https://ntrs.nasa.gov/search.jsp?R=19990031946 2020-06-15T22:30:41+00:00Z

NASA/TM—1999-209064

An Additive to Improve the Wear Characteristics of Perfluoropolyether Based Greases

David G.V. Jones, Mahmoud A. Fowzy, and James F. Landry
Castrol Industrial North American, Inc., Downers Grove, Illinois

William R. Jones, Jr.
Glenn Research Center, Cleveland, Ohio

Bradley A. Shogrin and QuynhGiao Nguyen
AYT Corporation, Brook Park, Ohio

Prepared for the
Annual Meeting
sponsored by the Society of Tribologists
and Lubrication Engineers
Las Vegas, Nevada, May 23–27, 1999

National Aeronautics and
Space Administration

Glenn Research Center

March 1999

This report is a preprint of a paper intended for presentation at a conference. Because of changes that may be made before formal publication, this preprint is made available with the understanding that it will not be cited or reproduced without the permission of the author.

Available from

NASA Center for Aerospace Information
7121 Standard Drive
Hanover, MD 21076
Price Code: A03

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22100
Price Code: A03

An Additive to Improve the Wear Characteristics of Perfluoropolyether Based Greases

David G. V. Jones
Mahmoud A. Fowzy
James F. Landry
Castrol Industrial North America, Inc.
Downers Grove, IL 60515

William R. Jones, Jr.
NASA Lewis Research Center
Cleveland, OH 44135

Bradley A. Shogrin
QuynhGiao Nguyen
AYT Corp.
Brookpark, OH 44142

ABSTRACT

The friction and wear characteristics of two formulated perfluoropolyether based greases were compared to their non-additive base greases. One grease was developed for the electronics industry (designated as GXL-296A) while the other is for space applications (designated GXL-320A). The formulated greases (GXL-296B and GXL-320B) contained a proprietary antiwear additive at an optimized concentration. Tests were conducted using a vacuum four-ball tribometer. AISI 52100 steel specimens were used for all GXL-296 tests. Both AISI 52100 steel and 440C stainless steel were tested with the GXL 320 greases. Test conditions included: a pressure $< 6.7 \times 10^{-4}$ Pa, a 200N load, a sliding velocity of 28.8 mm/sec (100 rpm) and room temperature ($\cong 23$ °C). Wear rates for each grease were determined from the slope of the wear volume as a function of sliding distance. Both non-additive base greases yielded relatively high wear rates on the order of 10^{-8} mm^3/mm using AISI 52100 steel specimens. Formulated grease GXL-296B yielded a reduction in wear rate by a factor of ~ 21, while grease GXL-320B had a reduction of ~12 times. Lower wear rates (~ 50 %) were observed with both GXL-320 greases using 440C stainless steel. Mean friction coefficients were slightly higher for both formulated greases compared to their base greases. The GXL-296 series (higher base oil viscosity) yielded much higher friction coefficients compared to their GXL-320 series (lower base oil viscosity) counterparts.

INTRODUCTION

Perfluoropolyethers (PFPE) are a class of liquid lubricants that have been used extensively for space applications (*1*) and more recently for magnetic recording media (*2*). In addition, these fluids are also candidates for advanced gas turbine engine applications (*3*). Several different structures are commercially available. One branched fluid is made by CsF catalyzed polymerization of hexafluoropropene oxide (HFPO)(K fluids) (*4*). A similar polymer is made by the UV catalyzed oxidation of HFPO (FY fluids) (*5*). A linear fluid (FZ fluids) is prepared by a similar process, but utilizing tetrafluoroethylene (*6*). A fourth material (D fluids) is produced by polymerization of tetrafluorooxetane followed by direct fluorination (*7*). Some of these materials are available as greases thickened with polytetrafluoroethylene.

There is a multiplicity of papers demonstrating the high wear rates generated with unformulated PFPE fluids in vacuum and under high loads (*8*)-(*18*). Others have shown the degradation characteristics of PFPEs in contact with a variety of surfaces in air, oxygen and vacuum (*19*)-(*21*). Several mechanisms of catalytic degradation have been invoked, including attacks by Lewis acids (*22*)-(*23*), oxides and nascent metals (*24*)-(*26*) and surface hydroxyl groups (*27*)-(*28*). The linear PFPEs are more prone to degradation than the branched polymers (*29*), but do exhibit very low volatility and excellent low temperature performance important for space applications (*1*). For semiconductor applications, low volatility is crucial, but low temperature fluidity is not a requirement.

Early work with antiwear or antidegradation additives was hampered by the insolubility of conventional additives in the PFPE basestocks. In recent years, a number of studies have involved the synthesis of PFPE soluble additives (*11*),(*30*)-(*35*). Some of these studies showed little or no wear reduction while others showed substantial reductions. However, none were performed on PFPE grease-based systems.

The objective of this study was to formulate two commercially available PFPE greases (one for space applications and the other for use in the semiconductor industry) with an antiwear additive and compare the friction and wear characteristics with the unformulated base greases in vacuum using a four-ball apparatus.

EXPERIMENTAL

Lubricants

Two different base greases were used in these studies. GXL-296A designed for semiconductor applications and GXL-320A for space applications. A compilation of their properties are listed in Table 1. The base fluid for the 320 series was an FZ PFPE. The base fluid for the 296 series was a mixture of an FZ and a K fluid. The antiwear additive used in this study is generically described as a carbonic acid calcium salt, 1:1 at a 10 wt % concentration in the 320 series and 5 wt % in the 296 series.

