear12	0.00/120.00	00:00:01	LB	No Data
EMP 8	2dgwear12	0.00/100.00	00:00:01	DEG. C	No Data

Mobil 28, 95 lb ad, 24 hrs



escription	Batch Name	Scale Range	Sample Freq.	Eng. Units	1 Day 00:02:00
OEFFRICT	2dgwear10	0.00/0.20	00:00:01		No Data
DAD	2dgwear10	0.00/120.00	00:00:01	LB	No Data
EMP	2dgwear10	0.00/100.00	00:00:01	DEG. C	No Data

Mobil 28, 95 lb[illegible]ad, 48 hrs



Description	Batch Name	Scale Range	Eng. Units	2 Days 00:27:40
COEFFICIENT OF FRICTION	2dgwear11	0.00/0.30	Coef	No Data
[illegible] TEMP.	2dgwear11	0.00/100.00	DEG.C	No Data
[illegible] LOAD	2dgwear11	0.00/1000.00	N	No Data

TELEPHONE 773-772-3577
FAX NO. 773-772-3778

Phoenix Chemical Laboratory, Inc.

FUEL AND LUBRICANT TECHNOLOGISTS
3953 SHAKESPEARE AVENUE
CHICAGO, ILL. 60647-3497

November 19, 2001

RECEIVED FROM Falex Corp.
1020 Airpark
Sugar Grove, IL 60554
Attn: Brian Holtkamp

SAMPLE OF Grease

LABORATORY NO. 01 11 2 11-16

MARKED See below

Lab. No.	01 11 2 11	01 11 2 12	01 11 2 13
Marked	#B22951 #TLAA4944	#B18872 #TLAA4945	#B16596 #TLAA4947
Ash, %	7.81	7.50	8.49
Penetration @ 77°F, Worked Strokes (1/4 scale)	309	313	309
NLGI Grade	Between 1 & 2	1	Between 1 & 2
Heptane Soluble, %	83.61	83.77	81.34
Heptane Insoluble, %	15.44	15.18	17.58
Emission Spectrographic Analysis			
Major	Aluminum	Aluminum	Aluminum
Minor	Calcium Iron Magnesium Sodium Silicon	Calcium Iron Magnesium Sodium Silicon	Calcium Iron Magnesium Sodium Silicon
Trace	Copper Lithium Manganese Strontium Titanium ZInc	Copper Lithium Manganese Strontium Titanium Zinc	Copper Lithium Manganese Strontium Titanium Zinc

PHOENIX CHEMICAL LABORATORY, INC. FOUNDED 1927

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FAX NO. 773-772-3778

Phoenix Chemical Laboratory, Inc.

FUEL AND LUBRICANT TECHNOLOGISTS
3953 SHAKESPEARE AVENUE
CHICAGO, ILL. 60647-3497

November 19, 2001

RECEIVED FROM Falex Corp.

SAMPLE OF Grease

LABORATORY NO. 01 11 2 11-16

MARKED See below

Lab. No.	01 11 2 14	01 11 2 15	01 11 2 16
Marked	#B052101 #TLAA4948	#B052101 #TLAA4949	#B052101 #TLAA4950
Ash, %	4.98	5.73	5.88
Penetration @ 77°F, Worked Strokes (1/4 scale)	272	317	287
NLGI Grade	2	1	2
Heptane Soluble, %	82.59	81.28	82.75
Heptane Insoluble, %	16.39	17.71	16.19
Emission Spectrographic Analysis			
Major	Calcium Lithium	Calcium Lithium	Calcium Lithium
Minor	Boron Bismuth Magnesium Sodium Silicon Zinc	Aluminum Boron Bismuth Copper Magnesium Sodium Zinc Phosphorus	Aluminum Boron Bismuth Copper Magnesium Sodium Zinc Phosphorus
Trace	Aluminum Chromium Copper Iron Manganese Phosphorus Lead Strontium	Chromium Iron Manganese Lead Strontium	Chromium Iron Manganese Lead Strontium

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FUEL AND LUBRICANT TECHNOLOGISTS
3953 SHAKESPEARE AVENUE
CHICAGO, ILL. 60647-3497

November 19, 2001

RECEIVED FROM Falex Corp.

SAMPLE OF Grease

LABORATORY NO. 01 11 2 11-16

MARKED See below

Lab. No.	01 11 2 11	01 11 2 12	01 11 2 13
Elemental Analysis by ICP			
Aluminum, %	0.862	0.817	1.028
Calcium, %	0.495	0.552	0.651
Iron, %	0.171	0.171	0.216
Sodium, %	0.601	0.601	0.873
Magnesium, ppm	826	874	2160
Copper, ppm	2.0	2.0	3.4
Manganese, ppm	5.9	5.7	5.8
Lithium, ppm	3.7	0.4	131.7
Titanium, ppm	78.8	74.7	103.6
Zinc, ppm	5.7	5.5	7.8
Strontium, ppm	2.6	2.7	2.5

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Phoenix Chemical Laboratory, Inc.

FUEL AND LUBRICANT TECHNOLOGISTS
3953 SHAKESPEARE AVENUE
CHICAGO, ILL. 60647-3497

November 19, 2001

RECEIVED FROM Falex Corp.

SAMPLE OF Grease

LABORATORY NO. 01 11 2 11-16

MARKED See below

Lab. No.	01 11 2 14	01 11 2 15	01 11 2 16
Elemental Analysis by ICP			
Lithium, %	2.62	2.76	2.48
Calcium, %	1.45	1.50	1.48
Boron, %	0.244	0.223	0.212
Zinc, %	0.119	0.137	0.121
Copper, ppm	3.3	2950	4620
Bismuth, ppm	532	706	916
Sodium, ppm	91.9	266	244
Magnesium, ppm	62.9	72.5	74.8
Aluminum, ppm	42.6	68.5	52.3
Iron, ppm	21.3	24.6	26.7
Phosphorus, ppm	231	1170	1770
Lead, ppm	14.9	24.7	25.2
Strontium, ppm	6.4	6.5	6.5
Manganese, ppm	0.4	0.3	0.2
Chromium, ppm	0.9	1.6	2.2

PHOENIX CHEMICAL LABORATORY, INC. FOUNDED 1927

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FAX NO. 773-772-3778

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FUEL AND LUBRICANT TECHNOLOGISTS
3953 SHAKESPEARE AVENUE
CHICAGO, ILL. 60647-3497

November 19, 2001

RECEIVED FROM Falex Corp.

SAMPLE OF Grease

LABORATORY NO. 01 11 2 11-16

MARKED See below

Infrared Analysis

The infrared spectra of the following fractions of the samples were run. The spectra are attached and are made part of this report by reference:

Lab. No. 01 11 2 11
1) As received.
2) Heptane soluble.
3) Heptane insoluble.

Lab. No. 01 11 2 12
1) As received.
2) Heptane soluble.
3) Heptane insoluble.

Lab. No. 01 11 2 13
1) As received.
2) Heptane soluble.
3) Heptane insoluble.

Lab. No. 01 11 2 14
1) As received.
2) Heptane soluble.
3) Heptane insoluble.

Lab. No. 01 11 2 15
1) As received.
2) Heptane soluble.
3) Heptane insoluble.

Lab. No. 01 11 2 16
1) As received.
2) Heptane soluble.
3) Heptane insoluble.

PHOENIX CHEMICAL LABORATORY, INC. FOUNDED 1927

TELEPHONE 773-772-0377
FAX NO. 773-772-3778

Phoenix Chemical Laboratory, Inc.

FUEL AND LUBRICANT TECHNOLOGISTS
3953 SHAKESPEARE AVENUE
CHICAGO, ILL. 60647-3497

November 19, 2001

RECEIVED FROM Falex Corp.

SAMPLE OF Grease

LABORATORY NO. 01 11 2 11-16

MARKED See below

Conclusions

The following conclusions are based on the data which have been obtained:

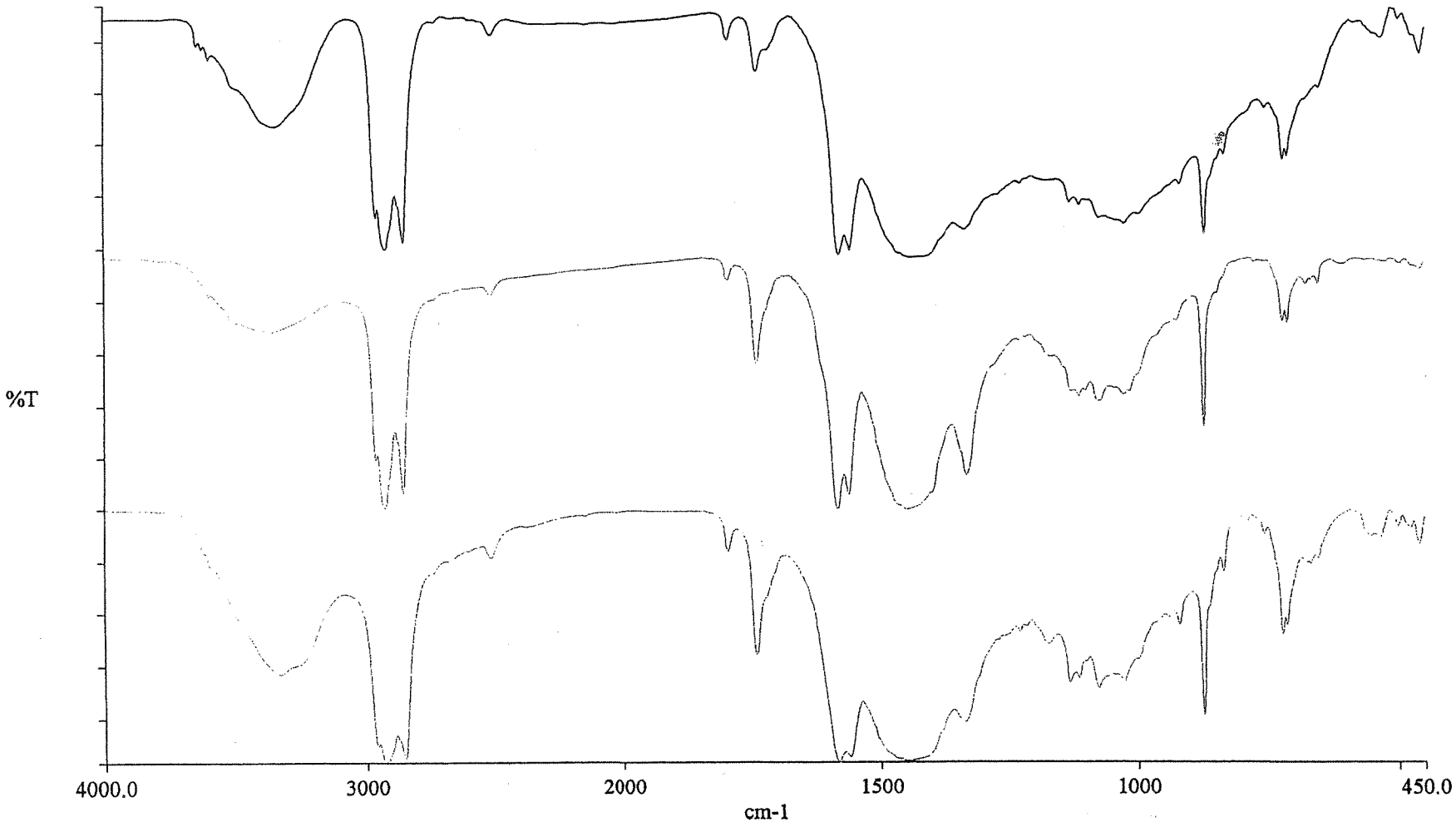
1) The samples identified as Lab. Nos. 01 11 2 11, 01 11 2 12 and 01 11 2 13 are substantially identical to each other. Each consists of a paraffinic mineral which has been thickened with a calcium complex soap. Each also contains an organophilic bentonite clay filler.

