NASA SP-7020

LUBRICATION, CORROSION and WEAR

A CONTINUING BIBLIOGRAPHY

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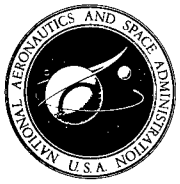
NASA SP-7020

LUBRICATION, CORROSION and WEAR

A CONTINUING BIBLIOGRAPHY

A Selection of Annotated References to Unclassified Reports and Journal Articles Introduced into the NASA Information System during the period January, 1962– March, 1965.



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Introduction

Through the medium of its Continuing Bibliography Program, NASA regularly publishes and distributes bibliographic summaries. Each of these bibliographies contains a compilation that represents the results of a thorough review of the current literature on a particular subject. The subject of each bibliography is selected on the basis of its direct relationship to recent developments in the space program, and in response to a clearly established interest on the part of aerospace specialists.

NASA SP-7020, titled "Lubrication, Corrosion and Wear", has been published and is distributed as a part of this program. It presents a selection of annotated references to unclassified reports and journal articles announced in *Technical Publications Announcements (TPA, Vol. 2),* and *Scientific and Technical Aerospace Reports (STAR),* and in *International Aerospace Abstracts (IAA).* The variety of special lubrication, corrosion, and wear problems, that arise in connection with the design and development of equipment and materials for use in the unique environment of space, has created numerous research programs to investigate and solve these problems. The references contained in NASA SP-7020 reflect this variety and cover such diverse topics as lubricating systems; design and performance of bearings; special applications of lubricants, e.g., as heat transfer and anti-corrosion agents; stress corrosion and fatigue cracking in metals and alloys; friction and wear characteristics of materials; and finally, types of corrosion and techniques for corrosion prevention. A limited number of references describing the instrumentation and methods for the testing of lubricants are also included.

Each entry in the bibliography consists of a citation and abstract. The listing of entries is arranged in two major groups. All report literature references appear in the first group and are subdivided according to their date of announcement in *TPA* or *STAR*. The second group contains published literature references subdivided according to their date of announcement in *IAA*. All reports and articles cited were introduced into the NASA Information System during the period January, 1962–March, 1965. Supplements to this bibliography will be issued if user response is sufficient and future references accumulate to an acceptable level.

A subject index and a personal author index are included.

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a continuing bibliography JUNE 1965

1962

TPA ENTRIES

N62-10009 National Aeronautics and Space Administration. Lewis Research Center, Cleveland.
LUBRICATING PROPERTIES OF CERAMIC-BONDED CALCIUM FLUORIDE COATINGS ON NICKEL-BASE ALLOYS FROM 75° TO 1900° F.
Harold E. Sliney. Feb. 1962, 39 p. 13 refs. (NASA TN D-1190) OTS, $1.00

Ceramic-bonded calcium fluoride coatings lubricated a vacuum-melted, nickel-base alloy (René 41) at temperatures up to 1900° F. An air-melted, nickel-base alloy (Inconel X) was effectively lubricated to 1500° F. The wear life of the coating on the air-melted alloy was good from 500° to 1500° F; on the vacuum-melted alloy, life was good from 500° to 1700° F and then fair up to 1900° F. The most favorable friction properties were obtained at high ambient temperature and high sliding velocity. Coatings applied to slightly preoxidized Inconel X or René 41 were more uniform in appearance and had better endurance life than coatings applied to the unoxidized metals.

N62-10084 National Aeronautics and Space Administration. Langley Research Center, Langley AFB, Va.
COEFFICIENTS OF FRICTION AND WEAR CHARACTERISTICS FOR SKIDS MADE OF VARIOUS METALS ON CONCRETE, ASPHALT, AND LAKEBED SURFACES.
Robert C. Dreher and Sidney A. Batterson. Jan. 1962, 34 p. 3 refs. (NASA TN D-999) OTS, $1.00

An investigation was made to obtain the coefficients of friction and the wear characteristics for skids made of various metals. Simulated landings and slideouts were made at forward speeds up to 180 feet per second on concrete, asphalt, and lakebed surfaces. The results indicate that coefficients of friction developed by wire-brush skids and some of the softer metal skids compare favorably with those developed by braked wheels with rubber tires; however, the wirebrush skids and the skids made of the softer metals showed the greatest amount of wear.

N62-10345 Bureau of Mines, Washington, D. C.
CORROSION OF ZIRCONIUM IN CUPRIC AND FERRIC CHLORIDES.
D. J. Stoops, M. D. Carver, and H. Kato. 1962. 11 p. 2 refs. (BM-RI-5945).

Effect of metallurgical and surface treatments on the corrosion behavior of arc-melted reactor-grade zirconium in cupric or ferric chloride solutions was investigated. An apparatus was constructed and specimens of various metallurgical conditions and surface treatments were tested for 6 days at 35° C., with aeration. Some correlations were observed between corrosion rate and the metal's condition and treatment. Specifically, the unattacked or least attacked specimens were those that had been etched as a final treatment before testing. The most severely attacked specimens were those that had been vacuum-annealed as a final treatment before testing. The moderately attacked specimens were those neither vacuum-annealed nor etched, but having a final surface treatment which left a cold-worked surface. Attack by cupric and and ferric chloride was by pitting with no preference for grain boundaries. The corrosion scale was composed predominately of very fine zirconium particles. Particles from the $FeCl_3$-corroded specimens were more pyrophoric than those from $CuCl_2$-corroded specimens, and appeared to have a higher surface area to volume ratio. Comparison of results to those of previous investigators showed that at certain salt concentrations the more pure, reactor-grade zirconium was quite resistant to attack while the less pure, graphite-melted zirconium was severely attacked. From an examination of earlier tests of zirconium in metal chlorides, there appeared to be a relationship between corrosion rate and the position of the metal in the electromotive force series of elements. Although the investigation was limited in scope, the indications that corrosion resistance in some solutions can be improved by increasing purity or by varying either metal condition or surface treatment should help to adapt the relatively new metal zirconium to applications in environments of chemical solutions.

N62-10710 Carnegie Inst. of Tech., Pittsburgh.
ON THE CORROSION OF SINGLE CRYSTALS, BICRYSTALS AND POLYCRYSTALS OF AN AUSTENITIC STAINLESS STEEL IN BOILING NITRIC ACID.
R. D. Leggett and H. W. Paxton. Washington, Office of Naval Research. Feb. 23, 1962. 33 p. 39 refs. (Contract Nonr 760(14) NR 036-029).

Single crystals, bicrystals and polycrystals of 20% Cr-20% Ni austenitic stainless steel were corroded in boiling nitric acid. The weight loss was independent of crystallographic orientation, grain size, and heat treatment. Metallographic observations showed no correlation between weight loss and microstructure. Adding 5 g./liter of Cr^{+6}, which is known to accelerate rates by one to two orders of magnitude, did not change the above conclusions. No significant change in the corrosion rates and morphologies occurred for single and bicrystals, even for those of high carbon (0.06%) and high nitrogen (0.24%) content, after aging under conditions which normally produce marked sensitization in polycrystalline samples. (Author Abstract)

N62-10778 North Carolina State Coll., Raleigh.
LUBRICATION BEHAVIOR OF LIQUID METALS.
[Yearly Summary Report, 1 Jan. 1961 through 1 Sept. 1961].

P. H. McDonald and J. P. Lamb. Wright-Patterson AFB, Ohio, Directorate of Materials and Processes. Jan. 1962. 15 p. 4 refs. (ASD-TR-61-459) (Contract AF 33(616)-5885; Project 7022).

This report surveys recent progress in the preliminary testing of experimental equipment for investigating the hydrodynamic and boundary lubrication behavior of liquid metals. Results of the first boundary lubrication tests are presented and briefly discussed. (Author Abstract)

N62-11084 Utah U., Salt Lake City

MECHANISMS OF FRICTION AND WEAR BETWEEN SOLID SURFACES.

Keith E. Boyd, Clark T. Rollins, and Arthur D. Thomas. Jan. 1962. vii, 62 p. 145 refs.

(ASD-TR-61-500) (Contract AF 33(616)-6833; Proj. 7022)

A low-velocity friction testing machine for surface velocities of from 1.0 foot per second to 15.0 feet per second and a high-velocity friction testing machine for surface velocities of from 1.0 foot per second to 200 feet per second are designed, fabricated and used to test a number of pairs of solid materials. Coefficients of friction as a function of several parameters were measured and plotted. It was found that a unique interface temperature between rubbing materials does not exist, but rather a random extremely variable temperature profile of considerable magnitude does exist. Data was obtained which gives evidence for deducing the effects of reactivity and solid solubility on the friction process. (Author Abstract)

N62-11142 Aerojet-General Corp., Azusa, Calif.

MERCURY CORROSION LOOP TESTING PROGRAM.

Monthly Technical Progress Report, 1 Feb. through 28 Feb., 1962.

P. I. Wood. Mar. 28, 1962. [8] p.

(Rept. LO584-01-5) (NASA Contract NAS 3-1925)

OTS: ph $1.10, mi $0.80.

The Mercury Corrosion Loop Testing Program continued through the fifth program month. Materials to be tested in the ten forced-convection corrosion test loops were selected; the materials are: Haynes 25, 9 Cr-1 Mo alloy, 9 Cr-1 Mo alloy clad with Type 316 stainless steel, AM-350 stainless steel, and columbium (niobium) clad with Type 316 stainless steel. Fabrication of the first four test loops is in progress. The first loop will be completed and in operation by mid-March. A centrifugal pump made from type 316 stainless steel is being tested. Bearing modifications were made to improve operation.

(Author Abstract).

N62-11162 Midwest Research Inst., Kansas City, Mo.

MATERIALS RESEARCH FOR LUBRICANTS AND HEAT TRANSFER FLUIDS.

Karl R. Mecklenburg. Wright-Patterson AFB, Ohio, Directorate of Materials and Processes, Jan. 1962. iv, 30 p. 3 refs.

(ASD-TR-61-737) (Contract AF 33(616)-6854; Proj. 3044)

Friction data are presented for copper on copper and for titanium on nickel for very low sliding speeds and light loads. The stick-slip apparatus used to obtain these data is described. Results are given for the initial part of an investigation in which the film conductance will be determined for liquid metals. A preprototype liquid metal boiler was operated at temperatures up to 1630°F with sodium. The design of a prototype liquid metal boiler for use in the next step of this work at temperatures up to 1800°F is described. Techniques used to handle sodium are outlined. Bearing life data are included for experimental greases run at high temperatures and speeds in the Pope Spindle. Screening runs with experimental grease made on the Navy Spindle at 350°F were not effective in selecting greases which would consistently run more than a few hours at high temperatures in the Pope Spindle. Wear scar data from the Four-Ball Wear Tester are given for experimental fluids. (Author Abstract)

N62-11531 Alcoa Research Labs., Aluminum Co. of America, New Kensington, Pa.

RESISTANCE OF WROUGHT HIGH-STRENGTH ALUMINUM ALLOYS TO STRESS CORROSION.

D. O. Sprowls and R. H. Brown. 1962. 32 p. 28 refs.

(Technical Paper No. 17)

The relatively few instances of stress-corrosion failures of aluminum alloys in service have resulted from residual or assembly tension stresses acting continuously in the short-transverse (or transverse, in the case of round and square sections) direction with relation to the grain structure. Test specimens machined in the longitudinal and long-transverse directions relative to the grain structure have demonstrated a high order of resistance to stress-corrosion cracking. Judicious selection of stress-relieved stock, or rough-machining parts as close as possible to the finished dimensions before solution heat treatment, and vigilance in preventing residual tension stresses from being built into a structure during assembly are primary requisites in avoiding stress-corrosion cracking problems. In cases where objectionable sustained-surface tension stresses cannot be avoided, selection of one of the more stress-corrosion resistant alloys and tempers, or shot peening, or other methods of cold-working the surface to develop compressive stresses may be used to minimize the hazard of stress-corrosion cracking. The dependability of protective coatings as a preventive measure is questionable under critical conditions, but may be of considerable value in borderline cases or in conjunction with surface working. (Author Abstract)

N62-11593 Atomic Energy Commission. Div. of Reactor Development, Washington, D. C.

NASA-AEC LIQUID METALS CORROSION MEETING, BROOKHAVEN NATIONAL LAB., DEC. 14-15, 1961.