Tribometer

A four-ball tribometer (Figure 1), operating in the boundary lubrication mode, was used to measure steady state wear rates and friction coefficients for each lubricant. Specimen configuration (Figure 2) is essentially the same as the ordinary four-ball apparatus, except for the use of 9.5 mm (3/8 in.) diameter 440C stainless steel (grade 10) or AISI 52100 chrome steel bearing balls (grade 25). A complete description of this device appears in reference *36*.

Testing Procedure

Cleaning and Preparation

The test balls were ultrasonically cleaned in baths of hexane, acetone and ethanol for 10 minutes each, respectively. The lubricant cup was also ultrasonically cleaned in a similar manner. The balls and cup were then blown dry with nitrogen. Further cleaning of the balls occurred with a 15 minute UV/ozone treatment, rotating the balls every 5 minutes. Within 5 minutes of this treatment, one of the balls was placed in the nitrogen purged tribometer and was used as the rotating ball. The other three balls were secured into the lubricant cup and covered with the test grease. The cup was then placed in a bell jar and evacuated for about 30 minutes at 0.01 Torr. The cup was then placed on the stage inside the tribometer and the chamber evacuated.

Testing

After reaching a pressure of less than 6.7×10^{-4} Pa, the experiment was started. The stage was pneumatically loaded against the upper ball and rotation was initiated. All tests were performed at room temperature, a load of 200 N (an initial Hertzian mean stress of 3.5 GPa), and a sliding speed of 28.8 mm/sec (rotating ball speed of 100 rpm). Frictional torque was monitored and recorded throughout the experiment by means of a Hall-effect position sensor. A minimum of four tests were run for each grease.

Wear was determined by measuring the wear scar diameters on the three stationary balls by using an optical microscope. A sample stage on the microscope was designed so that the wear scars could be measured without disassembling the balls from the cup. The experiment was continued using the same set of balls. A completed test run was four hours in length with interruptions every hour for wear measurements. After completion of the test, a wear rate (mm^3/mm) was calculated from the slope of the line which was obtained from a plot of wear volume as a function of sliding distance. An example of this data from a typical test is shown in figure 3.

RESULTS

Wear

Wear rate results, including standard deviations, appear in Table 2 for all greases tested. The number of tests performed with each grease is contained within the parentheses in the respective lubricant column. The space applications greases (320 series) were tested with both AISI 52100 steel and 440C stainless steel specimens. The electronics grade greases (296 series) were only studied with 440C steel specimens. Both base greases (GXL-296A and GXL-320A) yielded high wear rates in the range of 10^{-8} mm^3/mm using AISI 52100 steel specimens. In contrast, both formulated greases (GXL-296B and GXL-320B) exhibited more than an order of magnitude decrease in wear rate. These results are shown graphically in figure 4, where error bars represent one standard deviation. In addition, wear rates for 320A and 320B with 440C steel were 50 % less than that obtained with 52100 steel. For comparison, the base oil FZ-25 with 440C steel specimens also appears in figure 4.

Friction

Friction coefficients are also shown in Table 2. The mean friction coefficients are indicated, while the ranges are within the parentheses. Values for greases 320A and B with 440C specimens were not measured. The mean friction coefficients are also shown in figure 5, where the error bars represent the minimum and maximum for each grease. All greases had mean friction coefficients between 0.11 to 0.20. Both formulated greases yielded small increases in mean friction coefficient compared to their base greases. A much larger increase was seen when comparing the 320 greases with their 296 counterparts. The higher base oil viscosity of the 296 series contributes to this difference.

DISCUSSION

PFPE base lubricants normally operate in the corrosive wear regime under boundary lubrication conditions (*1*). In boundary contacts, PFPEs react with bearing surfaces producing a series of corrosive products. These products can then react with the existing surface oxides on the steel to produce metal fluorides (*12*). Metal fluorides are effective solid lubricants which provide protection for the surfaces in contact by reducing friction and wear. However, these fluorides can also attack and decompose PFPEs which results in the production of even more reactive species. The surface fluorides are constantly removed during the wear process which is the reason for the high substrate wear (i.e. corrosive wear). Overall, the very reaction than enables PFPEs to protect surfaces eventually leads to their total destruction.

The incorporation of additives into PFPE base fluids and greases reduces this corrosive wear phenomenon to more acceptable levels, thus prolonging the life of the lubricated couple. The mechanism of wear inhibition of the additive in this study is not known, but the additive probably acts as a getter for the corrosive acidic products produced during the tribological process. This would reduce the corrosive wear mechanism.

The base oil used for the GXL-296 series of tests was not tested by itself. However, in previous work (*37*), the base oil for the GXL-320 series was tested in the same tribometer using 440C specimens, under identical conditions. As shown in Figure 4, this base oil yielded a much lower wear rate (about one fourth) than its equivalent base grease (GXL-320A). This is probably the result of contact starvation.

SUMMARY OF RESULTS

1. Two unformulated base PFPE greases (GXL-296 (base) and GXL-320A) yielded high wear rates under vacuum at room temperature on the order of 10^{-8} mm^3/mm using AISI 52100 steel specimens.
2. A carbonic acid calcium salt additive at an optimized 10 wt % in GXL-320 series and 5 wt % in GXL 296 series greases, reduced wear rates by more than an order of magnitude.
3. Substituting 440 stainless steel specimens reduced wear another 50 per cent for greases (GXL-320A and 320B) compared to AISI 52100 steel.
4. Mean friction coefficients were in the range of 0.11 to 0.20. Small reductions were observed between the formulated and unformulated pairs. A large increase (~ 50 %) was observed between the GXL-320 and GXL-296 counterparts, which is probably related to the higher base oil viscosity for the 296 series of greases.

CONCLUSION

Formulated PFPE greases are now available that retain low temperature fluidity and low volatility, while exhibiting acceptable wear rates, for both space and semiconductor applications.