2) The samples identified as Lab. Nos. 01 11 2 14, 01 11 2 15 and 01 11 2 16 are substantially identical to each other but different from the samples previously identified as Lab. Nos. 01 11 2 11, 01 11 2 12 and 01 11 2 13. Each consists of a synthetic ester such as dioctyl sebacate which has been thickened with a lithium soap such as lithium 12-hydroxystearate. A small amount of a calcium carbonate filler is also present.

3) The sample identified as Lab. No. 01 11 2 13 may be contaminated with a lithium soap grease.

[redacted]
Arthur A. Krawetz

PHOENIX CHEMICAL LABORATORY, INC. FOUNDED 1927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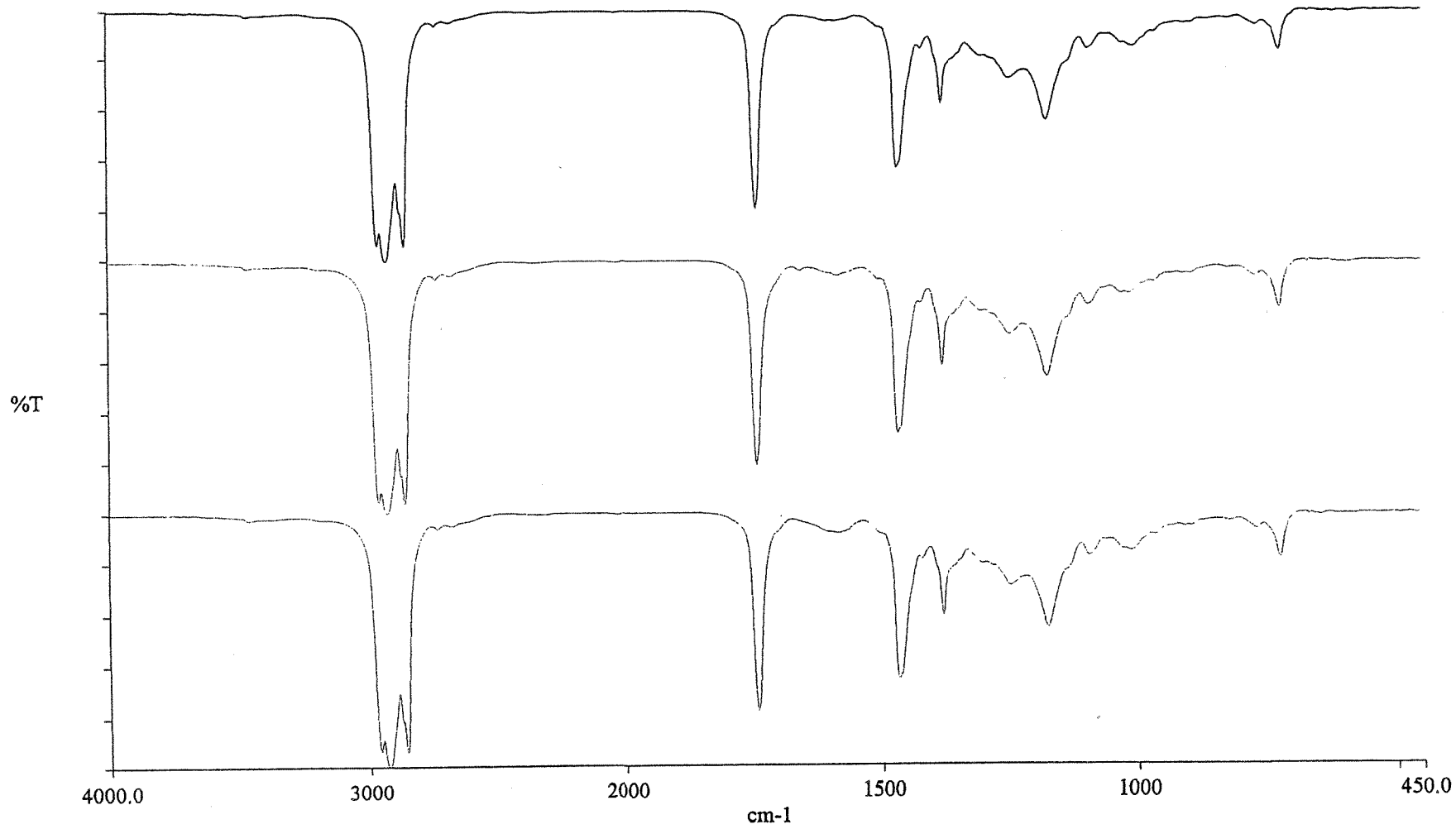
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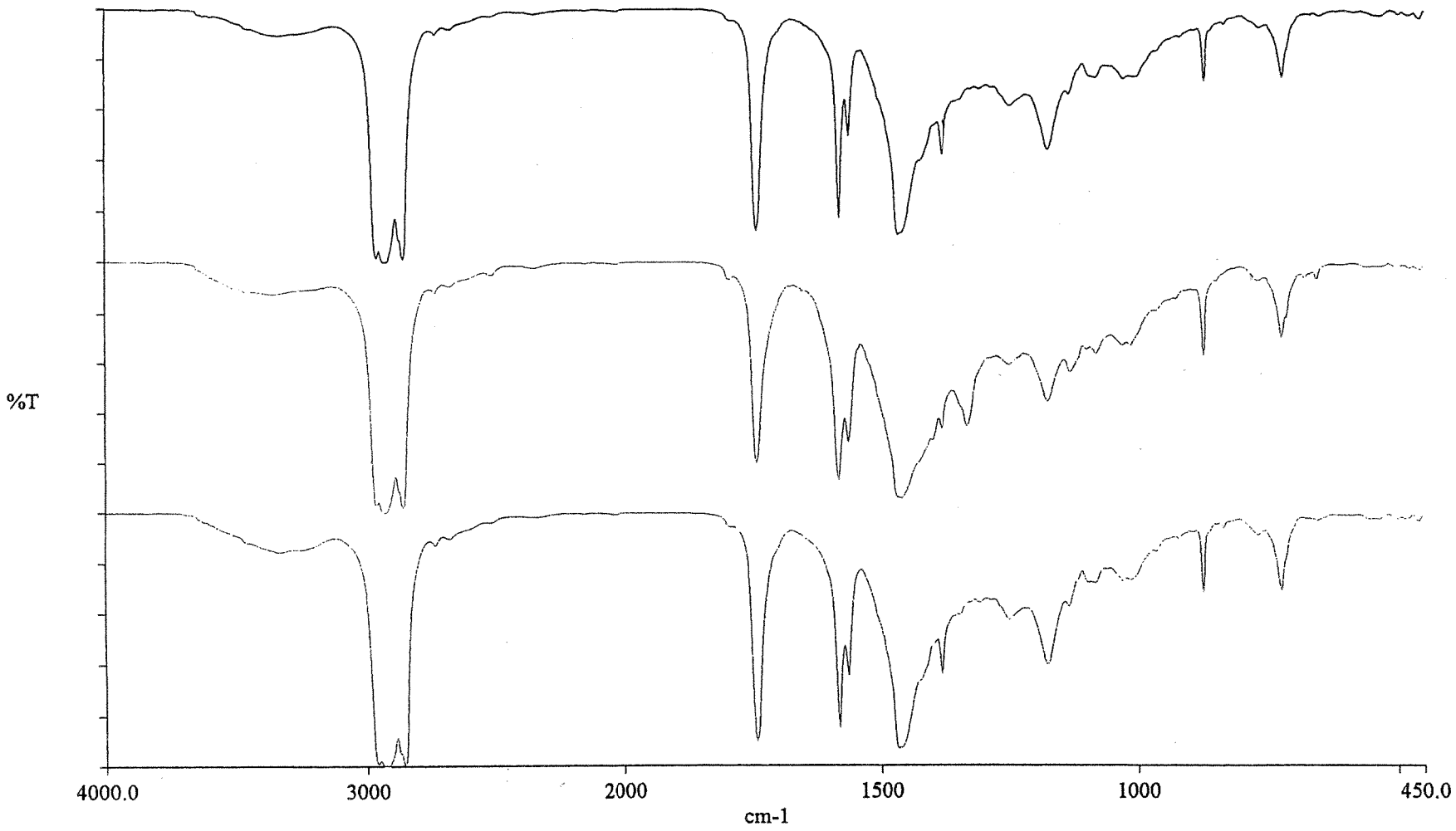
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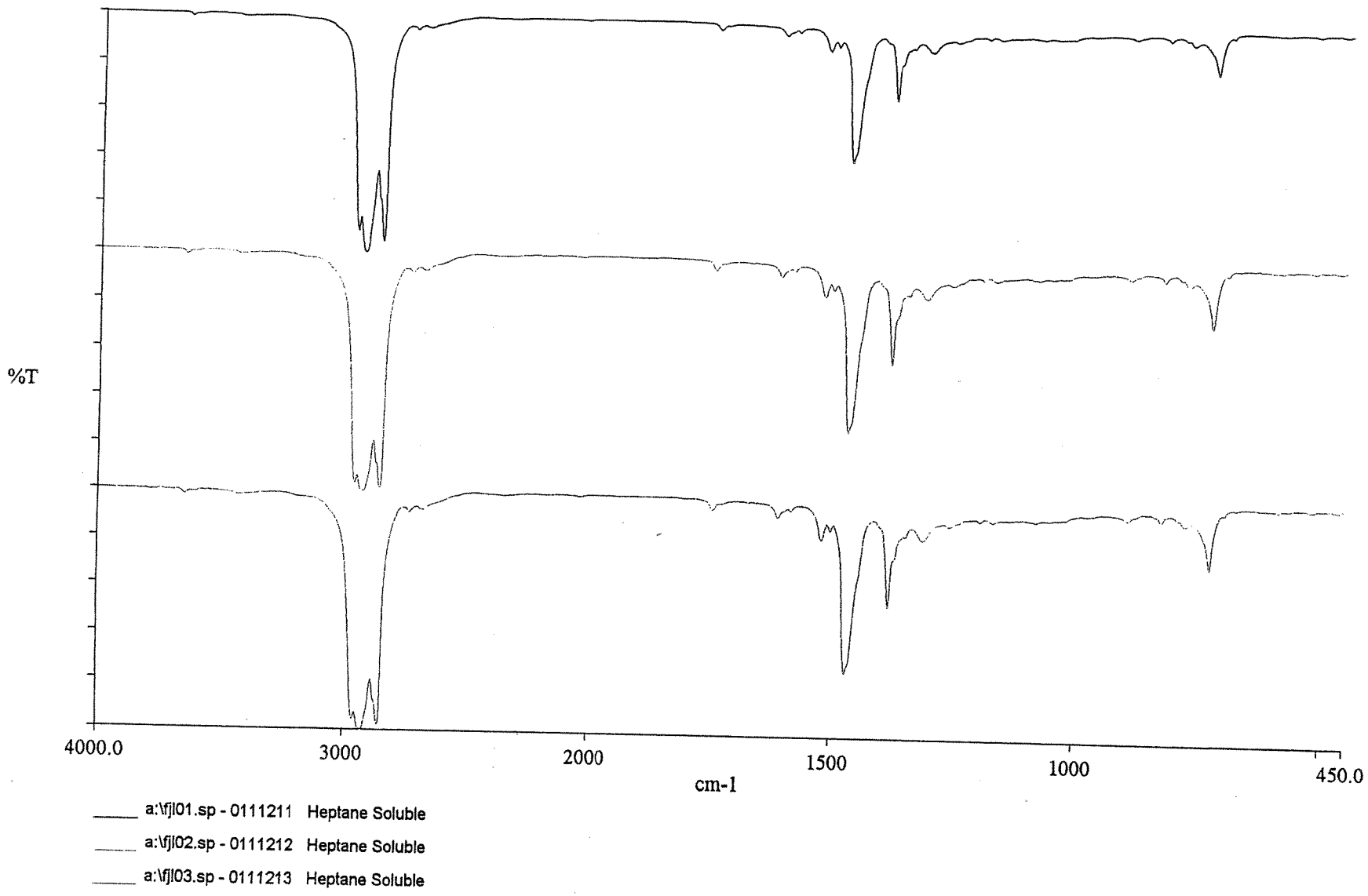
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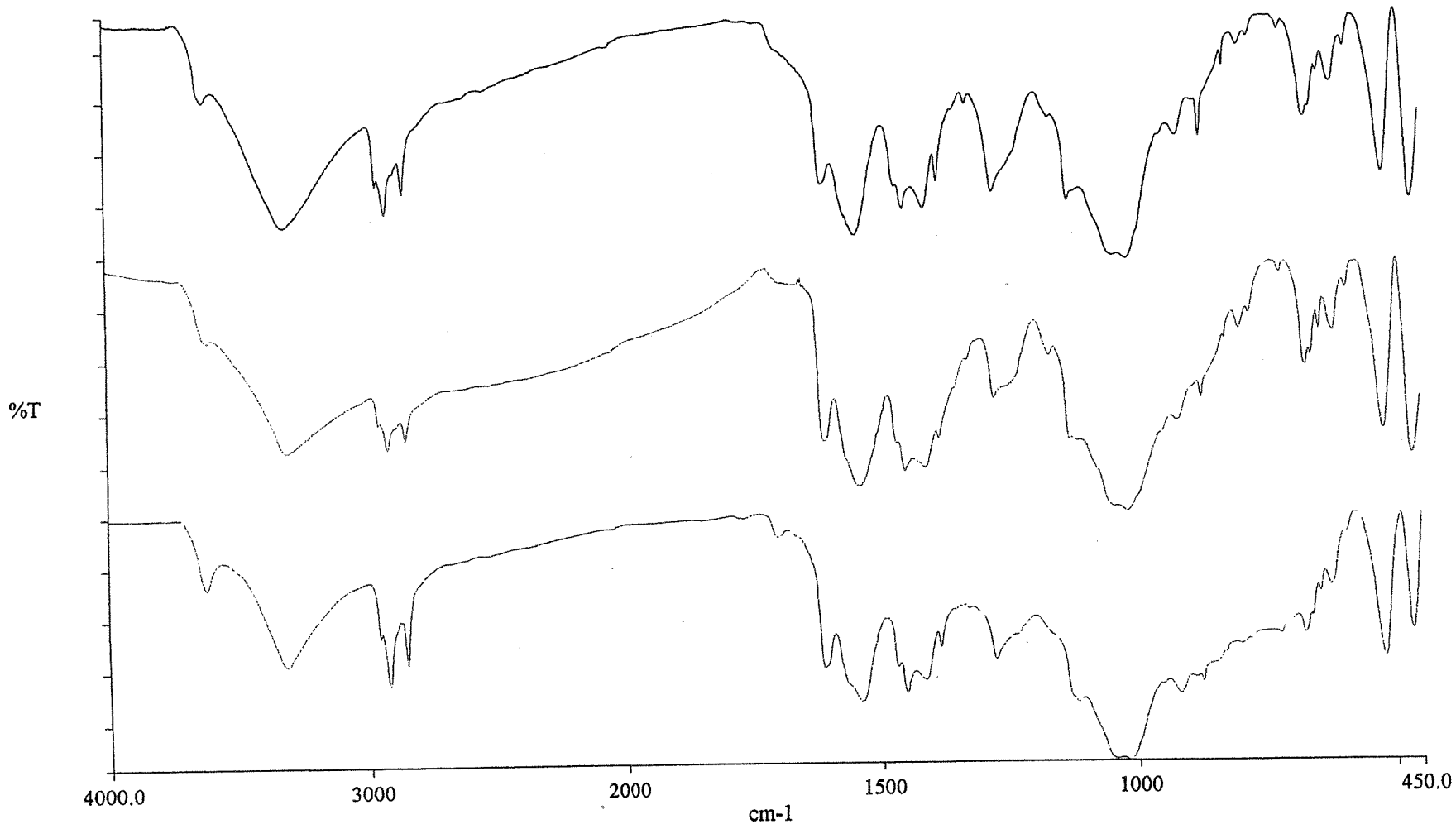
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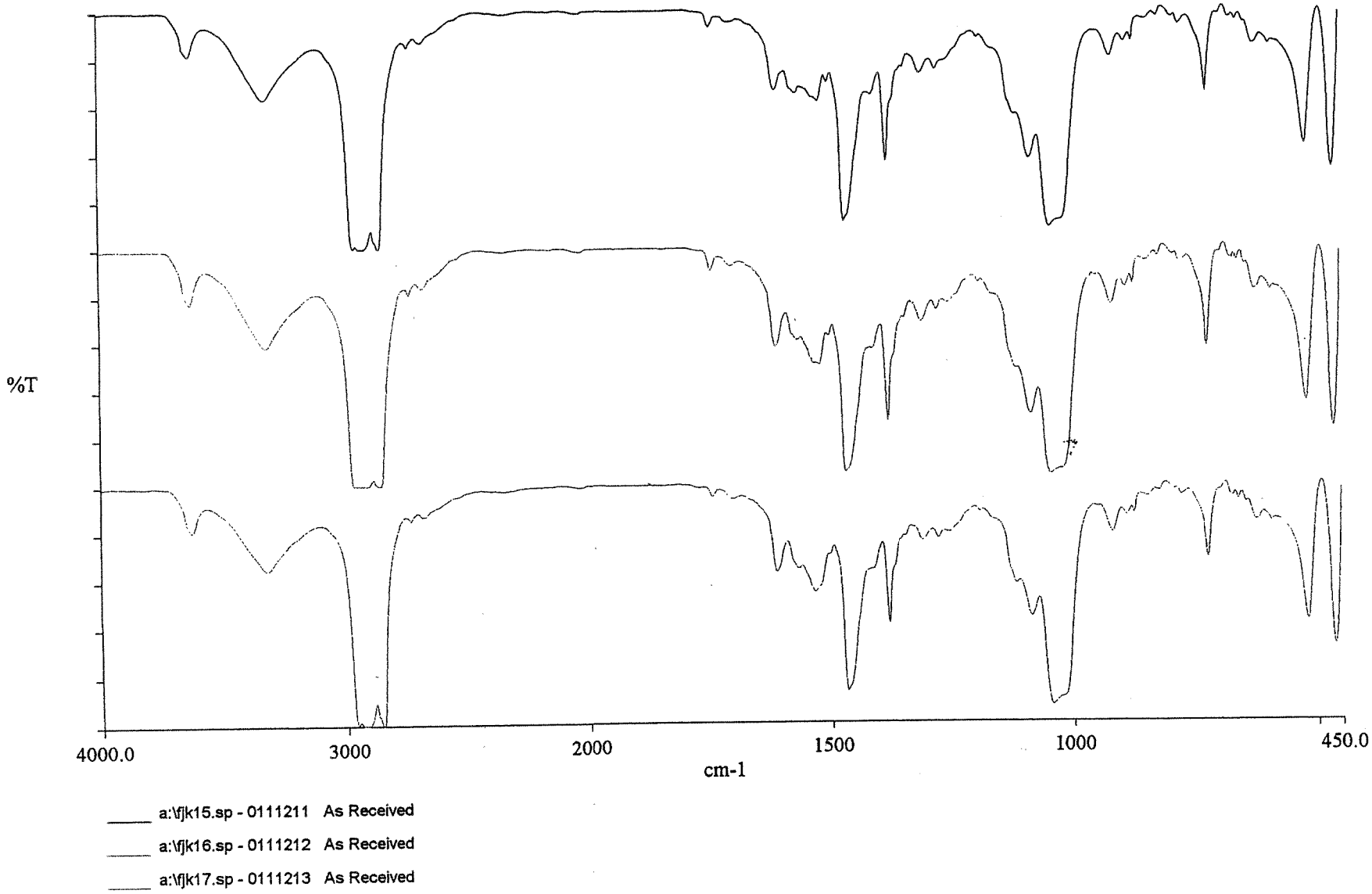
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a:\fjk17.sp - 0111213 As Received