Apr. 1962. v, 151 p.

(TID-7626, Pt. 1)

This report "may be considered a sequel to NASA Technical Note D-769."

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9. CARBON TRANSFER IN LIQUID SODIUM SYSTEMS. W. J. Anderson. p. 92-100. See N62-11602 05-18.
10. REPORT TO AEC-NASA LIQUID METALS CORROSION MEETING, BROOKHAVEN NATIONAL LAB., DEC. 14-15, 1961. p. 101-105. See N62-11603 05-18.
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N62-11596 Brookhaven National Lab., Upton, N. Y.
VAPOR-LIQUID CORROSION STUDIES IN MERCURY AND SODIUM SYSTEMS.
A. Fleitman, A. Romano, and C. Klamut. *In* NASA-AEC Liquid Metals Corrosion Meeting, Brookhaven National Lab., Dec. 14-15, 1961. p. 23-24. 3 refs. (See N62-11593 05-01)

A corrosion study program is under way to investigate the corrosive behavior of liquid mercury and mercury vapor from 600° to 1400°F and to investigate the corrosiveness of liquid sodium and sodium vapor from 1500° to 2400° F. The mercury experiments consist of running all-liquid and boiling natural convection loops, capsule tests, solubility studies of Fe, Co, Cr, Ti, and Cb in mercury, and a radioactive tracer loop experiment to study liquid carryover in the vapor phase and migration of soluble additives in the liquid phase. The materials tested include low carbon steel, 2 1/4 Cr-1 Mo steel, Haynes alloy 25, and Cb-1 Zr alloy. Analysis of the mercury corrosion test results is in progress. The sodium corrosion studies are primarily devoted to investigating the corrosion resistance and mode of attack of Cb-1 Zr alloy and other refractory alloys in liquid and gaseous sodium. In a capsule test, 1.2 grams of purified sodium was run for 720 hours at 2200° F. Although metallographic examination did not reveal any trace of corrosive attack, spectrographic analysis of the sodium showed 50 to 100 ppm Cb and 20 ppm Zr. A thermal convection loop and a high velocity boiling loop that will operate at 2200° F boiling are under construction. (V.D.S.)

N62-11597 Aerojet-General Nucleonics, San Ramon, Calif.
SUMMARY OF WORK ON LIQUID METAL CORROSION.
In NASA-AEC Liquid Metals Corrosion Meeting, Brookhaven National Lab., Dec. 14-15, 1961. p. 35-41. (See N62-11593 05-01)
(NASA Contract NAS5-417; AT(04-3)-251; AT(04-3)-368; AF 33 (616)-8119)

Mercury capsule tests are being conducted to investigate mercury corrosion. The capsules used are tubing, nearly filled with mercury and sealed with argon. The capsules are placed in vacuum furnaces in which the capsule bottoms are heated and the tops cooled, thus setting up a natural convection that results in a mass transfer. The capsule corrodes at the bottom, and collects a deposit near the top. Results show that for 405 stainless steel, only small mass transfer deposits occurred for Haynes 25 alloy, the depletion layer was largely Co_4W and Co_6W. Fifty percent of the corrosion products removed from a Haynes 25 capsule were smaller than ½ micron, the largest being approximately 0.020 inch in longest dimension. Hardness tests of the tube wall showed an initial softening (apparently due to stress relief) followed by hardening above the initial condition.

Other liquid metal programs in progress are as follows: A mercury forced-convection boiling loop experiment is being designed to simulate a full-scale boiler tube of the SNAP 8 configuration. In mercury solubility tests concentrations of metallic elements in mercury in contact with metals or alloys have been determined. Pumped loops are being used to test the compatibility of Cb-1Zr with boiling rubidium and cesium. No major corrosion in the rubidium loop test has been observed, although tiny crystals found in the condenser discharge are believed to be mass transfer deposits. In a rubidium capsule test experiment similar to the mercury solubility tests, corrosion and solubility data will be obtained for various containment materials for rubidium. The first phase of a lithium loop program has been started to demonstrate the feasibility of a thermionic space radiator on a liquid metal loop. The system will operate in high vacuum, and heat will be supplied by direct resistance heating, as in the rubidium and cesium loops. (V.D.S.)

N62-11598 Rocketdyne, Canoga Park, Calif.
ALKALI-METAL CORROSION STUDIES AT ROCKETDYNE.
W. T. Chandler. *In* NASA-AEC Liquid Metals Corrosion Meeting, Brookhaven National Lab., Dec. 14-15, 1961. p. 42-62. 2 refs. (See N62-11593 05-01)
(NASA Contract NAS5-453)

Research on sodium, potassium, cesium, and rubidium corrosion includes the following experiments: A boiling sodium loop operation for 35 hours at 1870° F did not produce any corrosion of the components. In experiments with a low-temperature boiling potassium loop, samples of molybdenum, columbium-1% zirconium, columbium, and tantalum showed decreasing levels of resistance to corrosion in that order. In the final run of the loop, specimens at the boiler discharge and downstream from the nozzle were attacked locally; and so were those in the purification loop; specimens in the purification loop were attacked more uniformly. In one series of capsule corrosion tests, the capsules were made of a nickel-based alloy (Hastelloy-X); in another, the capsules were made of columbium-1% zirconium. As received MSA potassium was used in these tests. Pronounced weight loss occurred in wrought and welded tabs of columbium and columbium-1% zirconium samples at 1450° to 2000° F. At exposures of 1800° and 1900° F, the tabs exhibited formation of a surface reaction layer. Relatively severe intergranular penetration was noted in the welded specimens. An interesting phenomenon that occurred in the heat-affected zone of columbium-1% zirconium weldments (at temperatures greater than 2000° F) was the apparent precipitation of a finely dispersed second phase which revealed an absence of grain boundaries. Cesium corrosion studies have shown that 321 stainless steel is corroded at 1830° F, but not at 1290° F. Molybdenum and tungsten showed little reaction or weight gain; nickel seemed to remain unattacked even at 1830° F, although microscopic examination revealed pronounced intergranular attack with no signs appearing on the surface. (V.D.S.)

N62-11599 AiResearch Mfg. Div., Garrett Corp., Phoenix, Ariz.
POTASSIUM CORROSION STUDIES.
E. A. Kovacevich. *In* NASA-AEC Liquid Metals Corrosion Meeting, Brookhaven National Lab., Dec. 14-15, 1961. p. 63-68. (See N62-11593 05-01)

Tests conducted under the SPUR program included static and dynamic tests with potassium. The static tests included refluxing and capsule tests to evaluate turbine and container materials, bearing materials, and alternator materials. The dynamic tests were conducted in forced circulation loops.

In the static tests, turbine and container materials (Hastelloy-X, molybdenum plus 0.5 weight percent zirconium) were tested 500 hours

at 1800° F and 1650° F. The bearing materials (Mo plus 0.5% Ti, Kennametal 94, tungsten) were tested in standard static capsule tests; coupons were exposed to liquid and vapor potassium. The alternator materials (high temperature potting compounds and solid ceramic bodies) were tested 500 hours in 1000° F liquid and vapor potassium. Results were as follows: the refractory materials appeared to be suitable for container and turbine applications; the bearing materials showed some weight change, although metallographic analysis shawed relatively little attack by potassium, the rotor and stator materials appear to be promising, and the solid ceramics, BeO and Al_2O_3 seemed satisfactory for use in potassium; the high temperature potting compounds were not compatible with potassium.

In the dynamic tests, a forced circulation loop fabricated from Hastelloy-X had operated for 530 hours at a temperature of 1800° F. Metallography of the hot leg showed intergranular attack to a depth of 0.04 inch; in the cold leg of the loop, predominantly nickel deposits were formed. In a test conducted with a two-phase forced circulation loop, a failure occurred after two hours of operation, owing to an electrical short. In addition to the failure, excessive contamination of the tantalum and columbium-zirconium material was evidenced. The loop is being modified. (V.D.S.)

N62-11601 Atomics International, Canoga Park, Calif.
LIQUID METAL CORROSION RESEARCH IN THE SNAP DEVELOPMENTAL PROGRAM.
M. A. Perlow and J. P. Page. *In* NASA-AEC Liquid Metals Corrosion Meeting, Brookhaven National Lab., Dec. 14-15, 1961. p. 87-91. (See N62-11593 05-01)

The materials, Hastelloy N, Hastelloy C, stainless steel 316, and Haynes 25, were tentatively selected for the SNAP reactor system and evaluated for corrosion resistance to NaK-78. A series of corrosion loop tests involved operation of the loops with intermittent interruptions to allow metallographic examination; another series involved continuous long-term (5000 hours) operation. Tests were conducted at 1200, 1300, 1400, and 1500° F—the temperature range of maximum design conditions. Results indicated that at 1200° F, corrosion of stainless steel 316 appears to be primarily intergranular; at 1400° F, general corrosion and pronounced leaching was evident in the steel, and at 1200° F, sharply defined regions were outlined while there was a more gradual transition from leached to normal structure at 1400° F. For Hastelloy N, the absolute magnitude of attack was much lower than for the stainless steels; two 1400° F specimens exposed for 5000 continuous hours exhibited very shallow intergranular attack to a depth of 0.0005 inch. All specimens of Hastelloy C (at 1200° F, 1400° F, and 1500° F for 5000 hours) exhibited very little erosion due to metal attack; the dominant effect was slight surface roughening. The Haynes 25, after interrupted exposure for 3000 hours at 1400° F, exhibited general leaching to a depth of 2 mils, and preferential leaching at grain boundaries to a depth of 3 mils; no noticeable surface recession occurred; specimens exposed for 5000 continuous hours at 1200° F generally exhibited less pronounced effects, and no leaching or intergranular attack was evident. There are insufficient fundamental data on the thermodynamics and kinetics of high-temperature liquid-metal corrosion processes to permit accurate prediction of incompatibility problems in reactor systems constructed of conventional materials operating at 1200° F and above. (V.D.S.)

N62-11603 Battelle Memorial Inst., Columbus, Ohio
REPORT TO AEC-NASA LIQUID METALS CORROSION MEETING, BROOKHAVEN NATIONAL LAB., DEC. 14-15, 1961.
In NASA-AEC Liquid Metals Corrosion Meeting, Brookhaven National Lab., Dec. 14-15, 1961. p. 101-105. (See N62-11593 05-01)

Investigations of creep of Mo-½ Ti alloy in potassium vapor involved tests at 80,000 psi and 1500° F. No deleterious effect of potassium vapor on creep was observed; higher temperature tests encountered serious instability problems. Creep test data are tabulated, and plans for additional tests are summarized. (V.D.S.)

N62-11604 Argonne National Lab., Ill.
MERCURY CORROSION OF TITANIUM AND TITANIUM ALLOYS AT ELEVATED TEMPERATURES.
James Y. N. Wang. *In* NASA-AEC Liquid Metals Corrosion Meeting, Brookhaven National Lab., Dec. 14-15, 1961. p. 107-108. (See N62-11593 05-01)

A program has been initiated to evaluate lightweight materials for use in a proposed lunar power plant, which consists of a fast reactor in a direct cycle with a mercury vapor turbine. A survey was made of the corrosion resistance to mercury of some sixteen commercially available titanium and titanium alloys. Static autoclave tests (700° F, 30-day exposure) indicated that the alloys, Ti-7Al-12Zr, Ti-2.5 Al-16V, Ti-5Al-5Sn-5Zr, and Ti-8Al-1Mo-1V, had low weight changes (-1.73 to 1.63 mg/cm²). Although a beta-type alloy suffered rapid failure by cracking in both vapor and liquid mercury, most of the alloys were more resistant to corrosion than unalloyed titanium. In most of the cases, minor cracking can be easily corrected by heat treatment prior to corrosion tests. An anodized film and a carburized layer on titanium exhibited good mercury resistance in a static system at 700° F; at 850° F, both samples suffered a severe mercury attack. The utilization of proper additives or inhibitors in mercury to reduce the corrosion attack on titanium is attractive because it permits using readily available lightweight materials for the proposed reactor. (V.D.S.)