REFERENCES

(1) Jones, W. R., Jr., "Properties of Perfluoropolyethers for Space Applications," *STLE Trans.*, **38** (3), 557-564 (1995).

(2) Moulder, J. F., Hammond, J. S. And Smith, K. L., "Using Angle Resolved ESCA to Characterize Winchester Disks," *Appl. Sur. Sci.*, **25**, 445-454 (1986).

(3) Snyder, C. E., Jr. and Dolle, R. E., "Development of Polyperfluoroalkylethers as High Temperature Lubricants and Hydraulic Fluids," *ASLE Trans.*, **19**, 171-180 (1976).

(4) Gumprecht, W. H., "PR-143-A New Class of High-Temperature Fluids," *ASLE Trans.*, **9**, 24-30 (1966).

(5) Sianesi, D., Pasetti, A., Fontanelli, R., Bernardi, G. C. And Caporiccio, G., "Perfluoropolyethers by Photooxidation of Fluoroolefins," *Chim. Ind. (Milan)*, **55**, 208-221 (1973).

(6) Sianesi, D., Zamboni, V. Fontanelli, R. And Binaghi, M., "Perfluoropolyethers: Their Physical Properties and Behavior at High and Low Temperatures," *Wear*, **18**, 85-100 (1971).

(7) Ohsaka, Y., "Recent Advances in Synthetic Lubricating Oils. (8). Perfluorinated Polyethers," *Petrotech (Tokyo)*, **8**, 9, 840-843 (1985).

(8) Carré, D. J., "The Performance of Perfluoropolyalkylether Oils under Boundary Lubrication Conditions," *Trib. Trans.*, **31**, 4, 437-441 (1988).

(9) Masuko, M., Fujinami, I. And Okabe, H., "Lubrication Performance of Perfluoropolyalkylethers Under High Vacuum," *Wear*, **159**, 249-256 (1992).

(10) Masuko, M., Jones, W. R., Jr. and Helmick, L. S., "Tribological Characteristics of Perfluoropolyether Liquid Lubricants under Sliding Conditions in High Vacuum," *J. Syn. Lubr.*, **11**, 2, 111-119 (1994).

(11) Nakayama, K., Dekura, T. And Kobayashi, T., "Effect of Additives on Friction, Wear, and Iron Fluoride Formation under Perfluoropolyether Fluid Lubrication in Vacuum and Various Atmospheres Containing Oxygen," *Wear*, **192**, 1768-185 (1996).

(12) Mori, S. and Morales, W., "Tribological Reactions of Perfluoroalkyl Polyether Oils with Stainless Steel Under Ultrahigh Vacuum Conditions at Room Temperature," *Wear*, **132**, 111-121 (1989).

(13) Hayashida, K., Yamamoto, K. And Nishimura, M., "Wear and Degradation Characteristics of Perfluoropolyethers (PFPEs) in High Vacuum," *Trib. Trans.*, **37**, 1, 196-200 (1994).

(14) Helmick, L. S. and Sharma, S., "Effect of Humidity on Friction and Wear for a Linear Perfluoropolyalkylether Fluid Under boundary Lubrication Conditions," *Lubr. Engr.*, **52**, 6, 437-442 (1996).

(15) Loewenthal, S., Esper, J., Pan, J. And Decker, J., "Space Telescope Fine Guidance Sensor Bearing Anomaly," 30th Aerospace Mechanisms Symp., NASA CP 3328, 1-11 (1996).

(16) Lenz, J., "Life Test Results for the Advanced Very High Resolution Radiometer Scanner," 30th Aerospace Mechanisms Symp., NASA CP 3328, 13-29 (1996).

(17) Conley, P. L. And Bohner, J. J., "Experience with Synthetic Fluorinated Fluid Lubricants," 24th Aerospace Mechanisms Symp., NASA CP 3062, 213-230 (1990).

(18) Baxter, B. H. And Hall, B. P., "The Use of Perfluoroether Lubricants in Unprotected Space Environments," 19th Aerospace Mechanisms Symp., NASA CP 2371, 179-207 (1985).

(19) Jones, W. R., Jr., Paciorek, K. J. L., Ito, T. I. And Kratzer, R. H., "Thermal Oxidative Degradation Reactions of Linear Perfluoroalkyl Ethers," *I & EC Prod. Res. and Dev.*, **22**, 166-170 (1983).

(20) Jones, W. R., Jr., Paciorek, K. J. L., Harris, D. H., Smythe, M. E., Nakahara, J. H. And Kratzer, R. H., "The Effects of Metals and Inhibitors on Thermal Oxidative Degradation Reactions of Unbranched Perfluoroalkyl Ethers," *I. & EC Prod. Res. and Dev.*, **24**, 417-420 (1985).

(21) Snyder, C. E., Jr. and Dolle, R. E., Jr., "Development of Polyperfluoroalkylethers as High Temperature Lubricants and Hydraulic Fluids," *ASLE Trans.*, **19**, 3,171-180 (1976).

(22) Carré, D. J. and Markowitz, J. A., "The Reaction of Perfluoropolyalkylether Oil with FeF$_3$, AlF$_3$ and AlCl$_3$ at Elevated Temperatures," *ASLE Trans.*, **28**, 1, 40-46 (1985).

(23) Kasai, P., "Perfluoropolyethers: Intramolecular Disproportionation," *Macromolecules*, **25**, 6791-6799 (1992).

(24) Zehe, M. J. and Faut, O. D., "Acidic Attack of PFPE Lubricant Molecules by Metal Oxide Surfaces," NASA TM-101962 (1989).