Company:	**Dombroff & Gilmore**	Page:	2
Date:	10/19/01	Project #:	01-111
Technician:	M. Rapp		

Test Method:	ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine:	Falex Block on Ring Test Machine
Serial #:	800135004198

Testing Specimens:

Sample ID:	**Mobil 28**
Falex ID #:	4994
Block Type:	H-30
Material:	SAE O1 tool steel
Finish (µin):	4-8
Hardness (Rc):	27-33
Falex ID #:	4938
Ring Type:	Falex S-10
Material:	SAE 4620 steel
Finish (µin):	6-12
Hardness (Rc):	58-63
Falex ID #:	4937

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	8/28/01
Test Number:	0107358

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.6629	22.2
Final	7.6589	22.1988
Loss	0.0040	0.0012

Block Scar Data

Measurement 1 (mm):	2.570
Measurement 2 (mm):	2.617
Measurement 3 (mm):	2.602
Average Scar (mm):	2.596
Standared Deviation:	0.020
Coefficient of Variation (%)	0.755
Volumetric Wear (mm^3):	0.5302
Final Pressure (psi):	14,088

Company:	**Dombroff & Gilmore**	Page:	5
Date:	10/19/01	Project #:	01-111
Technician:	M. Rapp		

Test Method:	ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine:	Falex Block on Ring Test Machine
Serial #:	800135004198

Testing Specimens:

Sample ID:	**Mobil 28**
Falex ID #:	4944
Block Type:	H-30
Material:	SAE O1 tool steel
Finish (µin):	4-8
Hardness (Rc):	27-33
Falex ID #:	4938
Ring Type:	Falex S-10
Material:	SAE 4620 steel
Finish (µin):	6-12
Hardness (Rc):	58-63
Falex ID #:	4937

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	9/6/01
Test Number:	0107361

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.7119	22.2836
Final	7.7091	22.2833
Loss	0.0028	0.0003

Block Scar Data

Measurement 1 (mm):	2.414
Measurement 2 (mm):	2.427
Measurement 3 (mm):	2.410
Average Scar (mm):	2.417
Standared Deviation:	0.007
Coefficient of Variation (%)	0.300
Volumetric Wear (mm^3):	0.4277
Final Pressure (psi):	15,133

Company:	**Dombroff & Gilmore**	Page:	3
Date:	10/19/01	Project #:	01-111
Technician:	M. Rapp		

Test Method:	ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine:	Falex Block on Ring Test Machine
Serial #:	800135004198

Testing Specimens:

Sample ID:	**Aeroshell 33**
Falex ID #:	4948
Block Type:	H-30
Material:	SAE O1 tool steel
Finish (µin):	4-8
Hardness (Rc):	27-33
Falex ID #:	4938
Ring Type:	Falex S-10
Material:	SAE 4620 steel
Finish (µin):	6-12
Hardness (Rc):	58-63
Falex ID #:	4937

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	8/28/01
Test Number:	0107359

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.6401	22.1687
Final	7.6380	22.1685
Loss	0.0021	0.0002

Block Scar Data

Measurement 1 (mm):	2.513
Measurement 2 (mm):	2.399
Measurement 3 (mm):	2.050
Average Scar (mm):	2.321
Standared Deviation:	0.197
Coefficient of Variation (%)	8.488
Volumetric Wear (mm^3):	0.3785
Final Pressure (psi):	15,761

Company:	**Dombroff & Gilmore**	Page:	6
Date:	10/19/01	Project #:	01-111
Technician:	M. Rapp		

Test Method:	ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine:	Falex Block on Ring Test Machine
Serial #:	800135004198

Testing Specimens:

Sample ID:	**Aeroshell 33**
Falex ID #:	4948
Block Type:	H-30
Material:	SAE O1 tool steel
Finish (µin):	4-8
Hardness (Rc):	27-33
Falex ID #:	4938
Ring Type:	Falex S-10
Material:	SAE 4620 steel
Finish (µin):	6-12
Hardness (Rc):	58-63
Falex ID #:	4937

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	9/6/01
Test Number:	0107362

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.6461	22.2403
Final	7.6431	22.2401
Loss	0.0030	0.0002

Block Scar Data

Measurement 1 (mm):	2.492
Measurement 2 (mm):	2.517
Measurement 3 (mm):	2.517
Average Scar (mm):	2.509
Standared Deviation:	0.012
Coefficient of Variation (%)	0.470
Volumetric Wear (mm^3):	0.4783
Final Pressure (psi):	14,580

Company:	**Dombroff & Gilmore**	Page:	7
Date:	10/19/01	Project #:	01-111
Technician:	M Rapp		

Test Method:	ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine:	Falex Block on Ring Test Machine
Serial #:	800135004198

Testing Specimens:

Sample ID:	**Weathered Aeroshell 33**
Falex ID #:	4949
Block Type:	H-30
Material:	SAE O1 tool steel
Finish (µin):	4-8
Hardness (Rc):	27-33
Ring Type:	Falex S-10
Material:	SAE 4620 steel
Finish (µin):	6-12
Hardness (Rc):	58-63

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	9/20/01
Test Number:	0107363

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.7024	22.2277
Final	7.6999	22.2275
Loss	0.0025	0.0002

Block Scar Data

Measurement 1 (mm):	1.480
Measurement 2 (mm):	1.515
Measurement 3 (mm):	1.485
Average Scar (mm):	1.493
Standared Deviation:	0.015
Coefficient of Variation (%)	1.035
Volumetric Wear (mm^3):	0.1008
Final Pressure (psi):	24,493

Company:	**Dombroff & Gilmore**	Page:	8
Date:	10/19/01	Project #:	01-111
Technician:	M Rapp		

Test Method:	ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine:	Falex Block on Ring Test Machine
Serial #:	800135004198

Testing Specimens:

Sample ID:	**Weathered Aeroshell 33**
Falex ID #:	4949
Block Type:	H-30
Material:	SAE O1 tool steel
Finish (μin):	4-8
Hardness (Rc):	27-33
Ring Type:	Falex S-10
Material:	SAE 4620 steel
Finish (μin):	6-12
Hardness (Rc):	58-63

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	360
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	9/20/01
Test Number:	0107364

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.7072	22.1877
Final	7.7059	22.1874
Loss	0.0013	0.0003

Block Scar Data

Measurement 1 (mm):	1.631
Measurement 2 (mm):	1.614
Measurement 3 (mm):	1.604
Average Scar (mm):	1.616
Standared Deviation:	0.011
Coefficient of Variation (%)	0.690
Volumetric Wear (mm^3):	0.1278
Final Pressure (psi):	22,629

Company:	**Dombroff & Gilmore**	Page:	1
Date:	10/19/01	Project #:	01-111
Technician:	M. Rapp		

Test Method: ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine: Falex Block on Ring Test Machine
Serial #: 800135004198

Testing Specimens:

Sample ID: **Mobil 28**
Falex ID #: 4994

Block Type:	H-30
Material:	SAE O1 tool steel
Finish (μin):	4-8
Hardness (Rc):	27-33
Falex ID #:	4938
Ring Type:	Falex S-10
Material:	SAE 4620 steel
Finish (μin):	6-12
Hardness (Rc):	58-63
Falex ID #:	4937

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	630
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	8/23/01
Test Number:	0107357

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.7200	22.1269
Final	7.7069	22.1262
Loss	0.0131	0.0007

Block Scar Data

Measurement 1 (mm):	3.459
Measurement 2 (mm):	3.577
Measurement 3 (mm):	3.476
Average Scar (mm):	3.504
Standared Deviation:	0.052
Coefficient of Variation (%)	1.486
Volumetric Wear (mm^3):	1.3052
Final Pressure (psi):	18,267

Company:	**Dombroff & Gilmore**	Page:	4
Date:	10/19/01	Project #:	01-111
Technician:	M. Rapp		