N62-11606 Materials Central, Aeronautical Systems Div., Wright-Patterson AFB, Ohio
WORKING FLUIDS PROGRAM.
David A. Kirk and John A. Roth. *In* NASA-AEC Liquid Metals Corrosion Meeting, Brookhaven National Lab., Dec. 14-15, 1961. p. 111-114. (See N62-11593 05-01)

Work is underway to study the thermophysical and transport properties of rubidium from 1000° F to 2000° F and to establish an accurate method of analyzing impurities found in the metal. The first objective will be to determine physical properties so that a Mollier diagram can be constructed. Then, measurements will be conducted to determine specific heat of the vapor, monomer-dimer ratio as a function of temperature and pressure, viscosity of liquid and vapor, and thermal conductivity of liquid and vapor.

N62-11685 Aerojet-General Corp., Azusa, Calif.
INVESTIGATION OF STRESS-CORROSION CRACKING OF HIGH-STRENGTH ALLOYS.
Informal Report of Progress, 1 Jan. through 31 Jan. 1962.
R. F. Kimpel. Mar. 1, 1962. 3 [3] p. 1 ref.
(Rept. No. L0414-01-13) (Contract DA-04-495-ORD-3069)

N62-11686 Aerojet-General Corp., Azusa, Calif.
INVESTIGATION OF STRESS-CORROSION CRACKING OF HIGH-STRENGTH ALLOYS.
Informal Report of Progress, 1 Feb. through 28 Feb. 1962.
R. F. Kimpel. Mar. 30, 1962. 2 [2] p.
(Rept. No. L0414-01-14) (Contract DA-04-495-ORD-3069)

N62-11695 Midwest Research Inst., Kansas City, Mo.
LUBRICATION STUDIES WITH LAMELLAR SOLIDS.
Final Report, June 1, 1961 to Dec. 31, 1961.
Paul Bryant. Wright-Patterson AFB, Ohio, Directorate of Materials and Processes, Jan. 1962. iv, 23 p. 18 refs.
(ASD-TDR-62-55) (Contract AF 33(616)-7823; Proj. 7022)

A basic research program is being conducted to determine the mechanisms of friction and wear for lamellar solid lubricants. Single crystals of graphite were grown and an UHV (2×10^{-13} Torr) controlled

atmosphere system was perfected. A stress-etch mechanism is proposed here to explain the effect of atmospheric gases upon the lubrication properties of lamellar solids. The proposed mechanism describes the observed reduction of cohesive energy (mica was 30 times stronger in vacuum than in air) by an external attack upon the bifurcation line or shearing edge; the mechanism thus depends on the well-established processes of surface adsorption and migration without requiring diffusion of air molecules between lamellae. (Author Abstract)

N62-11698 Sperry Gyroscope Co., Great Neck, N.Y.
NUCLEAR RADIATION RESISTANT GYRYSCOPE BEARING LUBRICANTS AND FLOTATION MEDIA.
[Final Report, Covering the Period Nov. 16, 1959 to Sept. 30, 1961]
Frank R. Callihan, Robert A. Falk, Armin S. Koch, Thomas P. Martins, and Charles L. Quatela. Wright-Patterson AFB, Ohio, Directorate of Materials and Processes, Feb. 1962. 28 p. 20 refs.
(WADD-TR-60-753, Pt. II) (Contract AF 33(616)-6817; ASD Proj. 1448)

Fluids for use as base stocks for the formulation of radiation-resistant lubricants were investigated; one of them, tert-butyl 1, 9-diphenylnonane, appears particularly promising and is recommended for further evaluation. Towards the objective of developing perfluoro-aromatic materials as highly stable fluids, methods for the preparation of hexafluorobenzene were investigated. A successful procedure involving the pyrolysis of dichlorofluoromethane was developed and is reported herein. (Author Abstract)

N62-11699 Wyandotte Chemical Corp., Mich.
THE SYNTHESIS AND EVALUATION OF NEW BASE STOCK FLUIDS FOR GAS TURBINE APPLICATION.
[Part II. Interim Report, Covering Work Conducted from Sept. 1, 1960 to Aug. 31, 1961]
Peter T. Kan, John D. Behun, Saiyid M. Naqvi, Marcia A. Jorgensen, and Patricia A. Gibson. Wright-Patterson AFB, Ohio, Directorate of Materials and Processes, Feb. 1962. xvii, 231 p. 25 refs.
(WADD-TR-60-838, Pt. II) (Contract AF 33(616)-6749; ASD Proj. 3044)

The synthesis and evaluation of new pyrazine derivatives for high temperature stable fluid applications are given. Candidate products, unsymmetrical 2,3-disubstituted- and 2,3,6-trisubstituted pyrazines, were prepared from 2-chloro-3-methylpyrazine and 2-chloro-3,6-dimethylpyrazine. Alkyl substituted pyrazines were synthesized from 2,5- and 2,6-dimethylpyrazines and tetramethylpyrazine. A wide variety of pyrazine derivatives were obtained in good-to-excellent yields. These compounds were screened for thermal and oxidative stability. Classes of compounds containing undesirable linkages were bypassed, and materials which showed promise were screened further. Correlations of the effect of variation in structure upon physical properties of the substituted pyrazines were made. Using these correlations, a stepwise achievement of the candidate products with further improved properties was realized. (Author Abstract)

N62-11735 Materials Research Lab., Inc., Richton Park, Ill.
ELEVATED TEMPERATURE STRESS CORROSION OF HIGH STRENGTH SHEET MATERIALS IN THE PRESENCE OF STRESS CONCENTRATORS.
Quarterly Progress Report No. 2, for the Period Sept. 1 to Nov. 30, 1961
S. Mostovoy and E. J. Ripling. [1962] 16 p. 3 refs.
(NASA Contract NASr-50)
OTS: ph $1.60, mi $0.80.

Longitudinal and transverse edge-notched tests have been carried out at -110 and +650° F on a number of materials after 650° F exposure in the presence of sea salt. The exposure stress was 40,000 psi for steel and superalloys and 25,000 psi for titanium. The notch strength of Inconel W and AM350, cold-reduced 20 or 45 percent followed by aging at 825 or 950° F, was found to be the same after exposure in the presence or absence of salt. The cobalt base alloy, V36, was also unaffected in the longitudinal direction, but showed a slight loss in transverse properties when tested at -110° F. The latter may simply have been scatter, however, since it was based on a single test; and even this one specimen exhibited a complete-shear fracture. The only titanium alloy (annealed 6 aluminum-4 vanadium) tested to date was seriously damaged by the salt coating. Three longitudinal and three transverse samples all failed during exposure in times varying from 23 to 950 hours under an applied stress of 25,000 psi at the notch bottom. Fracturing in the longitudinal samples formed a saw-toothed pattern across the notch width, while the transverse specimens broke out of the notch. Since the room temperature yield strength of the titanium was 140,500 in the longitudinal direction and 146,000 psi in the transverse direction, failure occurred at less than 0.2 of the room temperature yield strength for the longitudinal pieces and slightly more than 0.1 for the transverse specimens (using the cross-sectional area of the notch bottom for the longitudinal samples and of the smooth section for the transverse bars). (Author Abstract)

N62-11821 Directorate of Materials and Processes, Aeronautical Systems Div., Wright-Patterson AFB, Ohio.
DEVELOPMENT OF OPTIMUM METHODS FOR THE PRIMARY WORKING OF REFRACTORY METALS.
Interim Report, June 1, 1961 to July 31, 1961.
P. S. Duletsky and V. DePierre. Jan. 1962. 32 p. 2 refs.
(WADD-TR-60-418, Part III) (ASD Proj. 7351)

Improved lubrication techniques using Corning 7900 glass mixture were developed for extruding refractory metals at 4000° F. The suitability of zirconium oxide ceramic-coated steel dies for extrusion at 4000° F was confirmed. Improved extrusion facilities at WPAFB give reproducible, good quality, round and rectangular bar extrusions at temperatures up to 4000° F and reduction ratios of 9.5 to 1.
(Author Abstract)

N62-11841 Shell Development Co., Emeryville, Calif.
FUNDAMENTALS OF HIGH TEMPERATURE BEARING LUBRICATION.
Bimonthly Report 2, Feb.-Mar. 1962.
J. B. Accinelli and S. J. Beaubien. [1962] 12 p.
(S-13850) (Contract NOw-62-0239-c)

Studies in the 25-mm bearing rig provided valuable information on lubricant flow through the test bearing and the significance of this flow with respect to bearing performance, deposits, and wear. It was found that operation of the 25-mm rig at very high speeds (60,000 rpm) as previously assembled gave rise to a negative pressure above the test bearing. This negative pressure caused a reverse flow of lubricant through the test bearing which provided adequate lubrication, primarily from the sump vapors, up to the friction-limited temperature. If the lubricant flow was increased and was prevented from reversion by scavenging with vacuum and using a compensating slinger above the test bearing, then no friction-limited temperature was observed up to 830° F (instead of 750° F), deposits were very light and there was very little wear of the bearing components. This work suggests that, with adequate lubricant flow as determined in part by design considerations, ball bearings can be operated at very high temperatures for extended periods of time. (Author Abstract)

N62-11951 Illinois U., Urbana.
PROBLEMS IN CUTTING TOOL WEAR.
Final Report [Covering the Period 1 Sept. 1955 to 31 Jan. 1962].

K. J. Trigger and B. T. Chao. Feb. 1962. 34 p. 3 refs.
(ME Tech. Rept. ORD-1980-11; AROD-1492-11) (Contract DA-11-022-ORD-1980; DA Proj. 5B99-01-004; Ord. Res. & Dev. Proj. TB2-0001; Off. of Ord. Res. Proj. 1492)

The significance of adhesion between tool-work pairs and its influence on tool wear is discussed, together with the influence of microstructure. Factors affecting wear by abrasion and chemical activity are presented. Wear behavior for a wide variety of tool-work combinations are explicable in terms of a unified theory of cutting tool wear. However, a complete quantitative analysis is not yet possible. Experimental techniques and analytical procedures for the evaluation of interface temperature—and heat-flux distribution as previously reported—are incorporated by reference. (Author Abstract)

N62-12049 Materials Research Lab., Inc., Richton Park, Ill.
ELEVATED TEMPERATURE STRESS CORROSION OF HIGH STRENGTH SHEET MATERIALS IN THE PRESENCE OF STRESS CONCENTRATORS.
Quarterly Progress Report 3, for the Period Dec. 1, 1961 to Feb. 28, 1962.
K. Packer and E. J. Ripling [1962] 14 p. 3 refs.
(NASA Contract NASr-50)
OTS: ph $1.60, mi. $0.80.