(25) Herrera-Fierro, P., Pepper, S. V. and Jones, W. R., Jr., "X-Ray Photoelectron Spectroscopy Study of the Stability of Fomblin Z-25 on the Native Oxide of Aluminum," *J. Vac. Sci. Tech. A*, **10**, 4, (1992).

(26) Herrera-Fierro, P., Jones, W. R., Jr. and Pepper, S. V., "Interfacial Chemistry of a Perfluoropolyether Lubricant Studied by XPS and TDS," *J. Vac. Sci. Tech. A*, **11**, 2, 354-367 (1993).

(27) Morales, W., "The Decomposition of a Commercial Perfluoropolyalkylether on Alpha and Gamma Catalytic Aluminas," *Trib. Trans.*, **39**, 1, 148-156 (1996).

(28) Lyth, E. and Ng, L. M., "Surface Chemistry of Perfluoroether: A Study of the Reaction Mechanism of $(C_2H_5)_2O$ with an Al_2O_3 Surface by FTIR Spectroscopy," *J. Phys. Chem.*, **99**, 17615-17623 (1995).

(29) Paciorek, K. J. L. And Kratzer, R. H., "Stability of Perfluoroalkylethers," *J. Fluorine Chem.*, **67**, 169-175 (1994).

(30) Masuko, M., Takeshita, N. And Okabe, H., "Evaluation of Anti-Wear Performance of PFPE-Soluble Additives under Sliding Contact in High Vacuum," *Trib. Trans.*, **38**, 3, 679-685 (1995).

(31) Gschwender, L. J., Snyder, C. E., Jr. and Fultz, G. W., "Soluble Additives for Perfluorinated Lubricants," *Lubr. Engr.*, **49**, 9, 702-708 (1993).

(32) Srinivasan, P., Corti, C., Montagna, L. And Savelli, P., "Soluble Additives for Perfluorinated Lubricants," *J. Syn. Lub.*, **10**, 143-164 (1993).

(33) Jones, W. R., Jr., Ajayi, O. O. And Wedeven, L. D., "Enhancement of Perfluoropolyether Boundary Lubrication Performance," NASA TM 107306 (1996).

(34) Williams, J. R., Feuchter, D. K. and Jones, W. R., Jr., "Development and Preliminary Evaluation of Aryl Ester Boundary Additives for Perfluoropolyethers," NASA TM 106603 (1994).

(35) Shogrin, B. A., Jones, W. R., Jr., Herrera-Fierro, P., Lin, T. Y. and Kawa, H., "Evaluation of Boundary-Enhancement Additives for Perfluoropolyethers," NASA TM 107393 (1997).

(36) Masuko, M., Jones, W. R., Jr., Jansen, R., Ebihara, B., Pepper, S. V. and Helmick, L., "A Vacuum Four-Ball Tribometer to Evaluate Liquid Lubricants for Space Applications," *Lub. Engr.*, 5, 11, 871-875 (1994).

(37) Jones, W. R., Jr., Poslowski, A. K., Shogrin, B. A., Herrera-Fierro, P. and Jansen, M. J., "Evaluation of Several Several Space Lubricants Using a Vacuum Four-Ball Tribometer", NASA TM 208654 (1998).

Table 1. Typical Properties of Test Materials

TEST	TEST METHOD	GXL-320A	GXL-320B	GXL-296A	GXL-296B
BASE OIL DATA					
Viscosity, cS @ 100C	ASTM D445	45	45	44	44
40C		148	148	208	208
-40C		1123	1123	28000	28000
-54C		12000	12000	167000	167000
VI		350	350	256	256
Pour Pt., C		<-73	<-73	-60	-60
Vapor Press, Torr @ 20C	ASTM D92	$<10^{-13}$	$<10^{-13}$	$<10^{-13}$	$<10^{-13}$
100C	Knudsen	$<10^{-9}$	$<10^{-9}$	$<10^{-9}$	$<10^{-9}$
GREASE DATA					
Penetration,mm /10 worked	ASTM D1403	290	285	280	272
Dropping Pt., F	ASTM D2265	460	488	456	492
Four Ball Wear, mm (1200 rpm, 75C, 1 hr, 40 kg, N_2, 52100)	ASTM D2266	0.99	0.5	1.06	0.49
(600 rpm, 74C, 1 hr, 60 kg, N_2, 52100)		1.57	1.08	1.56	1.27
(368 rpm, 300C, 1 hr, 5.5 kg, N_2, 52100)		0.52	0.35	0.49	0.27
Evap. Loss, 22 hr @ 20C, %	ASTM D2595	1.4	2.0	0.19	0.14
Oil Separation, 22 hr @ 204C					
Oil Sep., %	FTM 321	12.4	10.3	6.3	6.3
Evap. Loss, %		0.11	0.16	0.14	0.14
Wt. Loss, %		12.5	10.5	6.4	6.4

Low Temp, Torque, g-cm @ -73C, starting	ASTM D1478	1430	1040	53000	38000
Running, 1 hr		637	650	froze	froze
Outgassing Vapor Press, torr @ 20C,	ASTM E1559	$<10^{-14}$	$<10^{-14}$	$<10^{-14}$	$<10^{-14}$
TML, 48 hr @ 150C, %	Lockheed	0.040	0.039	0.063	0.073
Vacuum Stability TML, %	ASTM E595	0.15	0.0	0.14	0.08
Collected Condensable, %		0.02	0.0	0.0	0.03
Bearing Test, Hrs first darkening	Kaydon Bearing	<60	140	160	>290
Copper Strip, 24 hr @ 100C	ASTM D130	1B	1B	1B	1B
Four Ball Weld Point, kg	ASTM D2595	>800	620	800	620
Liquid Oxygen Impact Test	ASTM D2512	Pass	Pass	Pass	Pass
Rust Preventative	ASTM D1743	Pass	Pass	Pass	Pass

