DISCUSSION

V. Hopkins[2] and R. Hubbell[2]

The authors have presented useful data on two films which are being used in several aerospace applications. The two films discussed in this paper were developed for NASA Marshall Space Flight Center and are commonly referred to as MLF-5 and MLF-9. It is not surprising that the wear-lives of these films were not affected by the radiation dosages mentioned in this paper. Considerable data were presented to substantiate this in June of 1967 at the Symposium on Lubrication in Nuclear Applications. The rub-shoe wear-life data presented by the authors agree fairly well with data obtained on the same film in our laboratory. The rub-shoe tests run in air on the MoS_2: Au(MLF-5) film at 1200 deg F probably has little meaning and any radiation effect would certainly be overshadowed by the oxidation of the MoS_2 at this temperature. Wear-life test run in air at 1000 deg F in our laboratory produced immediate failure. Rub-shoe tests in a vacuum environment were run in our laboratory in the MLF-5 film at 1000 and 1500 deg F at a 100-lb shoe load and a speed of 72 fpm. Wear-lives of 50,000 revolutions were obtained at 1000 deg F and approximately 3,000 revolutions were obtained at 1500 deg F.

The variation in wear-life test results in the ball bearing test is not too disturbing when each group of test results is considered (five tests per group which the authors call one test), but the variation from test one to test two does make one wonder. As the authors have pointed out, the variation is extreme, approximately 10 times for the MoS_2: Bi(MLF-9) lubricated bearings. The discussors feel that run-in of solid film lubricated bearing is extremely important and a procedure similar to the one which is contained in the paper should be followed. In addition, shielding of solid film lubricated bearing should be eliminated to give the wear debris a chance to get out of the bearing. It is assumed that the MoS_2: Au(MLF-5) lubricated bearings which were run in air were not shielded since the author mentions deposits on the flywheels and reed switches. This lack of shield did not improve bearing performance; the shielded bearing ran for an average of 110 hr while the unshielded bearing run in air averaged 27 hr. The difference in these test results could be due to the difference in atmospheres, but this seems unlikely.

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The authors are to be congratulated for adding to the information available on the effects of radiation on dry film lubricants. In general, the conclusion that inorganically bonded dry lubricants are not affected by radiation to 10^{11} ergs per gram (C) agrees with similar tests made on Falex testers in our laboratories at Marshall Space Flight Center.

A second interesting comparison can be obtained by comparing the author's data with data on the same lubricant obtained on another dual rub shoe machine operating at slightly different loads and speeds:

	Wear Life Cycles	
Temp.	355 rpm 110 lb Load	400 rpm 100 lb Load
Room temp.	65,000	112,000
600°F	18,000	11,000

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From these data it appears that at ambient temperature the lighter load provides much greater wear life, but at 600 deg F the temperature effect on wear life overshadows all other parameters.

The author's results on ball bearings tests with dry film lubricants bear out the necessity for removing wear debris from the bearings during run-in. It is also believed that more consistent results may have been obtained had the experimenters used some axial load on the bearings. The results from the second test on the MoS_2-Bi lubricant are not explained. Is it possible that an axial load applied during assembly could account for these results?

It would be interesting if the experimenters could repeat the bearing tests using ball retainers manufactured of a material such as polyimide. Such tests should localize the area of failure in the bearings.

Authors' Closure

The authors wish to thank Messrs. Hopkins, Hubbell, and Demorest for their interesting comments and discussions.

The following is offered in response to those questions and comments requiring further clarification:

1 The radiation effects data referred to by Messrs. Hopkins and Hubbell cannot be directly compared with the data reported here. Although data for the MoS_2: Bi film were presented at the 1967 symposium, the irradiation had been made with electrons and with gamma rays, the exposure level of the latter being 2×10^6 roentgens [$\sim 1.8 \times 10^8$ ergs/g(C)] compared to 1.5×10^{11} ergs/g(C) in our irradiation. More important, however, is the fact that our experiment utilized a reactor as the radiation source, since the neutron component was of principal interest. It is well known that inorganic materials are resistant to damage by electrons and gamma rays.

It might also be added that the work reported in this paper was conducted in 1965 and reported in detail in 1966 as Air Force reports (references [3, 4]).

2 As was stated in the paper (Experimental Procedure, Bearing Test), the bearings had double shields and were used as received from the manufacturer. They were randomly selected for each test. Some lubricant had escaped from the bearings during the test in air, but there was no indication that this occurred during the tests in vacuum.

3 With the exceptions noted in the paper, tests run in air and in vacuum were duplicated; therefore, it appears that the difference in test results was due in part to the difference in atmospheres.

4 To the knowledge of the authors, no axial load was applied during assembly of the bearings.

The authors were pleased to see that wear-life data of lubricants tested on different wear testers were in close agreement, in view of the fact that this is not always the case in lubricant evaluations by separate laboratories.