A continuing study of the effect of natural sea salt on the notch strength of super alloys and stainless steel corroborates a previous conclusion that these alloys are not embrittled by natural sea salt when exposed to 40,000 psi at 650° F for 1000 hours and subsequently tested at −110°F, room temperature, and 650°F. In the previous quarterly report Ti-6Al-4V specimens were shown to crack extensively when exposed to moderate stresses at 650° F in the presence of natural sea salts. Results on a super alpha alloy, Ti-8Al-1Mo-1V, were obtained during this quarter. Under the same test conditions, i.e., 650° F and 25,000 psi, this material, although somewhat more salt resistant than the 6-4 alloy, still cracked extensively during exposure. Indeed, all three longitudinal and one transverse specimen failed to reach 1000 hours under these exposure conditions. The remaining two transverse specimens surviving exposure had greatly reduced notch tensile strengths in subsequent tensile tests. Microstructural investigation of this alloy revealed that the cracking was primarily intergranular. Since most of the titanium specimens cracked away from the notch and near the edge of the heavy salt crust, lighter salt coatings were applied to only one side of a number of Ti-6Al-4V alloy specimens to insure oxygen accessibility at the notch bottoms and width. Failures continued to be remote from the notch, demonstrating that these fractures are not a result of insufficient aeration during exposure. (Author Abstract)

N62-12072 SKF Industries, Inc. Research Lab., Philadelphia, Pa.
INFLUENCE OF LUBRICATION ON ENDURANCE OF ROLLING CONTACTS.
Progress Report 2, Period Sept. 22, 1961 to Feb. 22, 1962.
N. E. Sindlinger, J. A. Martin, and D. F. Huttenlocher [1962] 96 p. 50 refs.
(SKF Rept. AL62T004) (Contract NOw-61-0716-C; SKF Proj. III-1)

Experimental studies involve three basic types of machines: the rolling four-ball tester, a flat washer and rolling element machine, and a two-ball apparatus being developed especially for this investigation. In the four-ball and two-ball machines, the contact conditions and lubrication between two balls in rolling contact, both with and without different kinds and degrees of slip, can be studied. Flat washer testing of other element configurations will be conducted as the program progresses. Recent developments reported in the literature are presented for use in calculating theoretical lubrication parameters in practical experimental systems. A new electrical conductivity technique has been developed for studying lubricants and contact conditions in the rolling four-ball tester, and some contact lubrication effects from preliminary experiments are presented. Radioisotope tracer tests to detect metal transfer under different lubrication conditions in the four-ball machine are in the final preparatory stages. These studies are aimed at defining the limits of full-film elastohydrodynamic lubrication and investigating contact lubrication in the elastohydrodynamic and boundary regimes. A bank of four-ball machines being readied for endurance testing and well-defined, high test lubricants have been selected to represent a cross section of lubricant fluids. A basic understanding of elastohydrodynamic effects on endurance, of course, will require precise measurements of the temperatures and pressures or deflections at rolling contacts in order to relate these lubrication parameters to bearing failure processes. Such studies will be undertaken later with the two-ball machine, designed to allow precise measurement of the deflections and lubricant film thickness between two rolling balls using refined X-ray techniques. (Author Abstract)

N62-12134 Petroleum Refining Lab., Pennsylvania State U., University Park.
FLUIDS, LUBRICANTS, FUELS AND RELATED MATERIALS.
Covers Work Conducted from Dec. 15, 1960 through Dec. 14, 1961.
E. Erwin Klaus, Merrell R. Fenske, and Elmer J. Tewksbury. Feb. 1962. 465 p.
(WADD-TR-60-898, Pt. II) (Contract AF 33(616)-7590; Proj. 3044)

A program is underway to characterize capabilities of fluids and lubricants for aeronautic or astronautic uses. Feasibility of commercial production of low temperature mineral oils is indicated. Formulations dependent on end use are suggested. Excellent blending efficiency for mineral oil-ester blends are shown. Data for phenyl ethers are included. Data suggest use of radioisotopes as an aid in measurement of relative polarity of additives, in establishment of lubrication mechanisms, and in analysis for impurities. Equipment and procedures for measurement of bulk modulus are described. A series of pressure-viscosity determinations is shown. Behavior of fluids in a system having a large pressure or temperature differential across a small leak or vent is discussed. Design and construction of units for measurement of heat capacity and thermal conductivity are illustrated. Prediction of useful life for fluids based on oxidation behavior is illustrated. Special M-2 tool steel bearings are evaluated. Stability of aromatic hydrocarbons is discussed.
(Author Abstract)

N62-12266 Massachusetts Inst. of Tech., Cambridge, Mass.
THE SIZE DISTRIBUTION OF WEAR FRAGMENTS: EFFECT OF SURFACE ENERGY ON THE WEAR PROCESS.
Final Report [1 Sept. 1958–28 Feb. 1962].
E. Rabinowicz and R. G. Foster. Apr. 10, 1962. 47 p. 18 refs.
(AROD-2166-1) (Contract DA-19-202-ORD-4705; DA Proj. 009925001)

The size of loose wear particles formed during the sliding of two materials is equal to 60,000 W_{ab}/p, where W_{ab} is the surface energy of adhesion and p the penetration hardness. Experimental results are presented which show that the experimental particle sizes obtained with many materials do indeed obey the theoretical relationship and that the particle size is, as predicted, almost independent of such external variables as speed, load, time, and geometry. Indeed, if particles of the wrong size are fed into the system, then they are rapidly broken down or built up until the correct size is reached. However, changes of atmosphere and the use of lubricants, which alter the energy of adhesion, do have a marked influence on wear particle size, and this fact suggests a possible use of wear particle measurement to rate boundary lubricants. Other surface interaction phenomena which are governed by the W/p ratio are derived, and it is suggested that the surface roughness generated during sliding is a function of this ratio. (Author Abstract)

N62-12360 Rensselaer Polytechnic Inst., Troy, N.Y.
RESEARCH ON HEAT AND MASS TRANSFER EFFECTS IN SLIDING METAL SYSTEMS LUBRICATED BY SOLID INTERFACIAL FILMS. Progress Report IV, Nov. 1, 1961–Jan. 31, 1962.
F. F. Ling. Feb. 1962. 19 p. refs.
(Contract AF 33(616)-8016)

This report discusses the completed apparatus (discussed in Progress Report I, May 1961) whose rider and slider system is capable of generating interface temperatures of 1000° F or higher for studying solid interfacial films. An example is given of the computed interface temperature based on perfect matching. (Author Abstract)

N62-12404 Rock Island Arsenal Lab., Ill.
REDUCTION OF FRETTING CORROSION OF GREASES BY USE OF EXTREME PRESSURE AND ANTIWEAR ADDITIVES. Technical Report.
S. Fred Calhoun. Feb. 20, 1962. 22 p. 18 refs.
(RIA-62-651) (DA Proj. 593-21-060)
OTS: $0.50.

A machine developed for the study of fretting is described. Five greases and six additives were selected and evaluated for their ability to minimize fretting. Three of the additives were primarily of the extreme pressure type and increased the mean Hertz load of all greases to which they were added. Two of them reduced the fretting of all greases while the third was effective in only three of the four greases. A fourth additive, primarily an antiwear type, had a slight adverse effect upon the mean Hertz load and appeared to promote fretting in all greases. A lubricity type additive, when used alone or in combination with an EP and an antiwear additive, resulted in a light decrease in fretting in the one grease in which it was tested. The effect of the additives was not uniform in all greases and some were benefited more than others. (Author Abstract)

N62-12423 Midwest Research Inst., Kansas City, Mo.
LUBRICATION BEHAVIOR AND CHEMICAL DEGRADATION CHARACTERISTICS OF EXPERIMENTAL HIGH TEMPERATURE FLUIDS AND LUBRICANTS. [Final Report, Jan. 1961 to Dec. 1961.]
Vernice Hopkins, Andrew D. St. John, and Donnell Wilson. Wright-Patterson AFB, Ohio, Directorate of Materials and Processes, Mar. 1962. 116 p. 7 refs.
(WADD-TR-60-855, Pt. II) (Contract AF 33(616)-6854; Proj. 3044)

MLO 60-294 resisted degradation from high shear stresses at 400°, 500°, 550°, and 600° F and wear of the hydraulic pump was small through 500° F. MLO 59-91 at 400° F permitted rapid wear in the hydraulic pump. MLO 59-692 was not degradated by high shear stresses at 550° and 700° F. QF-258 was not degradated at 550° F but experienced a drop in viscosity and flash point during a 100 hr. shear stability experiment at 700° F. Bulk modulus data are presented for MLO 60-294 and QF-258. Results of lubricant behavior in a rolling-sliding contact are presented, and a partial analysis of roller-cage stability is given. Development of the high pressure viscometer is discussed. Solid film lubrication of spherical bushings and the effects of thermal aging of a film are presented. Extreme pressure lubrication of M-10 tool steel at 400° and 600° F and of 52100 steel at 275° and 400° F with an ester of TMP with various additives is discussed. (Author Abstract)

N62-12525 American Oil Co., Whiting, Ind.
DEVELOPMENT OF GREASE LUBRICANTS FOR HIGH TEMPERATURE BALL AND ROLLER BEARINGS OF ELECTRICAL EQUIPMENT. [Report Covering Sept. 1960–Sept. 1961.]
A. C. Borg, K. R. Bunting, A. M. Dobry, R. G. Garst, J. H. Klauwers, H. M. Sellei, R. S. Barnes, and H. J. Liehe. Wright-Patterson, AFB, Ohio, Directorate of Materials and Processes, Feb. 1962. 68 p.
(Contract AF 33(616)-5797)
(WADD-TR-60-557, Pt. II)

The object of this work is the development of grease systems capable of operating in lightly loaded bearings over the temperature range of −65° F to 900° F. The most promising fluids are the higher phenyl content methyl silicones. Other potentially promising fluids are silphenylenes, polyphenyl ethers, chain-type polyphenyls, and phosphonitrilic chloride polymers and their complexes. Mass spectrograph studies on polyphenyls reveal that these materials have unusual stability under electron impact. Although the high molecular weight polyphenyls are solids with relatively high melting points, a mixed melting point study shows marked lowering in melting points on melts of mixtures of these materials. Imide-thickened greases, despite their apparent good high temperature characteristics as indicated by dropping points above 700° F, do not give satisfactory results in the high temperature bearing performance tests. This is true in both phenyl ethers and phenyl silicones. (Author Abstract)

N62-12572 Du Pont de Nemours (E. I.) and Co. Savannah River Lab., Aiken, S.C.
STRESS-CORROSION CRACKING OF STAINLESS STEEL; A LITERATURE SEARCH.
Myra S. Feldman. Feb. 1962. 69 p. 251 refs.
(Contract AT(07-2)-1)
(DP-683) OTS: $1.50.

References on the stress-corrosion cracking of stainless steel have been abstracted from the open literature through September 1961. (Author Abstract)

N62-12635 Rensselaer Polytechnic Inst., Troy, N.Y.
STRESS CORROSION CRACKING. Interim Report No. 1.
S. J. Acello and N. D. Greene. Apr. 16, 1962. 26 p. 24 refs.
(Contract DA-30-069-ORD-3077)

Anodic polarization measurements show that chloride additions up to 10^{-1} normal do not seriously affect the passive or transpassive dissolution behavior of austenitic stainless steels in sulfuric acid. However, the primary potential for passivation is shifted to more noble values, and the critical current for passivation is greatly increased. Stress corrosion cracking, which occurs at room temperature in 10 normal sulfuric acid with 0.5 normal sodium chloride, is not observed under anodic protection. Hence, anodic protection not only decreases general corrosion but prevents stress corrosion cracking. (Author Abstract)

N62-12641 TAPCO. Div. of Thompson Ramo Wooldridge, Inc., Cleveland, Ohio.
LIQUID-MERCURY LUBRICATED HYDROSPHERE BEARINGS.
G. Y. Ono and D. C. Reemsnyder. 1961. 35 p. 4 refs. For presentation at the ASME Spring Lubrication Meeting, Miami, Fla. May 8–9, 1961.

N62-12926 Oak Ridge National Lab., Tenn.
TRU CORROSION STUDIES.
J. L. English, J. C. Griess, and P. D. Neumann. *In its* Transuranium Quarterly Progress Rept. for Period Ending Feb. 28, 1962. (ORNL-3290) p. 76–78.

The development of separation processes for the transuranium elements, and of the process equipment, and the HFIR target fabrication; the design of the TRU facility and the development facilities; and

corrosion studies, analytical research and development, and preparation of U-232 samples for research are reported here. Work done by the Chemical Technology, Metallurgy, Engineering and Maintenance, and Reactor Chemistry Divisions of Oak Ridge National Laboratory and Design Group at Oak Ridge Gaseous Diffusion Plant in the Transuranium Element Processing Program is included. (Author Abstract)

N62-13035 Aerojet-General Corp., Azusa, Calif.
INVESTIGATION OF STRESS-CORROSION CRACKING OF HIGH-STRENGTH ALLOYS. [Preliminary Progress Report No. 15, 1 Apr. through 30 Apr. 1962.]
R. F. Kimpel. June 4, 1962. 6 p.
(Contract DA-04-495-ORD-3069)
(Rept. L0414-01-15)

Bent-beam and U-bend specimens of rocket motor case materials were used to evaluate the susceptibility to stress-corrosion cracking of welded and unwelded samples. The bent-beam specimens were stressed to 75% of the yield strength, and the U-bend specimens were bent over 12T- and 24T-diameter mandrels. The specimens were then exposed to environments representing some phase of the manufacturing, testing, and long-term storage of solid rocket motor chambers. The tests are nearing completion. (V.D.S.)