Table 2. Wear rates and friction coefficients of the test lubricants

Lubricant (# of runs)	*Ball Material*	*Mean Wear Rate x10^{-9} (mm^3/mm)*	*Wear Rate Std Deviation x10^{-9} (mm^3/mm)*	*Mean (Range) of Friction Coefficient*
GXL-320A (Base) (4)	AISI 52100 Steel	15	±1.1	0.11 (0.09-0.23)
GXL-320B (Formulated) (4)	AISI 52100 Steel	1.2	±0.3	0.14 (0.08-0.19)
GXL-320A (Base) (4)	440C Stainless Steel	6.2	±1.3	NM
GXL-320B (Formulated) (4)	440C Stainless Steel	0.74	±0.44	NM
PFPE Z-25 (Liquid) (4)*	440C Stainless Steel	1.7	±0.16	0.08 (0.05-0.10)
GXL-296A (Base) (3)	AISI 52100 Steel	11	±0.43	0.17 (0.14-0.32)
GXL-296B (Formulated) (3)	AISI 52100 Steel	0.53	±0.17	0.20 (0.13-0.25)

* From Reference 37

NM (not measured)

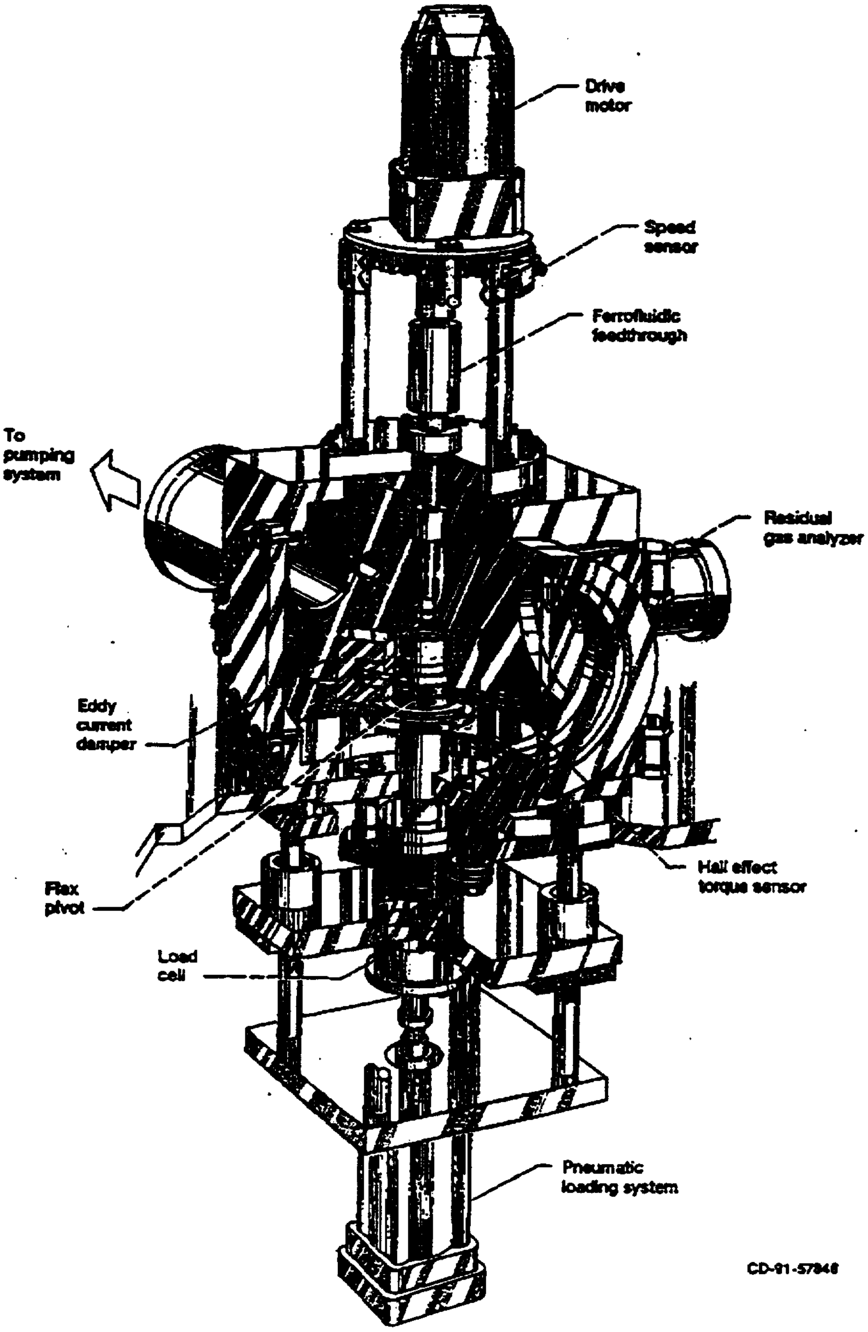


Figure 1.—Vacuum tribometer.