Test Method: ASTM D 3704, Wear Preventative Properties of Lubricating Greases in Oscillating Motion
Test Machine: Falex Block on Ring Test Machine
Serial #: 800135004198

Testing Specimens:

Sample ID: **Aeroshell 33**
Falex ID #: 4948

Block Type:	H-30
Material:	SAE O1 tool steel
Finish (µin):	4-8
Hardness (Rc):	27-33
Falex ID #:	4938
Ring Type:	Falex S-10
Material:	SAE 4620 steel
Finish (µin):	6-12
Hardness (Rc):	58-63
Falex ID #:	4937

Testing Conditions:

Speed (cpm):	87.5
Temperature (°C):	Ambient
Load (lb):	630
Duration (cycles):	5000
Oscillation Angle:	90°
Test Date:	8/29/01
Test Number:	0107360

Test Resuts:

Mass Data, g

	Block	Ring
Initial	7.7108	22.2273
Final	7.7021	22.2270
Loss	0.0087	0.0003

Block Scar Data

Measurement 1 (mm):	3.523
Measurement 2 (mm):	3.552
Measurement 3 (mm):	3.339
Average Scar (mm):	3.471
Standared Deviation:	0.094
Coefficient of Variation (%)	2.717
Volumetric Wear (mm^3):	1.2690
Final Pressure (psi):	18,439

Company:	**Dombroff & Gilmore**	Page:	1
Date:	9/6/01	Project #:	01-111
Technician:	D. Hlavacek		

Method:	ASTM D 2509, Measurement of Load-Carrying Capacity of Lubricating Grease
Machine:	Falex Timken Test Machine
Serial #:	002-93-574

Test Specimen:

Sample ID:	**Mobil 28**
Falex ID #:	4944
Block Material:	Carburized Steel
Finish (µin):	20-30
Hardness (Rc):	58-62
Ring Material:	Carburized Steel
Finish (µin):	20-30
Hardness (Rc):	58-62

Test Conditions:

Speed (rpm):	800 (± 5)
Temperature (°C):	37.8 (± 2.8)
Load (lb):	Various
Break-In (sec):	30
Duration (min):	10 / load stage
Test Date:	8/23/01
Test Number:	0202110

Test Results:

Applied Load, lb	Block Number	Result, (P)ass/(F)ail	Average Scar, mm	Coefficient of Friction
30	1	F	N/A	
18	1	P	1.195	0.2820
24	1	F	N/A	
21	2	F	N/A	

OK Load (lb):	**18**	Contact Pressure at OK load: 7651.9
Score Load (lb):	**21**	
Scar Width at OK Load (mm):	**1.195**	

Comments:

OK Load Value
The maximum load added to the lever system at which no scoring or seizure occurs. This load reflects the load carrying capacity of the lubricant.

Score Load Value
The minimum load added to the lever system at which scoring or seizure occurs.

Scar Width at OK Load
The average scar width at the load corresponding to the OK Load Value.

Company:	**Dombroff & Gilmore**	Page:	3
Date:	9/25/01	Project #:	01-111
Technician:	D. Hlavacek		

Method:	ASTM D 2509, Measurement of Load-Carrying Capacity of Lubricating Grease
Machine:	Falex Timken Test Machine
Serial #:	002-93-574

Test Specimen:

Sample ID:	**Mobil 28**
Falex ID #:	4944
Block Material:	Carburized Steel
Finish (µin):	20-30
Hardness (Rc):	58-62
Ring Material:	Carburized Steel
Finish (µin):	20-30
Hardness (Rc):	58-62

Test Conditions:

Speed (rpm):	800 (± 5)
Temperature (°C):	37.8 (± 2.8)
Load (lb):	Various
Break-In (sec):	30
Duration (min):	10 / load stage
Test Date:	9/6/01
Test Number:	0202112

Test Results:

Applied Load, lb	Block Number	Result, (P)ass/(F)ail	Average Scar, mm	Coefficient of Friction
18	1	P	1.208	0.1216
21	1	F		

		Contact Pressure at OK load:
OK Load (lb):	**18**	7569.6
Score Load (lb):	**21**	
Scar Width at OK Load (mm):	**1.208**	

Comments:

OK Load Value
The maximum load added to the lever system at which no scoring or seizure occurs. This load reflects the load carrying capacity of the lubricant.

Score Load Value
The minimum load added to the lever system at which scoring or seizure occurs.

Scar Width at OK Load
The average scar width at the load corresponding to the OK Load Value.

Company:	**Dombroff & Gilmore**	Page:	1
Date:	12/10/01	Project #:	01-111
Technician:	D. Hlavacek		

Method:	ASTM D 2509, Measurement of Load-Carrying Capacity of Lubricating Grease
Machine:	Falex Timken Test Machine
Serial #:	002-93-574

Test Specimen:

Sample ID:	**Mobil 28**
Falex ID #:	4944
Block Material:	Carburized Steel
Finish (µin):	20-30
Hardness (Rc):	58-62
Ring Material:	Carburized Steel
Finish (µin):	20-30
Hardness (Rc):	58-62

Test Conditions:

Speed (rpm):	800 (± 5)
Temperature (°C):	37.8 (± 2.8)
Load (lb):	Various
Break-In (sec):	30
Duration (min):	10 / load stage
Test Date:	12/10/01
Test Number:	0202122

Test Results:

Applied Load, lb	Block Number	Result, (P)ass/(F)ail	Average Scar, mm	Coefficient of Friction
18	1	P	1.212	0.1221
21	1	F		
24	1	F		
30	1	F		

OK Load (lb):	**18**	Contact Pressure at OK load:
Score Load (lb):	**21**	
Scar Width at OK Load (mm):	**1.212**	

Comments:

OK Load Value
The maximum load added to the lever system at which no scoring or seizure occurs. This load reflects the load carrying capacity of the lubricant.

Score Load Value
The minimum load added to the lever system at which scoring or seizure occurs.

Scar Width at OK Load
The average scar width at the load corresponding to the OK Load Value.

Company:	**Dombroff & Gilmore**	Page:	2
Date:	9/6/01	Project #:	01-111
Technician:	D. Hlavacek		

Method:	ASTM D 2509, Measurement of Load-Carrying Capacity of Lubricating Grease
Machine:	Falex Timken Test Machine
Serial #:	002-93-574

Test Specimen:

Sample ID:	**Aeroshell 33**
Falex ID #:	4948
Block Material:	Carburized Steel
Finish (µin):	20-30
Hardness (Rc):	58-62
Ring Material:	Carburized Steel
Finish (µin):	20-30
Hardness (Rc):	58-62

Test Conditions:

Speed (rpm):	800 (± 5)
Temperature (°C):	37.8 (± 2.8)
Load (lb):	Various
Break-In (sec):	30
Duration (min):	10 / load stage
Test Date:	8/27/01
Test Number:	0202111

Test Results:

Applied Load, lb	Block Number	Result, (P)ass/(F)ail	Average Scar, mm	Coefficient of Friction
15	1	P	0.788	0.1094
21	1	P	1.125	0.0920
27	1	P	1.286	0.1267
35	2	F	N/A	
30	2	P	1.359	0.0950

OK Load (lb):	**30**	Contact Pressure at OK load: 11214.2
Score Load (lb):	**35**	
Scar Width at OK Load (mm):	**1.359**	

Comments:

OK Load Value
The maximum load added to the lever system at which no scoring or seizure occurs. This load reflects the load carrying capacity of the lubricant.

Score Load Value
The minimum load added to the lever system at which scoring or seizure occurs.

Scar Width at OK Load
The average scar width at the load corresponding to the OK Load Value.

Company:	**Dombroff & Gilmore**	Page:	4
Date:	9/25/01	Project #:	01-111
Technician:	D. Hlavacek		

Method:	ASTM D 2509, Measurement of Load-Carrying Capacity of Lubricating Grease
Machine:	Falex Timken Test Machine
Serial #:	002-93-574

Test Specimen:

Sample ID:	**Aeroshell 33**
Falex ID #:	4948
Block Material:	Carburized Steel
Finish (µin):	20-30
Hardness (Rc):	58-62
Ring Material:	Carburized Steel
Finish (µin):	20-30
Hardness (Rc):	58-62

Test Conditions:

Speed (rpm):	800 (± 5)
Temperature (°C):	37.8 (± 2.8)
Load (lb):	Various
Break-In (sec):	30
Duration (min):	10 / load stage
Test Date:	9/6/01
Test Number:	0202113

Test Results:

Applied Load, lb	Block Number	Result, (P)ass/(F)ail	Average Scar, mm	Coefficient of Friction
30	1	P	1.063	0.079
35	1	F		

		Contact Pressure at OK load:
OK Load (lb):	**30**	
Score Load (lb):	**35**	14336.8
Scar Width at OK Load (mm):	**1.063**	

Comments:

OK Load Value
The maximum load added to the lever system at which no scoring or seizure occurs. This load reflects the load carrying capacity of the lubricant.

Score Load Value
The minimum load added to the lever system at which scoring or seizure occurs.

Scar Width at OK Load
The average scar width at the load corresponding to the OK Load Value.

Company:	**Dombroff & Gilmore**	Page:	5
Date:	9/25/01	Project #:	01-111
Technician:	D. Hlavacek		

Method:	ASTM D 2509, Measurement of Load-Carrying Capacity of Lubricating Grease
Machine:	Falex Timken Test Machine
Serial #:	002-93-574

Test Specimen:

Sample ID:	**Aeroshell 33 Weathered**
Falex ID #:	4949
Block Material:	Carburized Steel
Finish (µin):	20-30
Hardness (Rc):	58-62
Ring Material:	Carburized Steel
Finish (µin):	20-30
Hardness (Rc):	58-62

Test Conditions:

Speed (rpm):	800 (± 5)
Temperature (°C):	37.8 (± 2.8)
Load (lb):	Various
Break-In (sec):	30
Duration (min):	10 / load stage
Test Date:	9/20/01
Test Number:	0202114

Test Results:

Applied Load, lb	Block Number	Result, (P)ass/(F)ail	Average Scar, mm	Coefficient of Friction
30	1	P	1.373	0.12
35	1	F		
40	1	F		

OK Load (lb):	**30**	Contact Pressure at OK load: 11099.8
Score Load (lb):	**35**	
Scar Width at OK Load (mm):	**1.373**	

Comments:

OK Load Value
The maximum load added to the lever system at which no scoring or seizure occurs. This load reflects the load carrying capacity of the lubricant.