N62-13164 SKF Industries, Inc. Research Lab., Philadelphia, Pa.
INFLUENCE OF LUBRICATION ON ENDURANCE OF ROLLING CONTACTS. Progress Report No. 3. Feb. 22, 1962 to Apr. 22, 1962.
N. E. Sindlinger, J. A. Martin, and D. F. Huttenlocher. [June?] 1962. 128 p. 30 refs.
(Contract NOw-61-0716-C)
(Rept. AL62T013)

Experimental studies have continued with the rolling four-ball test machine using both conductivity and radioactive transfer techniques. Experimental studies have also been continued with a refined direct-beam X-ray method for studying oil-film thicknesses at the contact in the two-ball test machine, which is currently in the final design phase. The interaction of a lubricant film with the surface geometry of typical test balls in the four-ball tester has been analyzed theoretically; and the direct-beam, X-ray, oil-film thickness measurement method, as applied to parallel flats, has been mathematically analyzed. (Author Abstract)

N62-13167 Laboratories for Research and Development, Franklin Inst., Philadelphia, Pa.
EXPERIMENTAL DETERMINATION OF STABILITY BOUNDARIES FOR AN EXTERNALLY-PRESSURIZED, GAS-LUBRICATED THRUST BEARING. Interim Report.
Charles Stevenson and Lazar Licht. Feb. 1962. 44 p. 2 refs.
(Contract Nonr-2342(00); jointly supported by DOD, AEC, MA, and NASA)
(I-A2049-19) OTS: $4.60 ph, $1.52 mf.

Stability boundaries are determined experimentally for a circular, externally-pressurized, air-lubricated thrust bearing. The loci are presented on load-versus-supply pressure plots, showing the effects of varying certain parameters (recess depth; total throat area of supply nozzles; and rotor mass) on the stability of a 5-in. diameter bearing with a centrally-located 1-in. diameter recess. The influence of entrance effects in the region of admission of the bearing gap is investigated qualitatively. Results are discussed with reference to stable bearing design and operation and recommendations are made for future theoretical and experimental work. (Author Abstract)

N62-13198 Bettis Atomic Power Lab., Westinghouse Electric Corp., Pittsburgh, Pa.
A CORROSION EVALUATION OF THE EFFECTS OF THE CITRIC ACID—DISODIUM EDTA DECONTAMINATION PROCESS ON PLANT STRUCTURAL MATERIALS WITH AND WITHOUT ULTRASONICS TREATMENT.
R. E. Moore. *In its* Bettis Technical Review: Reactor Technology, May 1962. p. 73–86. 2 refs. (See N62-13193 09-01)

Unrestricted use of the CA-EDTA process in decontamination of nuclear plant components was questioned because of corrosive attack on some structural materials. Tests were conducted to determine the extent of the corrosive effects of the CA-EDTA process. Materials evaluated are grouped according to corrosion resistance in CA-EDTA with and without ultrasonics treatment. (Author Abstract)

N62-13209 Shell Development Co., Emeryville, Calif.
DEVELOPMENT OF A PROTOTYPE RADIATION RESISTANT BEARING AND GEAR LUBRICANT. [Final] Technical Documentary Report [Sept. 1960-Sept. 1961].
C. L. Mahoney. Wright-Patterson AFB, Ohio, Directorate of Materials and Processes, Mar. 1962. 119 p. 28 refs.
(Contract AF 33(616)-7601)
(ASD-TR-61-652)

The polyphenyl ethers have the physical properties and stability to permit their use under environments far too severe for conventional lubricants. While their high-speed bearing performance is good, viscosities at high temperatures are too low to give sufficient load carrying capacity for some gear applications, so additives have been examined as a means of improving their gear load-carrying capacity. Suitable additives must meet the conflicting requirements of high activity towards metal surfaces and little effect on the stability of the ethers. No additive examined completely satisfied these requirements. Only aromatic derivatives had sufficient stability and these materials generally did not improve load carrying capacity. However, some aromatic phosphate derivatives, when used in high concentrations (3–10%), appreciably improved the lubrication properties, and their effects on the oxidation, radiation and thermal stability of the polyphenyl ethers was low. Such additives may be suitable where requirements are low. (Author Abstract)

N62-13211 Directorate of Materials and Processes, Aeronautical Systems Div., Wright-Patterson AFB, Ohio.
A REVIEW OF THE AIR FORCE MATERIALS RESEARCH AND DEVELOPMENT PROGRAM. [Interim] Technical Documentary Report [1 July 1960-30 June 1961].
Junie J. Banks and Donna J. Tate. Mar. 1962. 210 p. 312 refs.
(WADC-TR-53-373, Suppl. 8)

These reports cover basic and applied research in the materials area being conducted by the Metals and Ceramics, Nonmetallic Materials, Physics, Manufacturing Technology, and Applications Laboratories of the Directorate of Materials and Processes. (Author Abstract)

N62-13454 Rock Island Arsenal Lab., Ill.
THERMAL STABILITY OF ALIPHATIC DIESTERS. Technical Report.
R. LeMar. Feb. 20, 1962. 30 p. 4 refs.
(RIA Lab Rept. 62-653) OTS: $0.75.

The thermal stability of the ethyl and n-butyl diesters of adipic and sebacic acid was evaluated at 475°F under nitrogen in the presence of four metals (in and above the fluid) for several time periods. Di-2-ethylhexyl sebacate was tested for comparison purposes. Changes

in several physical and chemical diester properties and metal specimen weights were determined after exposure. The adipates showed greater stability as regards changes in viscosity, neutralization number and weight of immersed steel specimen than did the sebacates. The reverse was true as regards changes in color, precipitate volume, and degree of carbonization. The longer-chain sebacates sublimed large amounts of acidic material onto cooler regions of the test cell. None of the diesters were corrosive to specimens in the gas phase, although staining did occur. None of the diesters were corrosive to immersed copper, aluminum or monel metal during exposure. All were corrosive to immersed steel.

Comparison with similar tests on two diesters with steel omitted show that steel and the diesters have a mutually deleterious effect. Steel caused greater color change, freezing point change, precipitate volume, and carbonization. It also appears that adipic acid is more rapidly decomposed than sebacic acid in the presence of dissolved iron salts. Corrosivity tests on these diesters (after thermal exposure) in the presence of air indicated some of them to be corrosive to steel. It was found that these diesters could undergo considerable chemical decomposition with only moderate changes in most of their physical properties in the presence of copper, aluminum and monel metal.

(Author Abstract)

N62-13501 Rocketdyne, Canoga Park, Calif.

H-1 LUBRICATION STUDIES. [Covering Period 1 Nov. 1960 to 1 Mar. 1962.]

O. I. Thorsen. Mar. 1, 1962. 127 p. 55 refs.
(NASA Letter Contract NAS7-3; G. O. 5868)
(Rept. R-3451) OTS: $10.10 ph, $4.01 mf.

This report presents the results of various lubrication studies to pretreat gear surfaces with extreme pressure (EP) additives, platings, and coatings so that these gear surfaces function properly when later lubricated in RP-1 (kerosene) only. A total of 32 additives and 16 platings and coatings were tested in the Falex tester and a WADD (Ryder type) gear tester. The results of these tests and recommendations are reported. Included is a review of the effort necessary to make the WADD gear tester operate at a high speed (20,000 rpm) and high load (4000 + lb per in. of gear face). (Author Abstract)

N62-13603 Mellon Inst., Pittsburgh, Pa.

STRESS CORROSION OF HIGH STRENGTH STEELS AND ALLOYS; ARTIFICIAL ENVIRONMENT. Quarterly Scientific Report No. 15, for the Period Nov. 1, 1961-Jan 31, 1962.

C. J. Owen and W. D. Ruble. [1962] 64 p. 1 ref.
(Contract DA-36-034-ORD-3277RD)

A brief review of experimental procedures, including test methods, apparatus, sample preparation, and testing, is presented for reference purposes. Cumulative stress corrosion test data for the various bent-beam and U-bend tests on high strength missile alloys are given. Included are bent-beam data for D6Ac, Vascojet 1000, AM355, PH15-7 Mo, B120VCA, and 4137 Co and U-bend data for 300M, AM355, PH15-7 Mo, B120VCA, 4137 Co, Ardeform 301, and U-modified 4137 Co. The low-alloy steels 4137 Co, 300M, and Vascojet 1000 are definitely susceptible to stress corrosion in varying degree. The AM355, PH15-7 Mo, B120VCA, and Ardeform 301 alloys are not susceptible, regardless of strength level of exposure. Alloy modification of the 4137 Co with uranium has very markedly decreased the stress corrosion susceptibility of this alloy. (Author Abstract)

N62-13615 Ministry of Aviation. Technical Information and Library Services (Gt. Brit.)

OIL FOR WATCHES AND AIRBORNE INSTRUMENTS. OELE FUER UHREN UND BORDGERAETE.

M. Herfurtner. May 1962. 29 p. 301 refs. Transl. from D. F. L. Rept. no. 75, 30-10-1957, Germany.
(TIL/T.4974)

The review includes: fatty oils; mineral oils; synthetic oils; solid lubricants; oil-free bearings; the influence of the lubricant on the materials; behavior of lubricants at high and low temperatures; research and test methods; recent experiments; and new proposals and the future outlook. (Author Abstract)

N62-13625 National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

FRICTION, WEAR, AND EVAPORATION RATES OF VARIOUS MATERIALS IN VACUUM TO 10^{-7} mm Hg.

Donald H. Buckley, Max Swikert, and Robert L. Johnson. Repr. from ASLE Trans., v. 5, 1962. p. 8-23. 38 refs. Presented at the ASLE Lubrication Conf., Chicago, Ill., Oct. 1961.

Evaporation data on soft metals, lubricating inorganic compounds, and various reference materials are reported for temperatures from 75°F to 1000°F in vacuum as low as 10^{-7} mm Hg. Observations on modes of vacuum degradation (e.g., evaporation or dissociation) and methods of experimentation are related. Friction and wear data are presented for several unlubricated metals (e.g., type 440-C steel) and metals coated with inorganic (e.g., MoS_2, CaF_2), as well as with soft metal films in vacuum at ambient pressures between 10^{-6} and 10^{-7} mm Hg.

(Author Abstract)

N62-13665 Bureau of Mines, Washington, D.C.

CHEMICAL AND GALVANIC CORROSION PROPERTIES OF HIGH-PURITY VANADIUM.

Charles B. Kenahan, David Schlain, and Walter L. Acherman. 1962. 26 p. 6 refs.
(BM-RI-5990)

Vanadium is subject to only light corrosion in phosphoric acid at temperatures up to 60°C and has a moderate corrosion rate in this acid at 100°C. It is relatively corrosion-resistant in sulfuric and hydrochloric acids up to 60°C but corrodes rapidly at 100°C. It corrodes rapidly in dilute nitric acid at 35°C. Vanadium is almost inert in 10-percent solutions of formic, acetic, lactic, tartaric, and citric acids; in 9-percent oxalic acid, it corrodes slowly up to 60°C and rapidly at 100°C. Vanadium is resistant to corrosion in substitute ocean water, tapwater, and in 3-percent sodium chloride and 10-percent sodium hydroxide solutions. It is readily attacked, however, by 20-percent ferric chloride, 20-percent cupric chloride and 5-percent mercuric chloride solutions. Vanadium is protected by contact with magnesium, aluminum, and steel SAE 4130 in substitute ocean water, by magnesium and aluminum in 3-percent sodium chloride solution, and by magnesium in tapwater. Vanadium protects copper in substitute ocean water. When vanadium and stainless steel are coupled in sulfuric acid solutions, both metals are usually unaffected by contact, whereas the corrosion rate of titanium in sulfuric acid is greatly reduced by contact with vanadium. (Author Abstract)

N62-13711 Aerojet-General Corp., Azusa, Calif.

INVESTIGATION OF STRESS-CORROSION CRACKING OF HIGH-STRENGTH ALLOYS. [Sixteenth] Informal Report of Progress, Period Covered: 1 May through 31 May 1962.

R. F. Kimpel. June 25, 1962. 6 p.
(Contract DA-04-495-ORD-3069)
(Rept. L0414-01-16)

Bent-beam and U-bend specimens were used in evaluating the susceptibility to environmental stress-corrosion cracking of unwelded

samples of the candidate alloys. The bent-beam specimens were stressed to 75% of the yield strength, and the U-bend specimens were bent over 12T- and 24T-diameter mandrels. The specimens were then exposed to environments representing some phase of the manufacturing, testing, or long-term storage of solid-rocket motor chambers. Tabulated data indicate which alloys are susceptible to stress-corrosion cracking in the environments tested and which environments induce stress-corrosion cracking of the alloys tested. (V.D.S.)