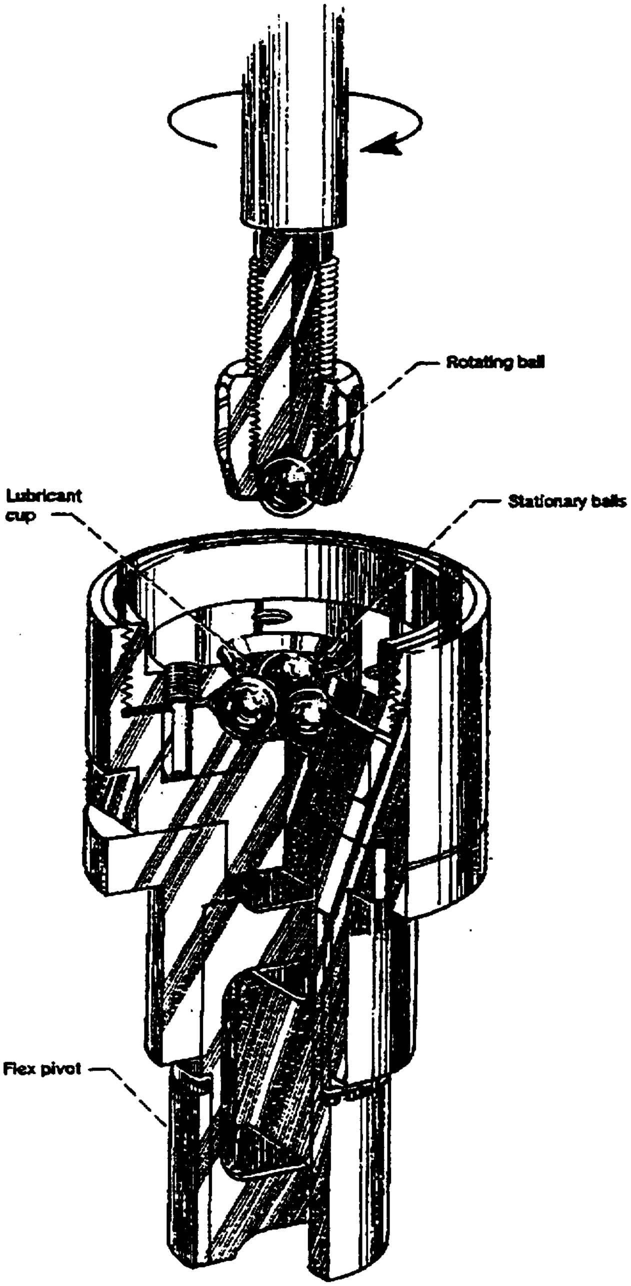
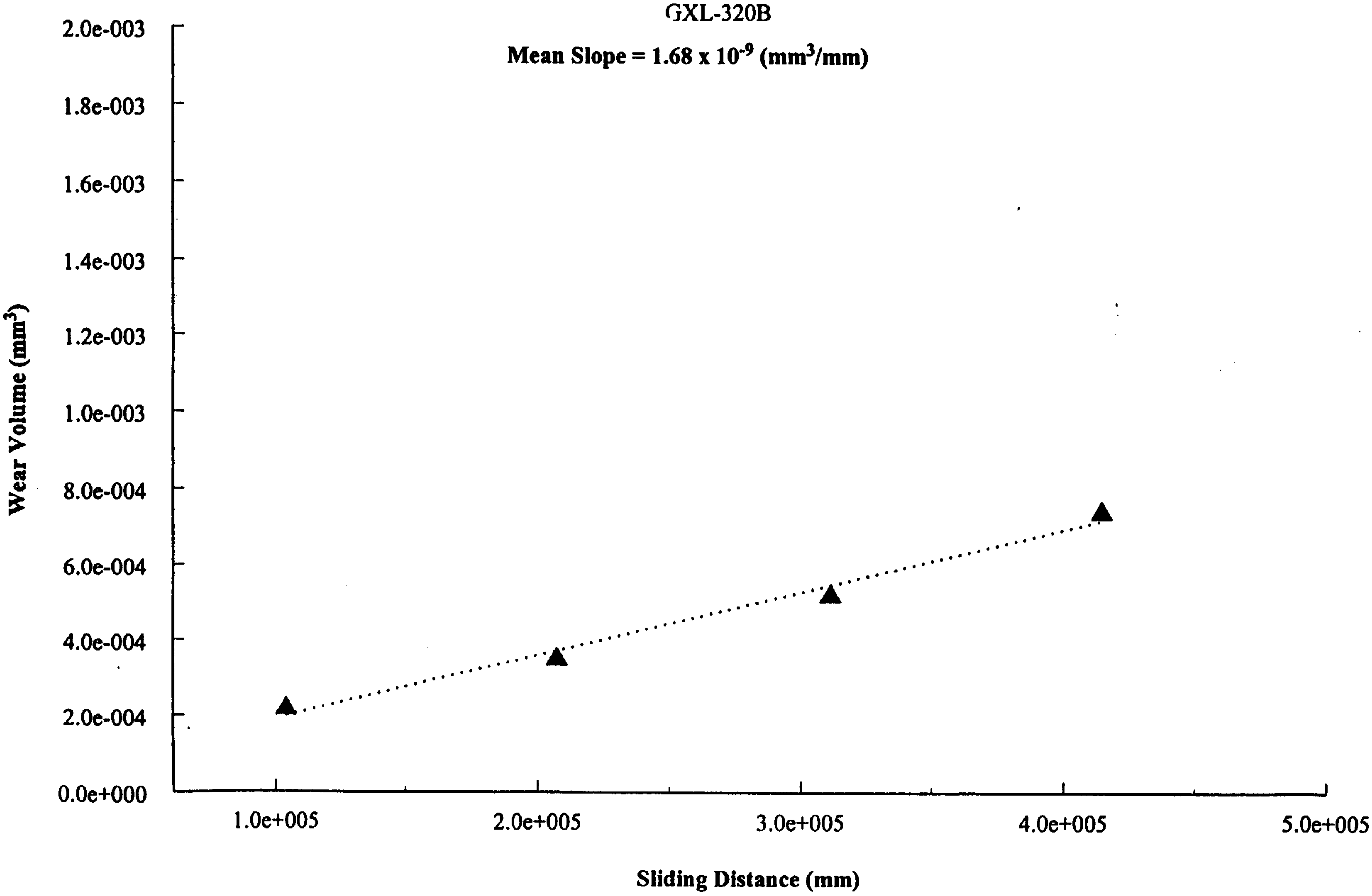


Figure 2.—Specimen Configuration.

