MASTER

WANL-TMI-316

Name: Astronuclear Laboratory

Date: October 16, 1962

Subject: DETERMINATION OF
COEFFICIENT OF FRICTION

Reference: 00:00:75-1W

REFERENCE

TEST REPORT

Distribution List:

W. H. Esselman
J. Kenney, Jr.
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INTRODUCTION

Of importance to the successful design of a nuclear reactor is the accurate determination of the coefficients of friction for various core materials under anticipated service conditions. All parameters which will affect these values must be investigated. Among the more important parameters to be considered are: (1) the effect of temperature; (2) atmospheric effects, including high degrees of vacuum; (3) condition of the mating surfaces; (4) degree of outgassing of test materials; (5) grain orientation; (6) effect of normal force; and (7) effect of velocity.

A brief survey of the literature shows that Items (1) through (4) listed above are the more important factors. One laboratory concludes that Item (3) is the most important factor.

A series of experiments were undertaken to attempt to clarify reported work and investigate conditions which have not been reported to date. This required the design and construction of a reliable test apparatus which would not lose its effectiveness in the extreme conditions imposed by the test parameters. An experimental program was established to probe the conditions which would be encountered in a nuclear reactor. These conditions involved high temperatures, ultra-high vacuum, and interrelated effects such as outgassing of the material following periods of heat application. The experiment was designed so that surface condition effects could also be observed.

This is a preliminary report, and any conclusions based on the data obtained to date must be verified by additional tests.

TEST APPARATUS

The test equipment (Figures 1 and 2) consisted of a pair of stationary grips or holders, each of which contained a sample of one of the materials under test. The samples are situated so that they face each other. Between the two faces is driven a flat specimen with parallel surfaces, made from the other test material involved.

The latter specimen is driven by a vertical holder aligned axially with a controlled speed motor drive. Included in this linkage is an SR-4 strain gage dynamometer which is used to measure the load required to "pull" or "push" the vertical specimen. The normal force is applied by means of a weight suspended on a pulley and attached to the top of one stationary holder, so that the load is exerted against the other stationary holder which is fixed with a spring steel flex plate; the bottom of each stationary holder is pinned. Normal forces can be varied quite readily by using different weights.

The dynamometer output is fed to a strain gage indicator and thence to a X-Y Recorder which plots the friction force as a function of time or displacement. The heating element is a tantalum sheet cylinder. The entire system is enclosed in a bell jar and is evacuated by a 4-inch diffusion pump roughed out by a mechanical pump. The heating element, heating controls, and vacuum system have been previously described by Manjoine, et al., in "Universal High-Temperature Testing Machine for Vacuum or Controlled Atmosphere", ASTM, 1959.

TEST PROCEDURE

To obtain the most significant data in the shortest period of time, the following sequence of testing for each combination of materials was devised:

<u>Step No.</u>	<u>Condition</u>
1.	Room temperature, ambient atmosphere, Normal force = 10 psi.

<u>Step No.</u>	<u>Condition</u>
2.	Normal force changed to 2 psi.
3.	System evacuated.
4.	Temperature raised to 1000°R.
5.	Temperature lowered to 540°R.
6.	Temperature raised to 3000°R.
7.	Temperature lowered to 540°R.
8.	System opened to ambient atmosphere.

Thus, a difference of two normal forces may be compared at room temperature in ambient atmosphere; three temperature levels can be observed; and the effect of vacuum at various levels of outgassing can be considered. The most important factors are introduced into the experiment. Each series of steps, designated B, C, and D, is performed three times with each combination of materials to check reproducibility. Where possible, each step is repeated two times, so that the run numbers for each series of conditions will be concurrent. Series A was used to check out the loading system.

Velocity of the moving specimen was 0.02 in./min. and the amount of motion involved was 0.02 inches in each direction. Each run was begun in the "pull" direction.

The initial mating surfaces of the test specimens were in the "as machined" condition, the final cut being made with a milling tool. No attempt was made to further polish the specimen surfaces.

TEST RESULTS

To date, two materials have been compared. Three series of runs have been made with HLM Graphite (extrusion direction) on ZTA Graphite (normal to extrusion direction). μ_s is used to designate the static coefficient of friction. The dynamic value is designated by μ_D .

The following results have been obtained:

μ_S	μ_D	Readings	Temp. °R	Press, mm. Hg.	Normal Force, PSI
.18-.16	.16-.13	5	540	760	10
.18-.17	.16-.15	8	540	760	2
.18-.16	.16-.15	6	540	10^{-6}	2
.25-.23	.23-.20	5	1000	10^{-6}	2
.41-.21	.40-.18	9	540	10^{-6}	2
.27-.18	.23-.14	9	3000	10^{-6}	2
.59-.25	.54-.25	9	540	10^{-7}	2
.24-.19	.21-.19	7	540	760	2

Although nine runs were made at each condition, those readings which were obviously in error due to failure of electrical circuitry have been omitted.

Figure 3 shows this data in graphical form. The coefficient of friction determination is plotted for each run.

Test D was pumped for an additional 15.5 hours between runs 19 and 20.

DISCUSSION OF TEST RESULTS

The results in general indicate that the value of μ_S between HLM Graphite and ZTA Graphite is between 0.18 and 0.16 until it is heated to 1000°R. On heating, μ_S increases to 0.25 to 0.23. During cooling, this value increases and then decreases with pumping time to 0.21. On a subsequent run, heating to 3000°F has little effect on the value. However, once again, during cooling it builds up and only after a period of pumping of approximately 20 hours does it return to the range of 0.23 to 0.20. This phenomena is demonstrated in Figure 4.

Further investigation will have to be conducted to determine the cause of friction buildup between the surfaces on cooling. This increase is not apparent at a stabilized temperature, and can be removed by continued pumping.

CONCLUSIONS

1. Change in normal force from 10 to 2 psi has no significant bearing on results.
2. Vacuum alone does not increase μ . No effect of vacuum was found prior to heating.
3. Once the specimen has been outgassed at 3000°R, μ is increased almost 33% in subsequent runs in ambient atmosphere.
4. The surface condition effect is much more critical at 3000°R than at lower temperatures. That is, friction is lessened with each additional run.
5. A wide variation in μ is found after the materials have been outgassed. The variation is greater at 3000°R than 1000°R. This variation has been correlated to length of pumping time.
6. The amount of time the system is pumped, once cooling has begun, seems to have a great effect on values of μ . These values decrease with additional pumping.

FIGURE 1

Assembly Drawing of Friction Test Fixture

E.F.V.
8/10/62

FIGURE 2

Detailed Cross Sections of Friction Test Fixture

Condition

Bearing Stress
psi,
Temperature,
OR
Pressure
mm Hg

10

2

2

2

2

2

2

2

2

540

540

540

1000

540

3000

540

540

760

760

10^{-6}

10^{-6}

10^{-6}

10^{-6}

10^{-7}

760

TEST SERIES

HLM on ZTA

● B
○ C
x D

Coefficient of Friction

0.5

0.4

0.3

0.2

0.1

0.0

outgassed
for 15 Hrs.

o(.56)(.59)

Run Number

FIGURE 3

Determination of Coefficient of Friction for Graphite, μ_s

SIGNATURE

DATE

CURR/NO.