N62-13813 Aerojet-General Corp., Azusa, Calif.
MERCURY CORROSION LOOP TESTING PROGRAM. Quarterly Report, 1 Jan. through 31 Mar. 1962.
Apr. 27, 1962. 35 p.
(NASA Contract NAS3-1925)
(Rept. 0584-04-2) OTS: $3.60 ph, $1.25 mf.

The Mercury Corrosion Loop Testing Program continued through the second quarter. Materials to be tested in the 10 forced-convection test loops were selected; the materials are: Haynes 25, 9 Cr-1Mo alloy clad with Type 316 stainless steel, AM 350 stainless steel, and columbium (niobium) clad with Type 316 stainless steel. The eight-test-cell facility was completed, and all utilities were installed. Pneumatic and electronic instrumentation for all test cells was installed and calibrated. Fabrication was initiated on the first four Haynes 25 loops. The first loop was 85% assembled at the end of the quarter. A centrifugal pump made from Type 316 stainless steel was tested; bearing modifications were made to improve operation. (Author Abstract)

N62-13875 Directorate of Materials and Processes, Aeronautical Systems Div., Wright-Patterson AFB, Ohio.
A STATISTICAL ANALYSIS OF THE FRICTIONAL PERFORMANCE OF SOLID FILM LUBRICANTS. PART II—CERAMIC BONDED FILM IN AIR. Technical Documentary Report [May 1960 to May 1961.]
Martin R. Adams and Mary D. Lum. March 1962. 45 p. 10 refs.
(WADD-TR-61-49, Pt. II)

This report presents a statistical analysis of the performance of a ceramic bonded solid film lubricant. The ceramic bonded film, PbS/B_2O_3 (in a six to one weight ratio of lubricant to binder), was developed by the Midwest Research Institute under contract with the Air Force and is of interest in the 700 to 1000°F temperature range. Experiments were conducted on the Hohman A-6 tester with two loading shoes. The analysis of variance shows that, within the range of the variables studied, the main effects of bearing load and ambient temperature are significant and that a response to a change in temperature depends on speed.

The results are analyzed with an approximate and with an exact statistical method. The two methods lead to identical conclusions. (Author Abstract)

N62-13876 Celanese Chemical Co., Clarkwood, Tex.
THE SYNTHESIS AND EVALUATION OF AROMATIC ESTERS AS POTENTIAL BASE STOCK FLUIDS FOR GAS TURBINE ENGINE LUBRICANTS. Technical Documentary Report [Jan. to Dec. 1961].
Wallace E. Taylor, Claiborn L. Osborn, and Nollie F. Swynnerton. Jan. 1962. 75 p. 7 refs.
(Contract AF 33(616)-6786)
(WADD TR 60-913, Pt. II)

The synthesis and evaluation are reported for several new carboxylic acid esters, prepared as lubricant base stock candidates for operation at bulk oil temperatures of 450–500°F. The esters were prepared from various combinations of 2,2-dimethylalkyl acids, n-alkyl and aromatic dibasic acids, plus alkylated phenoxyphenols, dihydroxydiphenyl ethers, resorcinol, alkylphenols and neopentyl glycol(2,2-dimethylpropane-1,3-diol). The physical properties and oxidative and thermal stabilities of these esters were determined and are correlated with their structural configuration. Several of the esters were thermally stable at 750°F and resistant to autoxidation at 450°F. Esters of 2,2-dimethylpentanoic acid and substituted phenoxyphenols had pour points ranging from −3° to +28°F. One neopentyl glycol ester, di-2,2-dimethylpropane-1,3-diol mono-2,2-dimethylpentanoate) azelate, was thermally stable above 700°F and, with inhibitors, resistant to oxidation at 450°F. This ester has a pour point of −40°F. Suggestions are made for future work with esters of similar structure to increase their stability. (Author Abstract)

N62-13883 Airborne Instruments Lab. Div. of Cutler-Hammer, Inc., Melville, N.Y.
LUBRICANT FOR HIGH-VACUUM ENVIRONMENT. PART II. Technical Documentary Report [Nov. 1960 to Dec. 1961].
Martin M. Freundlich and Stanley J. Jagodowski. Wright-Patterson AFB, Ohio, Directorate of Materials and Processes, Feb. 1962. 46 p. 5 refs.
(Contract AF 33(616)-6845)
(WADD-TR-60-728, Pt. II)

The objective of this work was to determine vapor pressures and evaporation rates of four experimental high-temperature fluids in a high-vacuum environment over a wide range of temperatures. The vacuum microscale developed in this investigation was improved and the measurement method refined. The microscale was checked with n-heptadecane, and the results showed good agreement with published values. The following four fluids were supplied by ASD; and their evaporation-rate and vapor-pressure curves are given: (1) hexaphenyl ether, (2) Siloxane, (3) silicone fluid QF 6-7040, and (4) silicone fluid F 6-7024. (Author Abstract)

N62-14005 National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
EVALUATION OF BALL-BEARING PERFORMANCE IN LIQUID HYDROGEN AT DN VALUES TO 1.6 MILLION.
Herbert W. Scibbe and William J. Anderson. Repr. from ASLE Trans., v. 5, 1962. p. 220-232. 7 refs.

Experimental data were obtained in liquid hydrogen (-423°F) on two series of 40-mm-bore ball bearings utilizing various retainer materials. Effects of diametral clearance and retainer material on limiting DN value (product of bearing bore in mm and shaft speed in rpm) were investigated at thrust loads to 500 lb and at speeds to 41,200 rpm. An analysis was made to determine the effect of ball size and race curvatures on the heat generated in bearings of both series as a result of ball spin. The results, supported experimentally, indicate that higher limiting DN values at a specific thrust load could be obtained with an extremely light series (1908) bearing with open-race curvatures than with a light series (108) bearing. Successful operation to a DN value of 1.6 million was obtained with 1908 bearings (at 110 lb thrust load) using two different retainer materials. The glass-fiber-filled PTFE (polytetrafluoroethylene) retainer exhibited much less wear than the MoS_2-filled phenolic retainer at these test conditions. (Author Abstract)

N62-14032 Mellon Institute, Pittsburgh, Pa.

STRESS CORROSION OF HIGH STRENGTH STEELS AND ALLOYS; ARTIFICIAL ENVIRONMENT. Quarterly Scientific Progress Report No. 16, for the Period Feb. 1, 1962-Apr. 30, 1962.

C. J. Owen and J. Jaskowski. [1962] 68 p.
(Contract DA-36-034-ORD-3277RD)

A brief review of the experimental procedures utilized in the stress corrosion testing program is presented for reference purposes. During the period covered by this report, all three strength levels of Vascojet-1000 and two strength levels of D6Ac U-bend samples were subjected to stress corrosion testing in five synthetic environments. The V-1000 data indicate that the alloy is the most susceptible of all groups tested to date. No minimum strength level of inhibition is indicated by the data for this alloy. Failure during testing of the V-1000 samples was often of the multiple-crack catastrophic type rather than of the single-crack type. The D6Ac data indicate that, of the low alloy, high strength steels tested to date, this material is the least susceptible to stress corrosion failure. Data for stress corrosion testing of comparative heats of V-1000 and D6Ac substantiate the order of magnitude of failure observed for the foregoing. Tables of cumulative stress corrosion test data for other alloys being tested by both the U-bend and bent beam test methods are presented for comparative reference. (Author Abstract)

N62-14101 International Business Machines Corp. Research Lab., San Jose, Calif.

APPROXIMATE METHODS FOR TIME-DEPENDENT GAS FILM LUBRICATION PROBLEMS.

W. A. Michael. May 1, 1962. 52 p. 13 refs.
(Contract Nonr-3448(00))
(RJ-205)

The pressure in a thin film of gas undergoing laminar, isothermal flow is given by the so-called Reynolds equation, a nonlinear second order partial differential equation of parabolic type. The Reynolds equation plays a central role in the theory of gas film lubrication. This paper is devoted to a study of numerical procedures based upon finite differences for obtaining approximate solutions. A number of explicit, semiexplicit, and implicit difference schemes are examined from the point of view of truncation error, stability, and computational efficiency. (Author Abstract)

N62-14287 International Business Machines Corp. Research Lab., San Jose, Calif.

THE DYNAMIC BEHAVIOR OF PLANE, SELF-ACTING PIVOTED SLIDER BEARINGS OF INFINITE LENGTH, WITH AN INCOMPRESSIBLE LUBRICATING FILM.

W. Stuiver and R. S. McDuffie. June 1, 1962. 67 p. 6 refs.
(Contract Nonr 3448(00))
(RJ-215)

The dynamic behavior of plane, self-acting, pivoted slider bearings of infinite length is examined for the case of an incompressible lubricating film. The equations of motion for the slider are derived, with the lubricant force expressed exclusively in terms of the motion-coordinates and their derivatives and the parameters that characterize the system. The equilibrium positions of the system are determined numerically and the stability of small motions in the neighborhood of these positions is examined. The nature of large motions is investigated by numerical integration of the equations of motion, and the transient behavior of the system is shown and discussed for some specific cases. (Author Abstract)

N62-14363 Illinois U., Urbana.

SOLID FILM LUBRICANT-BINDER PHENOMENA: PbS-B_2-O_3 SYSTEM. [Final] Technical Documentary Report [Apr. 1, 1961 to Mar. 31, 1962].

H. R. Thornton, Doris M. Krumwiede, J. F. Benzel, R. J. Forlano, and Dwight G. Bennett. Wright-Patterson AFB, Ohio, Directorate of Materials and Processes, May 1962. 46 p. 6 refs.
(Contract AF 33(616)-7978)
(ASD-TDR-62-449, Pt. I)

The basic techniques, X-ray diffraction, microscopy, and fusion studies, along with the supplementary techniques of differential thermal analyses and friction and wear measurements, are described as related to the PbS-B_2O_3 system. Data indicated that PbS and B_2O_3 were the only crystalline phases expected in the majority of the specimens. A glassy phase exists between 300° and 1500° F. The lubrication mechanism in the high B_2O_3-low PbS mixtures is a function of the liquid phase present, while the liquid phase only affects the low B_2O_3-high PbS mixtures above 980° F. Frictional compatibility is necessary between the lubricating pigment and binder over the entire temperature range. (Author Abstract)

N62-14392 Directorate of Materials and Processes, Aeronautical Systems Div., Wright-Patterson, AFB, Ohio.

PROCEEDINGS OF THE AIR FORCE-NAVY-INDUSTRY PROPULSION SYSTEMS LUBRICANTS CONFERENCE [HELD IN SAN ANTONIO, TEXAS ON NOV. 15-17, 1960. Final] Technical Documentary Report.

G. A. Beane IV and K. L. Berkey. May 1962. 237 p. 72 refs.
(Co-sponsored by Southwest Research Inst. under Contract AF 33 (616)-7223)
(ASD-TDR-62-465)

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N62-14851 General Electric Co. Vallecitos Atomic Lab., San Jose, Calif.

STRESS CORROSION OF TYPE 304 STAINLESS STEEL IN SIMULATED SUPERHEAT REACTOR ENVIRONMENTS.

G. G. Gaul, W. L. Pearl, and M. Siegler. Feb. 26, 1962. 41 p. 5 refs.

(Contract AT(04-3)-189)

(GEAP-4025; Informal AEC R & D Rept. 568-T 10-2) OTS: $1.00.

A fuel jacket failure that occurred in the Type 304 stainless steel clad fuel element exposed in the Vallecitos Boiling Water Reactor super-heated steam loop (SADE) was attributed to chloride-stress corrosion-cracking. In order to better understand the failure, a test program was carried out to try to reproduce the rapid stress corrosion attack in the simulated superheat reactor environment of the CL-1 superheat facility. The test results indicated that chemical and chloride stress corrosion attack can act either singularly or in combination to produce the type failures experienced in the SADE and CL-1 tests. The presence of stress had little apparent effect on the uniform corrosion rate of the test sheaths, except when the stresses were high enough to cause creep. The creep resulted in scale spalling with some accelerated corrosion in the areas of scale cracking. (Author Abstract)

N62-15268 Radiation Effects Information Center, Battelle Memorial Inst. Columbus, Ohio.