Figure 3. Typical Test



GXL-320B

Mean Slope = 1.68 x 10^{-9} (mm^3/mm)

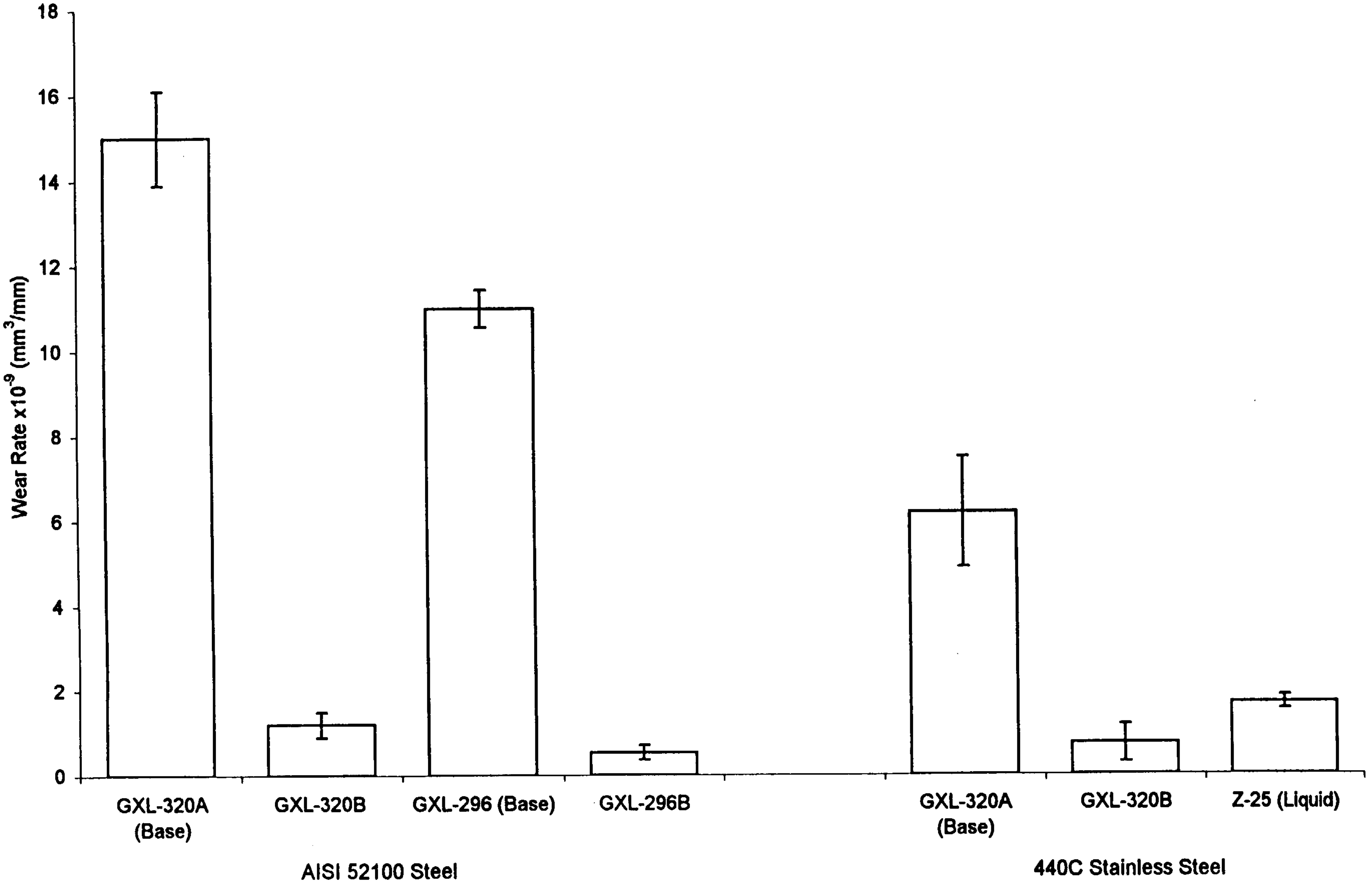


Figure 4. Wear rate results from vacuum 4-ball tribometer

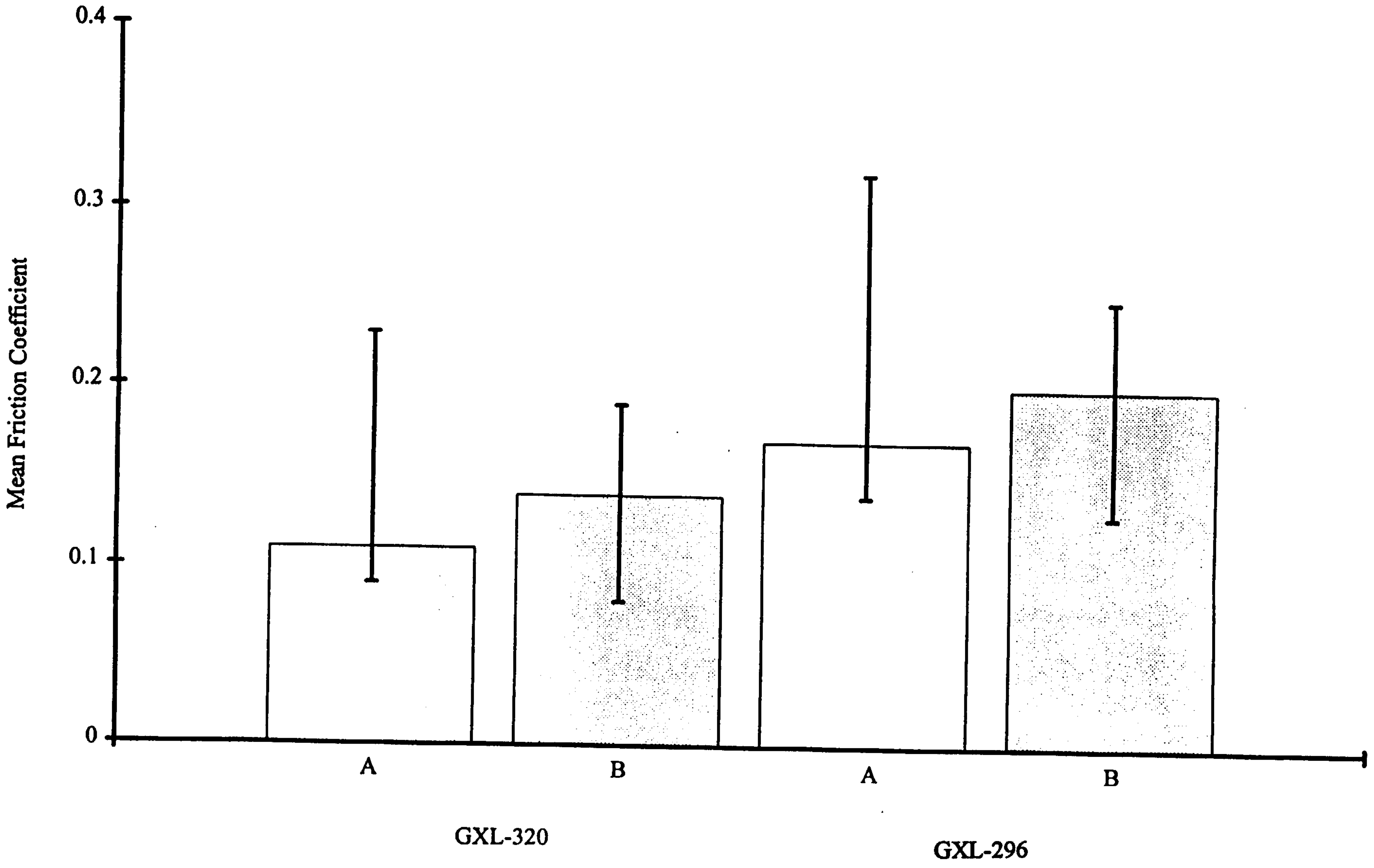


Figure 5. Mean Friction Coefficients of the Formulated and Unformulated Greases with AISI 52100 steel specimens.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
March 1999

3. REPORT TYPE AND DATES COVERED
Technical Memorandum

4. TITLE AND SUBTITLE
An Additive to Improve the Wear Characteristics of Perfluoropolyether Based Greases

5. FUNDING NUMBERS
WU-615-63-00-00

6. AUTHOR(S)
David G.V. Jones, Mahmoud A. Fowzy, James F. Landry, William R. Jones, Jr., Bradley A. Shogrin, and QuynhGiao Nguyen

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
John H. Glenn Research Center at Lewis Field
Cleveland, Ohio 44135-3191

8. PERFORMING ORGANIZATION REPORT NUMBER
E-11615

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NASA TM—1999-209064

11. SUPPLEMENTARY NOTES
Prepared for the Annual Meeting sponsored by the Society of Tribologists and Lubrication Engineers, Las Vegas, Nevada, May 23–27, 1999. David G.V. Jones, Mahmoud A. Fowzy, and James F. Landry, Castrol, Industrial North American, Inc., Downers Grove, Illinois 60515; William R. Jones, Jr., Glenn Research Center; Bradley A. Shogrin and QuynhGiao Nguyen, AYT Corporation, Brook Park, Ohio 44142. Responsible person, William R. Jones, Jr., organization code 5140, (216) 433–6051.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified - Unlimited
Subject Category: ~~34~~ 27 Distribution: Nonstandard

This publication is available from the NASA Center for AeroSpace Information, (301) 621–0390.