Score Load Value
The minimum load added to the lever system at which scoring or seizure occurs.

Scar Width at OK Load
The average scar width at the load corresponding to the OK Load Value.

Company:	**Dombroff & Gilmore**	Page:	6
Date:	9/25/01	Project #:	01-111
Technician:	D. Hlavacek		

Method:	ASTM D 2509, Measurement of Load-Carrying Capacity of Lubricating Grease
Machine:	Falex Timken Test Machine
Serial #:	002-93-574

Test Specimen:

Sample ID:	**Aeroshell 33 Weathered**
Falex ID #:	4949
Block Material:	Carburized Steel
Finish (µin):	20-30
Hardness (Rc):	58-62
Ring Material:	Carburized Steel
Finish (µin):	20-30
Hardness (Rc):	58-62

Test Conditions:

Speed (rpm):	800 (± 5)
Temperature (°C):	37.8 (± 2.8)
Load (lb):	Various
Break-In (sec):	30
Duration (min):	10 / load stage
Test Date:	9/21/01
Test Number:	0202115

Test Results:

Applied Load, lb	Block Number	Result, (P)ass/(F)ail	Average Scar, mm	Coefficient of Friction
30	1	P	1.666	0.119
35	1	F		
40	1	F		

OK Load (lb):	**30**	Contact Pressure at OK load: 9147.7
Score Load (lb):	**35**	
Scar Width at OK Load (mm):	**1.666**	

Comments:

OK Load Value
The maximum load added to the lever system at which no scoring or seizure occurs. This load reflects the load carrying capacity of the lubricant.

Score Load Value
The minimum load added to the lever system at which scoring or seizure occurs.

Scar Width at OK Load
The average scar width at the load corresponding to the OK Load Value.

Company:	***Dombroff & Gilmore***	Page:	1
Date:	12/10/01	Project #:	01-111
Technician	N. Pekoc		

Method: Modified Thrust Washer
Machine: Falex High Performance Multi-Specimen Test Machine, Computer Controlled Version
Serial #: 809C35001108

TEST SPECIMENS:

Upper Material:	**1018 Steel**
Finish (μ in.):	14-18
Hardness (HRc):	15-25
Falex ID #:	4935
Lower Material:	**1018 Steel**
Finish (μ in.):	14-18
Hardness (HRc):	15-25
Falex ID #:	4936

TEST CONDITIONS:

Test Speed (rpm):	5
Temperature (°C):	Ambient
Duration:	2 min/stage
Test Load (lb):	**200 to 2200**
Mean Test Radius (in):	0.531

Test Results:

Test Date:	11/17/01	11/20/01	11/18/01	11/20/01
Test Number:	09036	09039	090937	090940
Upper Falex ID #:	4935	4935	4935	4935
Lower Falex ID #:	4936	4936	4936	4935
Lubricant:	**Mobil 28**	**Mobil 28**	**Aeroshell 33**	**Aeroshell 33**
Lubricant Falex ID #:	4944	4944	4948	4948
SaveFile Name:	DGSTLTHRW1	DGSTLTHRW4	DGSTLTHRW2	DGSTLTHRW5
Test Program Name:	DGSTLTHRW	DGSTLTHRW	DGSTLTHRW	DGSTLTHRW
Mass Loss, Upper (g):	0.0001	0.0009	0.0003	0.0013
Mass Loss, Lower (g):	0.0001	0.0028	0.0039	0.0007

Load Step, N	CoF	CoF	CoF	CoF
889 (200 lb.)	0.132	0.146	0.146	0.154
1334 (300 lb.)	0.130	0.130	0.132	0.132
1779 (400 lb.)	0.127	0.124	0.126	0.128
2224 (500 lb.)	0.124	0.123	0.122	0.126
2669 (600 lb.)	0.120	0.119	0.117	0.124
3114 (700 lb.)	0.117	0.117	0.115	0.124
3559 (800 lb.)	0.116	0.116	0.114	0.123
4003 (900 lb.)	0.115	0.113	0.112	0.122
4448 (1000 lb.)	0.114	0.111	0.111	0.122
4893 (1100 lb.)	0.113	0.110	0.110	0.122
5338 (1200 lb.)	0.112	0.109	0.109	0.122
5783 (1300 lb.)	0.112	0.108	0.108	0.121
6228 (1400 lb.)	0.112	0.108	0.108	0.121
6672 (1500 lb.)	0.111	0.107	0.108	0.120
7117 (1600 lb.)	0.111	0.107	0.108	0.123
7562 (1700 lb.)	0.110	0.106	0.107	0.131
8007 (1800 lb.)	0.108	0.107	0.109	0.137
8452 (1900 lb.)	0.108	0.106	0.110	0.140
8896 (2000 lb.)	0.112	0.106	0.112	0.134
9341 (2100 lb.)	0.137	0.105	0.118	
9786 (2200 lb.)	0.138	0.104	0.130	

Comments: This is Preliminary testing to find friction characteristics of these greases.
See Graphs for Torque, Friction Coefficient, Load, Speed, and Specimen Temperature trends.

Company:	***Dombroff & Gilmore***	Page:	2
Date:	12/10/01	Project #:	01-111
Technician	N. Pekoc		

Method:	Modified Thrust Washer
Machine:	Falex High Performance Multi-Specimen Test Machine, Computer Controlled Version
Serial #:	809C35001108

TEST SPECIMENS:

Upper Material:	**1018 Steel**
Finish (μ in.):	14-18
Hardness (HRc):	15-25
Falex ID #:	4935
Lower Material:	**1018 Steel**
Finish (μ in.):	14-18
Hardness (HRc):	15-25
Falex ID #:	4936

TEST CONDITIONS:

Test Speed (rpm):	5
Temperature (°C):	Ambient
Duration:	2 min/stage
Test Load (lb):	**200 to 2200**
Mean Test Radius (in):	0.531

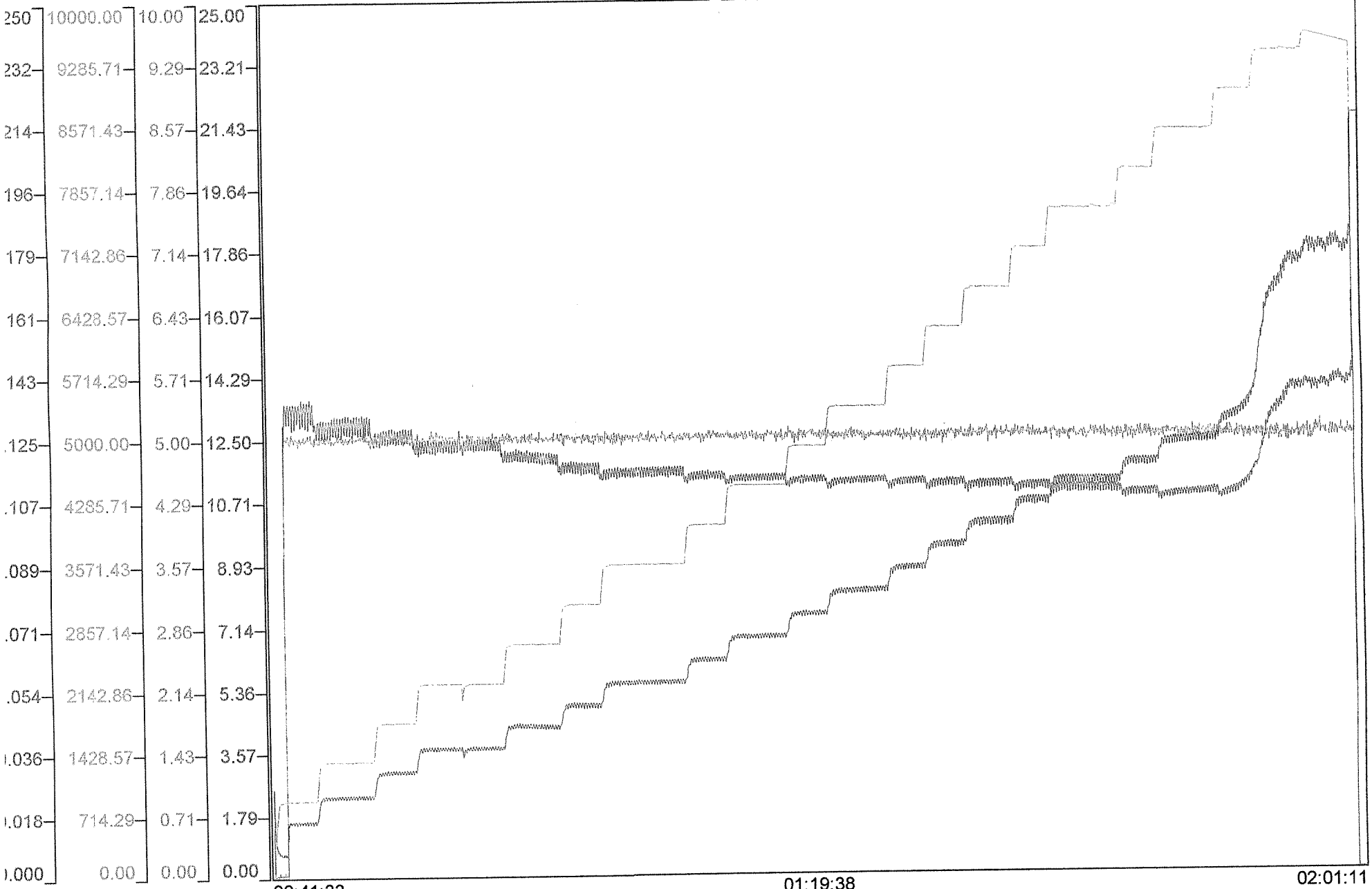
Test Results:

Test Date:	11/18/01	11/20/01
Test Number:	09038	09041
Upper Falex ID #:	4935	4935
Lower Falex ID #:	4936	4936
Lubricant:	**Aeroshell 33 weathered**	**Aeroshell 33 weathered**
Lubricant Falex ID #:	4949	4949
SaveFile Name:	DGSTLTHRW3	DGSTLTHRW6
Test Program Name:	DGSTLTHRW	DGSTLTHRW
Mass Loss, Upper (g):	0.0010	0.0028
Mass Loss, Lower (g):	0.0012	0.0013

Load Step, N	CoF	CoF
889 (200 lb.)	0.173	0.158
1334 (300 lb.)	0.140	0.140
1779 (400 lb.)	0.133	0.132
2224 (500 lb.)	0.127	0.128
2669 (600 lb.)	0.122	0.126
3114 (700 lb.)	0.120	0.125
3559 (800 lb.)	0.119	0.124
4003 (900 lb.)	0.117	0.121
4448 (1000 lb.)	0.118	0.121
4893 (1100 lb.)	0.115	0.123
5338 (1200 lb.)	0.115	0.130
5783 (1300 lb.)	0.113	0.133
6228 (1400 lb.)	0.112	0.161
6672 (1500 lb.)	0.110	0.120
7117 (1600 lb.)	0.110	0.107
7562 (1700 lb.)	0.109	0.101
8007 (1800 lb.)	0.111	0.101
8452 (1900 lb.)	0.117	0.098
8896 (2000 lb.)	0.115	0.095
9341 (2100 lb.)	0.109	0.092
9786 (2200 lb.)	0.111	0.092

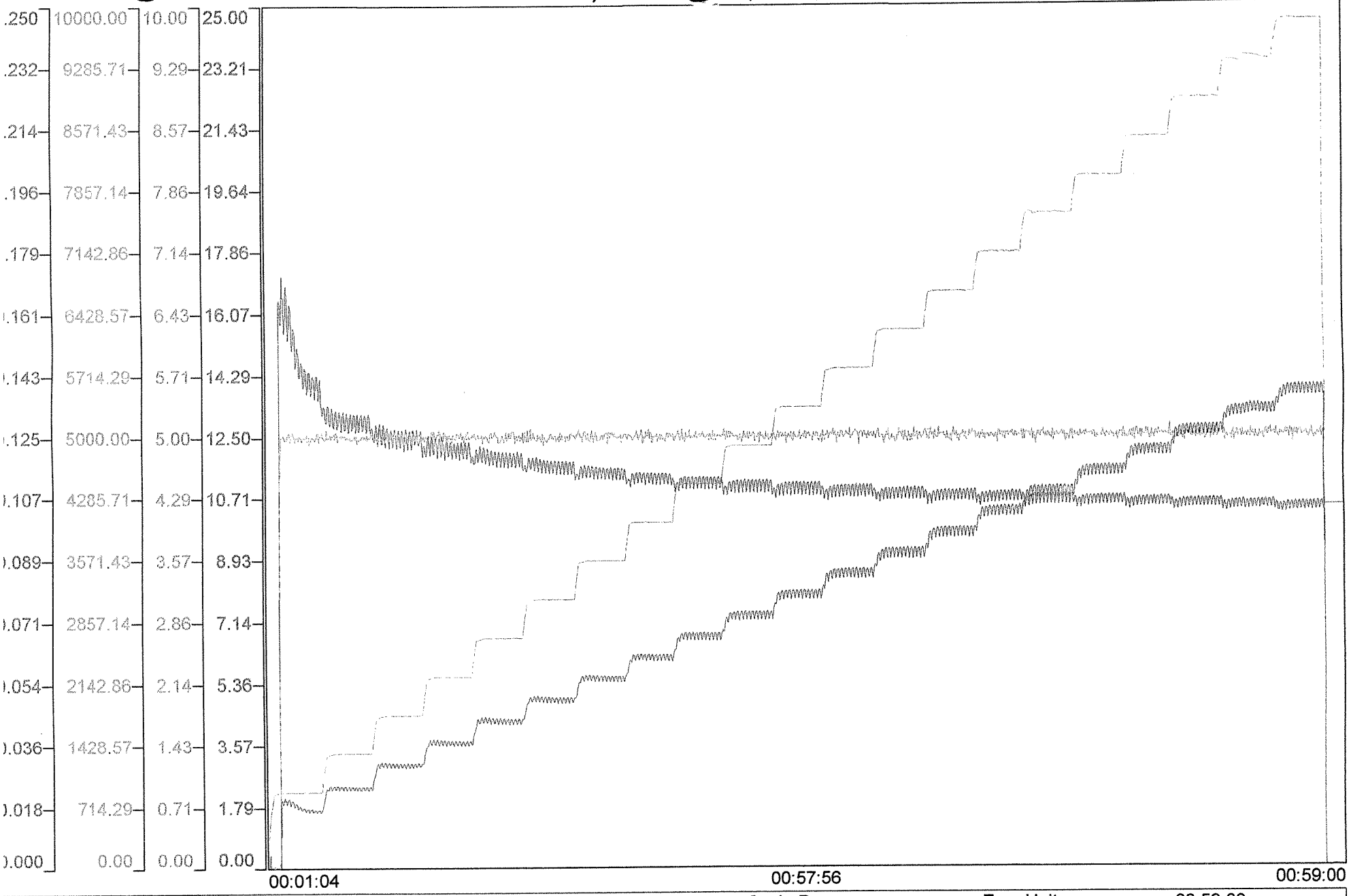
Comments: This is Preliminary testing to find friction characteristics of these greases.
See Graphs for Torque, Friction Coefficient, Load, Speed, and Specimen Temperature trends.

1018 Steel, Mc[illegible] 28, run1



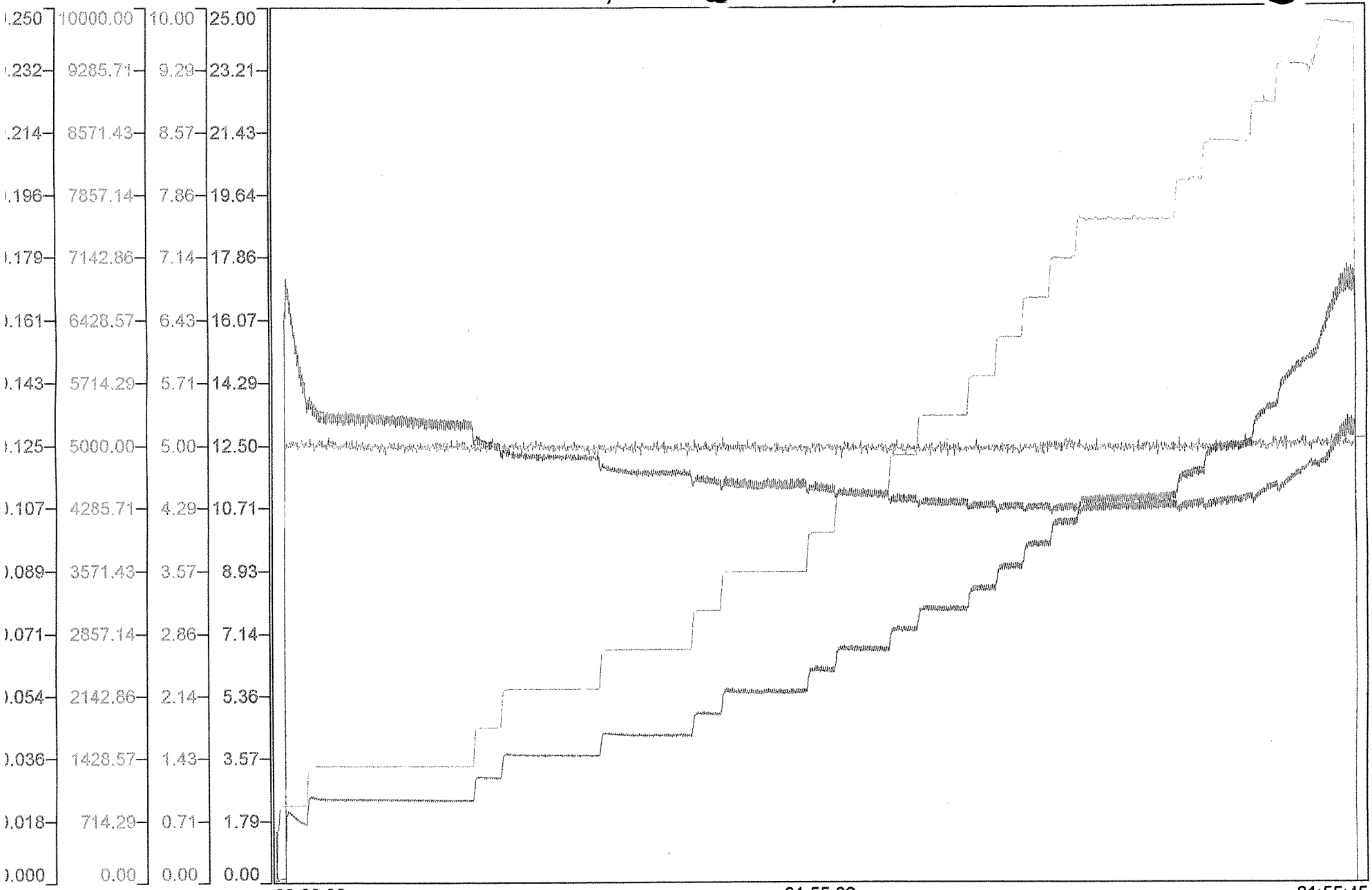
Description	Batch Name	Scale Range	Eng. Units	02:01:11
COEFFICIENT OF FRICTION	dgstlthrw1	0.000/0.250	Coef	0.215
SPECIMEN LOAD	dgstlthrw1	0.00/10000.00	N	0.00
SPECIMEN RPM	dgstlthrw1	0.00/10.00	rpm	0.00
TORQUE	dgstlthrw1	0.00/25.00	N-m	8.59e-04