THE EFFECT OF NUCLEAR RADIATION ON LUBRICANTS AND HYDRAULIC FLUIDS.

S. L. Cosgrove and R. L. Dueltgen. May 31, 1961. 113 p. 111 refs.

(Contract AF 33(616)-7375)

(REIC Rept. 19)

Radiation studies on organic compounds considered significant to lubricant and hydraulic-fluid development are reviewed, and their significance is discussed. Radiation-resistant gas-turbine-lubricant studies have led to the development of polyphenyl ethers, alkylated aromatics, and alkylated aromatic ethers. Meta-linked polyphenyl ethers show promise for use between 0° and 800° to 900° F and at dosages up to 10^{11} ergs g^{-1} (C). Inhibited alkylated aromatics, while showing pour points to -50° F suffer from excessive high-temperature coking tendencies. Inhibited aromatic ethers are less radiation-resistant than the polyphenyl ethers, but have a useful temperature range of about -35° to 600° F. Calresearch 59R-439 hydraulic fluid, an inhibited isopropyl-1,9-diphenylnonane, is the most promising radiation-resistant formulation. The extremely stable polyphenyl ethers should find application where higher pour points (about 5° F) can be tolerated. Commercial dry-film lubricants appear to be unaffected by gamma exposures to 2×10^{11} ergs g^{-1} (C). Alkali-metal silicates appear to be satisfactory binders for high-temperature applications, and exposures to 4.4×10^{11} ergs g^{-1} (C) or higher. Metal matrices may be needed for temperatures of 1000 F and simultaneous exposures to 10^{12} ergs g^{-1} (C). Most important is the need for evaluating lubricants and hydraulic fluids under dynamic (in-source) conditions. Indications are that some existing materials previously considered too unstable, on the basis of static tests, may be acceptable for use in modified components despite extensive radiation-induced property changes. (Author Abstract)

N62-15935 General Electric Co., Schenectady, N.Y.

DESIGN CRITERIA FOR BEARING SYSTEMS FOR USE IN HIGH TEMPERATURE AIRCRAFT ELECTRICAL ACCESSORIES. PHASE III. [Final] Technical Report [May 1958 to Aug. 1961].

P. Lewis. Wright-Patterson AFB, Ohio, Flight Dynamics Lab., May 1962. 84 p. 7 refs.

(Contract AF 33(616)-5766)

(ASD-TR-61-232)

A program is described which had as its objective the attainment of several cycles of operation including portions at 700° F and the simulated pressure of 80,000 feet. Major attention was given to grease-packed bearing systems. The most successful performance was obtained with both an auxiliary grease supply and periodic injection of base fluid to the grease. A circulating grease system is described which shows promise for improved elevated temperature operation. Some attention was given to the use of an oil-lubricated system. This was not as promising as the grease system. Dry operation is discussed, and preliminary data is presented. (Author Abstract)

N62-15936 Cornell U., Ithaca, N.Y.

AN ATTEMPT TO DETERMINE THE EFFECT OF ENVIRONMENT ON SLOW CRACK GROWTH IN HIGH-STRENGTH ALUMINUM.

A. M. Willner and H. H. Johnson. July 1962. 19 p. 5 refs.

(Contract Nonr-3286(01)(x))

(Tech. Memo 212)

An investigation was undertaken to determine whether slow-crack growth due to stress corrosion can be observed in short-time tests on 2024-T3 and 7075-T6 aluminum high-strength alloys used in aircraft construction. These alloys were tested in environments of humidified argon, salt water, purified argon, and distilled water. A metallographic study of the structure of the aluminum in the vicinity of the notch was made to determine why crack initiation is characterized by an audible snap. The effects of environment on low-cycle fatigue of 7075-T6 aluminum was also investigated. Alloy specimens, 0.19 in thick, were tested, using resistance techniques, under as much as 98.5% of their maximum gross-sectional stress for as long as 1 hour. No slow crack growth could be detected except in the NaCl environment. A small "V" shaped region, corresponding to the formation of a stable crack, was noted in the 0.1N NaCl solution; this corrosion process appears to be associated with the chemical removal or load breaking of a protective surface film. The audible snap phenomenon may be associated with a hardness gradient near the root of the notch. Human errors in regulating the load in the low-cycle fatigue tests at a peak load of 85 to 90% of the fracture load were found to be of the same order of magnitude as the effects being investigated, and the greater part of the crack growth was found to occur during increasing load, so the results of this part of the study are considered inconclusive. Thicker specimens and/or a longer testing time may help to show more pronounced results. (M.P.G.)

N62-15944 Aerojet-General Nucleonics, San Ramon, Calif.

ARMY GAS-COOLED REACTOR SYSTEMS PROGRAM: EFFECTS OF GAS CORROSION AND AGING ON ML-1 TURBINE ALLOYS.

B. E. Farwell and J. S. Brunhouse. Aug. 1962. 41 p.

(Contract AT(10-1)-880)

(IDO-28591; UC-25) OTS: $1.00.

Gas corrosion resistance and changes in mechanical properties of alloys to be used in the ML-1 gas turbines are evaluated. The alloys were subjected to anticipated maximum operating conditions in three coolants proposed for ML-1 operation: reference gas (99.5 vol % nitrogen + 0.5 vol % oxygen), air, and nitrogen. The tests revealed that corrosion of Inconel, Inconel 713C, Incoloy 901, and Type 347 stainless steel was negligible in all coolants after exposure for 5000 hours at 1300° F; corrosion of Type 304 stainless steel (used for piping and tubing only) was negligible after 5000 hours at 900° F. Oxidation

of Type 422 stainless steel at 1200° F in oxidizing atmospheres was significant; however, as 1200° F is higher than design conditions (1000° F), it is believed that serious oxidation will not occur during operation. Aging reduced room temperature ductility of Inconel 713C and N-155 (Multimet Alloy) after 5000 hours at 1300° F.
(Author Abstract)

N62-16038 Armour Research Foundation, Chicago, Ill.
MECHANISM OF WEAR OF NONMETALLIC MATERIALS. [Summary Report, Jan. through Oct. 1961].
C. H. Riesz and H. S. Weber. Wright-Patterson AFB, Ohio, Directorate of Materials and Processes, June 1962. 27 p. 24 refs.
(Contract AF 33(616)-6920)
(WADC-TR-59-316, Pt. IV)

Friction and wear of single-crystal sapphire surfaces were studied at 10^{-6} mm Hg over a temperature range of 25° to 1550° C. Highest coefficients of friction were found at ambient temperature, particularly when basal planes were in sliding contact. Under certain conditions fracture tracks were produced. Orientation dependence was observed up to approximately 1300° C. Friction-related basal dislocations were detected at temperatures as low as 600° C. A proposed mechanism of friction and wear suggests that two types of frictional junctions are formed. At ambient temperature the junctions are adhesive in nature, highly orientation dependent, and related to surface phenomena. At elevated temperature friction is only slightly influenced by orientation, and plastic deformation, based mainly on the highly active basal slip system, leads to "weld-junctions" and flow in bulk. The relative contributions of the two types of junctions provide anomalous coefficients of friction for sapphire at or around 600° C both under vacuum and in air. (Author Abstract)

N62-16110 Ordnance Tank-Automotive Command, Detroit, Mich.
ENGINE CORROSION STUDY. Final Report—Phase 1 [July 1958-Oct. 1961].
James DeGroot. June 29, 1962. 60 p.

An attempt was made to delay the reprocessing cycle of installed engines in vehicles stored outdoors from one year to a minimum of three years. Despite improvements in application techniques, corrosion occurs primarily in the cylinder area in less than one year. By the use of newly developed or improved preservative materials it is possible that maintenance in storage reprocessing operations can be greatly reduced. The VCI oil used in the test proved far superior to the presently used MIL-L-21260 oil after a minimum of three years outdoor storage under actual conditions. Of 24 cylinders (2 test engines) using the VCI oil, 17 were corrosion-free after three years. The other 7 cylinders developed spotty and not too severe corrosion during the third year of storage. In contrast, MIL-L-21260 oil displayed sufficient corrosion on 12 of 24 cylinders to question satisfactory operation of the engine after reassembly, without considerable rework and/or salvage. Half of the cylinders showed corrosion in the first year. There was no apparent attack from the VCI oil or VCI crystals on nonferrous or nonmetallic components of the engine. The two greatest causes of corroded cylinders of engines are: temperature conditions that produce alternate condensation and evaporation of moisture; combustion products producing an acidic environment.
(Author Abstract)

N62-16292 National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
EFFECT OF NINE LUBRICANTS ON ROLLING-CONTACT FATIGUE LIFE.
Erwin V. Zaretsky, William J. Anderson, and Richard J. Parker. Washington, NASA, Oct. 1962. 42 p. 32 refs.
(NASA TN D-1404) OTS: $1.25.

The rolling-contact fatigue life groups of AISI M-2 and AISI M-1 alloy steel balls run with nine lubricants was obtained at room temperature in the fatigue spin rig and at 300° F in the five-ball fatigue tester. There appears to be a correlation among the following variables: plastically deformed-profile radius of the ball-specimen track at ambient temperature, lubricant type, and rolling-contact fatigue life. No correlation was found between contact temperature obtained with different lubricants and fatigue life. At 300° F the chlorinated methyl-phenyl silicone and the mineral oils produced the longest fatigue lives, while at room temperature the silicone and the di-2-ethylhexyl sebacates generally gave the longer lives.
(Author Abstract)

N62-16423 Union College, Schenectady, N. Y.
THE PROBABILITY OF INTERMITTENT CONTACT OF EXTERNALLY PRESSURIZED GAS BEARINGS EXCITED BY STOCHASTICALLY DEFINED FORCING OF THE BEARING SUPPORTS.
Joseph Modrey. Aug. 1962. 39 p. 9 refs.
(Contract Nonr (G)-00028-62)

This report describes the analytics necessary to express the reliability of gas bearings in terms of the probability of damage due to the random vibration of bearing supports encountered in a service environment. The case of a flexible rotor supported on externally pressurized gas bearings is specifically referred to. Both the linear and nonlinear bearing stiffness examples are investigated.
(Author Abstract)

N62-16474 Mechanical Technology, Inc., Latham, N. Y.
GAS LUBRICATED SPHERICAL BEARINGS. Technical Report.
C. H. T. Pan. Apr. 1, 1962. 48 p. 10 refs.
(Contract Nonr-3730(00))
(MTI-62TR5)

The gas lubricated hemispherical bearing is considered theoretically. First, the isothermal Reynolds' equation for a thin film between arbitrary curved surfaces is derived. The equation is then applied to a hemispherical bearing. External pressurization is considered by assuming a "point" source at the pole. The self-acting effects are studied by a perturbation analysis assuming a small displacement ratio of the journal center. Extension to moderate values of displacement ratios is treated by means of the linearized ph method. Numerical results for comparison with other bearing configurations and an earlier analysis are given. (Author Abstract)

N62-16761 National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
CERAMIC SURFACE FILMS FOR LUBRICATION AT TEMPERATURES TO 2000° F.
R. L. Johnson and H. E. Sliney. Repr. from Am. Ceram. Soc. Bull., 41, no. 8, Aug. 15, 1962. p. 504-508. refs.

The introduction of some oxides, sulfides, and halides at the interface between sliding metal surfaces decreases the adhesive forces between them and thereby often reduces the friction coefficient; galling and metal transfer are reduced or eliminated and low wear rates often result. Data are presented on NASA investigations of the lubricating properties of selected inorganic compounds as powders, naturally formed scales on metals, and as components of ceramic coatings. Coatings which have shown considerable promise are lead monoxide bonded to stainless steels with lead silicate (good to 1250° F) and calcium fluoride coatings bonded to nickel-base alloys with a cobalt oxide, barium oxide, boric oxide binder (good to 1900° F). (Author Abstract)

N62-16781 Armour Research Foundation, Chicago, Ill.

MECHANISM OF WEAR OF NONMETALLIC MATERIALS. [Interim Report, Jan.-Dec. 1960].