12b. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 words)***

The friction and wear characteristics of two formulated perfluoropolyether based greases were compared to their non-additive base greases. One grease was developed for the electronics industry (designated as GXL–296A) while the other is for space applications (designated as GXL–320A). The formulated greases (GXL–296B and GXL–320B) contained a proprietary antiwear additive at an optimized concentration. Tests were conducted using a vacuum four-ball tribometer. AISI 52100 steel specimens were used for all GXL–296 tests. Both AISI 52100 steel and 440C stainless steel were tested with the GXL 320 greases. Test conditions included: a pressure $<6.7 \times 10^{-4}$ Pa, a 200N load, a sliding velocity of 28.8 mm/sec (100 rpm) and room temperature (≅23 °C). Wear rates for each grease were determined from the slope of the wear volume as a function of sliding distance. Both non-additive base greases yielded relatively high wear rates on the order of 10^{-8} mm^3/mm using AISI 52100 steel specimens. Formulated grease GXL–296B yielded a reduction in wear rate by a factor of ~21, while grease GXL–320B had a reduction of ~12 times. Lower wear rates (~50%) were observed with both GXL–320 greases using 440C stainless steel. Mean friction coefficients were slightly higher for both formulated greases compared to their base greases. The GXL–296 series (higher base oil viscosity) yielded much higher friction coefficients compared to their GXL–320 series (lower base oil viscosity) counterparts.

14. SUBJECT TERMS
Tribology; Grease; Lubricant additives

15. NUMBER OF PAGES
24

16. PRICE CODE
A03

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102