1018 Steel, Mob[illegible]8, HL, run 2



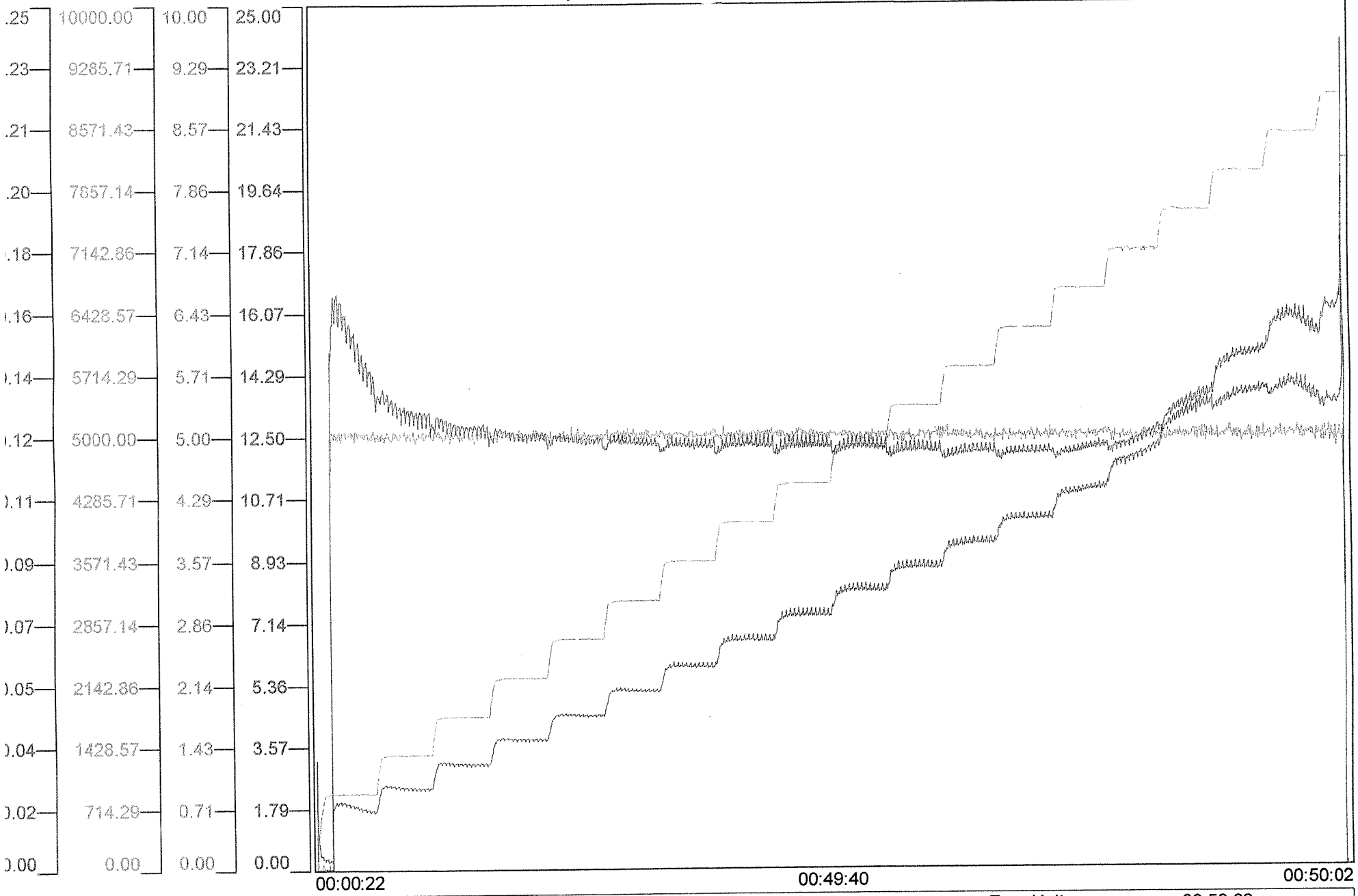
Description	Batch Name	Scale Range	Eng. Units	00:59:00
COEFFICIENT OF FRICTION	dgstlthrw4	0.000/0.250	Coef	0.104
SPECIMEN LOAD	dgstlthrw4	0.00/10000.00	N	0.00
SPECIMEN RPM	dgstlthrw4	0.00/10.00	rpm	0.00
TORQUE	dgstlthrw4	0.00/25.00	N-m	-8.75e-03

1018 Steel, Aerc ell 33, run 1



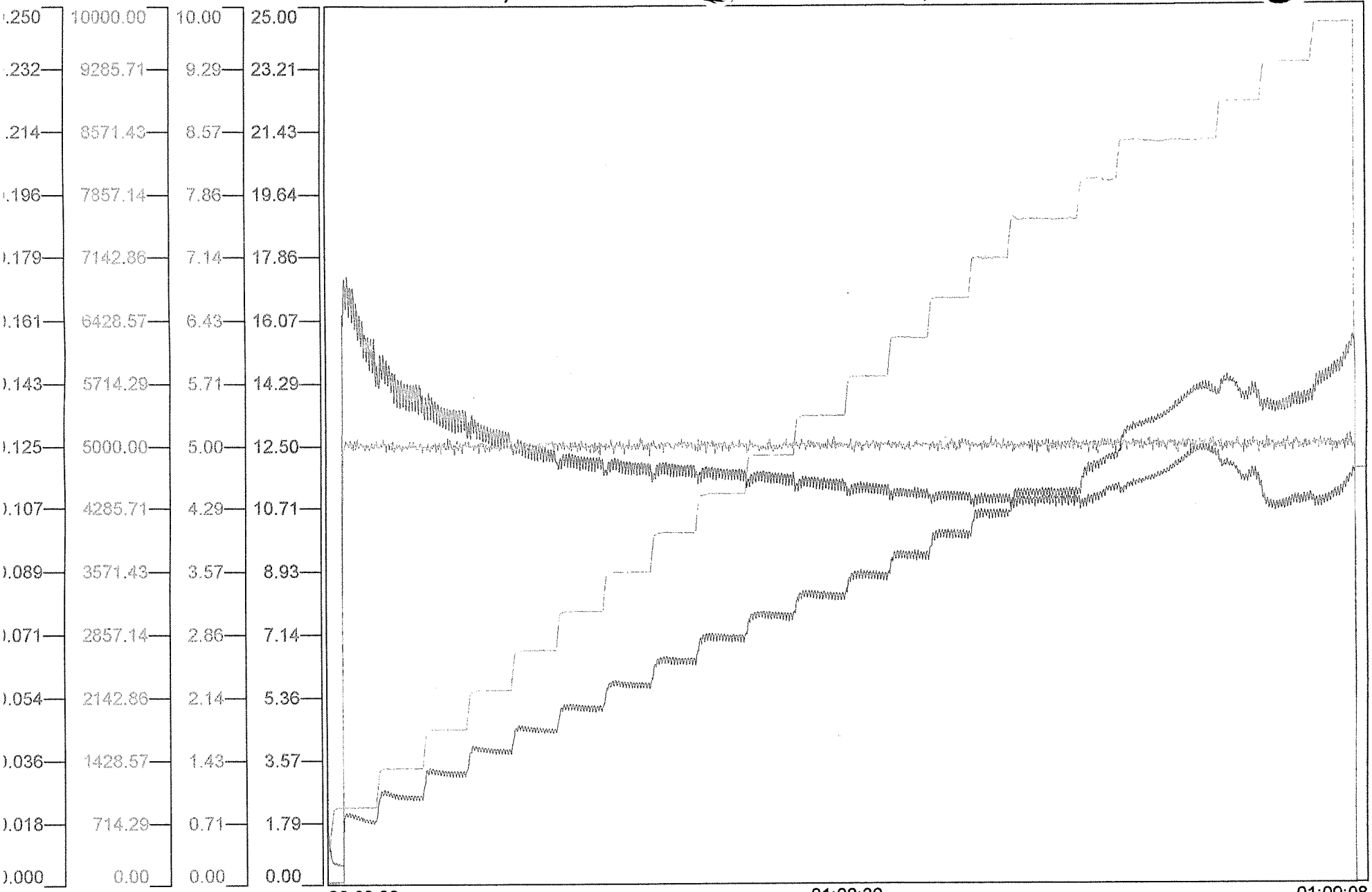
Description	Batch Name	Scale Range	Eng. Units	01:55:45
COEFFICIENT OF FRICTION	dgstlthrw2	0.000/0.250	Coef	0.127
SPECIMEN LOAD	dgstlthrw2	0.00/10000.00	N	0.00
SPECIMEN RPM	dgstlthrw2	0.00/10.00	rpm	0.00
TORQUE	dgstlthrw2	0.00/25.00	N-m	6.93e-03

1018 Steel, Aerosol 33, HL run 2



Description	Batch Name	Scale Range	Eng. Units	00:50:02
COEFFICIENT OF FRICTION	dgstlthrw5	0.00/0.25	Coef	***
SPECIMEN LOAD	dgstlthrw5	0.00/10000.00	N	***
SPECIMEN RPM	dgstlthrw5	0.00/10.00	rpm	***
TORQUE	dgstlthrw5	0.00/25.00	N-m	***

1018 steel, Aeroshell 3[illegible] weathered, run 1



Description	Batch Name	Scale Range	Eng. Units	01:09:08
COEFFICIENT OF FRICTION	dgstlthrw3	0.000/0.250	Coef	***
SPECIMEN LOAD	dgstlthrw3	0.00/10000.00	N	***
SPECIMEN RPM	dgstlthrw3	0.00/10.00	rpm	***
TORQUE	dgstlthrw3	0.00/25.00	N-m	***