C. H. Riesz and H. S. Weber. Wright-Patterson AFB, Ohio, Directorate of Materials & Processes, Feb. 1962. 29 p. 24 refs.
(Contract AF 33(616)-6920)
(WADC-TR-59-316, Pt. III)

Friction and wear of single-crystal sapphire sliding under 10^{-3} mm Hg vacuum from 30° to 1550° C were studied. Surface cleanliness was of prime importance. High coefficients of friction and stick-slip sliding occurred at and below 300° C. From 300° to 1000° C lower coefficients and smooth sliding occurred. Above 1000° C high stick-slip appeared, but at 1350° and 1550° C less stick-slip and lower coefficients dominated. Chevron-shaped subsurface fractures of the sapphire plate were observed in the wake of the sapphire slider at and below 300° C. Their formation was orientation-dependent and occurred when the C_o-axis of the plate was inclined 86°-89° to the surface, opposite to the direction of sliding. In the absence of fracture, extensive adhesions were noted. Under high vacuum a weld-adhesion mechanism of sliding friction seems useful, especially above 1000° C. Below 300° C it may be valid only if clean surfaces are in sliding contact; molecular forces influence sliding friction and may cause strong adhesions. (Author Abstract)

N62-17441 General Electric Co. Vallecitos Atomic Lab., San Jose, Calif.

RARE EARTH OXIDES AND RARE EARTH BORATES CORROSION, COMPATIBILITY, AND RADIATION EFFECTS

E. W. Hoyt, W. V. Cummings, D. L. Zimmerman, and H. E. Perrine
Apr. 17, 1962 43 p 12 refs
(Contract AT(04-3)-189)
(GEAP-3909) OTS: $1.00

Some rare earth oxides and rare earth borates were prepared, fabricated into test pieces, and examined in environments likely to be encountered in nuclear applications. This report lists information on crystal structure, phase stability, fabrication, aqueous corrosion, compatibility with metals, and radiation effects of these materials. The studies were not meant to be exhaustive as they were part of a larger control rod materials program. However, the results should prove useful to anyone considering using either the rare earth oxides or the rare earth borates in reactor environments. Author

N62-17471 Rock Island Arsenal Lab., Ill.

THE EFFECT OF VAPOR DEGREASING ON WEAR LIFE AND SALT SPRAY LIFE OF RESIN-BONDED SOLID FILM LUBRICANTS Technical Report

G. P. Murphy and F. S. Meade Feb. 20, 1962 19 p 2 refs
(RIA-62-652) OTS: $0.50

Two resin-bonded, solid film lubricants were applied to anodized aluminum and zinc-phosphatized, steel-test specimens. One portion of the coated specimens was subjected to a ten-minute exposure in a conventional industrial vapor degreaser containing trichloroethylene. A second portion of the coated specimens was subjected to a similar exposure for a sixty-minute period. Some of the degreaser-treated specimens were further exposed for one week in a 20% salt-spray cabinet. The effect of degreasing and combination of degreasing and salt-spray exposure on the wear life of the coatings was determined on a Falex Lubricant Tester. The following conclusions were drawn: (1) Vapor degreasing for periods in excess of ten minutes decreased the salt-spray protection provided by the solid film lubricant. (2) Vapor degreasing for periods up to one hour has no deleterious effect on the wear of solid film lubricants. (3) Vapor degreasing followed by salt-spray exposure has no effect on the wear life of solid film lubricants applied over sealed anodized aluminum. If the anodized film is not sealed, vapor degreasing followed by salt-spray exposure produces a drastic reduction in the wear life. Author

N62-17472 Rock Island Arsenal Lab., Ill.

THE EFFECT OF OXIDATION ON GREASE LUBRICITY Technical Report

G. P. Murphy June 13, 1962 40 p 6 refs
(RIA-62-2098) OTS: $1.00

Commercial and experimental greases were subjected to oxidation by means of pressurized oxygen at elevated temperatures under both static and dynamic conditions. Measurements of penetration, neutralization number, saponification number, carbonyl oxygen, and wear were made on the greases before and after oxidation. An attempt was made to separate and identify the products formed by oxidation and to determine their effect on wear. The main points of information obtained from this study are: (1) an oxidized grease displays greater wear than the original grease, and the maximum wear increase occurs at the temperature at which the grease was oxidized; (2) both soap and oil type affect the oxidation stability and the amount of oxidative wear; (3) oxidation is accelerated by dynamic conditions; (4) the soap acts as a catalyst to both oxidation and oxidative wear; (5) nongaseous oxidation products formed are organic acids, esters, aldehydes, ketones, and oil insoluble resinous material; (6) oxidative wear is caused by an alcohol-soluble, readily neutralized material. This material is reddish brown in color and has infrared spectra bands at 3.0-3.2 and 5.7-5.9 microns. It is acidic in nature and may be a mixture of free acids. Author

N62-17544 Illinois U. Engineering Experiment Station, Urbana

THE INFLUENCE OF WATER VAPOR AND ANNEALING ON THE STRENGTH OF SODA-LIME GLASS RODS

D. Shadman Sept. 1962 34 p 9 refs
(Contract Nonr-2947(02)(X))
(T&AM-228)

This investigation was undertaken to study corrosion of soda-lime glass rods by water vapor and the resulting effect on the strength of the rods. Due to the thinness of corrosion layer, it was not practical to measure the variation of its thickness with the time of corrosion. Consequently, as a measure of corrosion, the breaking strength of the rods, after being exposed to saturated steam for various lengths of time, was determined. The result of the short-time steam treatment was to increase the breaking strength of the rods. However, the strength of the rods decreased considerably upon further treatment. The explanation given for this behavior is based upon the flaw theory. To separate the effect of temperature from corrosion on the rods, two groups of specimens were annealed in air at the same temperature as the saturated steam. The results obtained were compared with the corroded and untreated control group. Author

N62-17562 Nuclear Metals, Inc., Concord, Mass.

FUNDAMENTAL AND APPLIED RESEARCH AND DEVELOPMENT IN METALLURGY Progress Report to U.S. Atomic Energy Commission, May 1962

A. R. Kaufmann AEC Div. of Tech. Information, July 31, 1962 26 p 2 refs
(Contract AT(30-1)2784)
(NMI-2107) OTS: $0.50

Tensile tests of refractory metal alloys were carried out. Results indicated that the 5 atomic-percent addition of rhenium is detrimental to the room-temperature strength properties of alloyed molybdenum. This addition lowers the ductility without achieving a significant increase in strength. At elevated temperatures, however, the molybdenum-5 atomic-percent rhenium alloy has ultimate strengths that are 6000 to 8000 psi above those of unalloyed molybdenum, and the alloy also exhibits substantial ductility. Hafnium at the 5 atomic-percent level is detrimental to the ductility of molybdenum; this addition causes molybdenum to become brittle, even at 1600° C. Niobium, unlike molybdenum, is strengthened by small additions of

rhenium, the effect being more pronounced at elevated temperatures. Tantalum also is effectively strengthened by a 5 atomic-percent addition of either rhenium or ruthenium, the ruthenium appearing to be more effective. In hardness measurements, the alloys exhibited hardnesses substantially above those of the unalloyed base metals. In evaluating zone-refined beryllium, crystals of different purity levels were stressed in tension at room temperature. Results showed that for high-purity crystals, the critical resolved shear stress for prismatic slip actually has a greater purity dependence than does the critical resolved shear stress for basal slip; the data also indicated that the temperature dependence of the yield stress is increased by purification. V.D.S.

N62-17680 Sundstrand Aviation-Denver, Colo.

LIQUID METAL BEARING PERFORMANCE IN LAMINAR AND TURBULENT REGIMES

Paul H. Stahlhuth and Richard J. Trippett Chicago, Am. Soc. of Lubrication Engr. [1962] 25 p 3 refs Presented at the 17th ASLE Annual Meeting, St. Louis, May 1962

(Contract AF 33(616)-6860)

(ASLE Paper-62AM-2B-1) $0.50 members, $1.00 nonmembers

The design and development of a high speed journal bearing test rig is described. Test results are presented for water and high temperature liquid potassium lubricated journal bearings. The test program included investigations of bearing torque, lubricant flow rate and stability limits for bearings operating in the laminar regime, through the transition to turbulent flow and in the turbulent flow regime. Good correlation with theory was obtained in the laminar regime as indicated by plots of friction parameter versus Reynolds Number at zero load. The transition from laminar flow occurred at higher speeds than predicted by Taylor's criterion under all conditions of load. Recorded bearing torques in the nonlaminar regimes were four to forty times as great as predicted by laminar theory. The results of the materials compatibility study which supplemented the bearing study are summarized. Author

N62-70869 Lewis Research Center, Cleveland, Ohio

HALOGEN-CONTAINING GASES AS LUBRICANTS FOR CRYSTALLIZED-GLASS-CERAMIC-METAL COMBINATIONS AT TEMPERATURES TO 1500° F.

Donald H. Buckley and Robert L. Johnson. October 1960. 19p. OTS price, $0.50.

(NASA TECHNICAL NOTE D-295)

The gases CF_2Cl-CF_2Cl and CF_2Br-CF_2Br were used to provide lubrication for Pyroceram 9608 sliding on various nickel- and cobalt-base alloys. The use of Pyroceram 9608 minimized the corrosive wear encountered with metal-metal combinations using halogen-containing gases reported in earlier research. In the friction and wear experiments, a hemispherically tipped rider (Pyroceram 9608) under a 1200-gram load slid on a disk (nickel- or cobalt-base alloy) rotating at 3200 ft/min. The gas CF_2Br-CF_2Br was an effective lubricating agent for Pyroceram 9608 sliding on Hastelloy R-235 and Inconel X at temperatures up to 1400° F. The gas CF_2Cl-CF_2Cl was effective in providing lubrication for Pyroceram 9608 on various cobalt-base alloys at 1000° F.

N62-70876 Lewis Research Center, Cleveland, Ohio

USE OF LESS REACTIVE MATERIALS AND MORE STABLE GASES TO REDUCE CORROSIVE WEAR WHEN LUBRICATING WITH HALOGENATED GASES.

Donald H. Buckley and Robert L. Johnson. August 1960. 18p. OTS price, $0.50.

(NASA TECHNICAL NOTE D-302)

The gases CF_2Cl-CF_2Cl, CF_2Cl_2, and CF_2Br-CF_2Br were used to lubricate metals, cermets, and ceramics at temperatures to 1400° F. The use of cermets and ceramics decreased corrosive wear at high temperatures with these gases as lubricants. In friction and wear experiments, a hemispherically tipped rider under a 1200-gram load slid on a disk rotating at speeds from 75 to 8000 feet per minute. The gas CF_2Cl-CF_2Cl was found to be an effective lubricant for Al_2O_3 sliding on Stellite Star J at temperatures to 1400° F. The gas CF_2Br-CF_2Br provided effective lubrication for the cermet K175B (nickel-bonded metal carbide) sliding on Hastelloy R-235 (nickel-base alloy) at temperatures to 1200° F.

1963
STAR ENTRIES

N63-10055 Deutsche Versuchsanstalt für Luft- und Raumfahrt. Inst. für Werkstoff-Forschung, Aachen (W. Germany)

REIBKORROSION—EINE ÜBERSICHT [FRICTION CORROSION—A SURVEY]

F.-C. Althof and K. Gerischer [1962] 15 p 31 refs In German Presented at the Scientific Soc. for Aviation Annual Meeting, Brunswick, W. Germany, Oct. 9-11, 1962

(Wissenschaftlichen Gesellschaft für Luftfahrt Paper. 60) Available from Friedrich Vieweg & Son, Burgplatz 1, Brunswick, W. Germany

The problems of friction corrosion and fretting oxidation are discussed to point out methods of control. Further research must be done on fretting corrosion in order to select appropriate measurement values. The influence of friction corrosion on dynamic behavior is dependent upon loading requirements. A.S.

N63-10084 Automation Industries Inc., Ultrasonic Div., Torrance, Calif.

DEVELOPMENT OF ULTRASONIC INSPECTION TECHNIQUES AND EQUIPMENT TO RESOLVE CORROSION CONDITION IN NAVY AIRCRAFT

Joe B. Ramsey [1962] 25 p

(Contract NOA(S) 59-0150; Sub-contracted by Douglas Aircraft Co., Inc., El Segundo, Calif.)

This report contains the results of investigations to develop ultrasonic inspection equipment and techniques for determining the corrosion condition in Navy aircraft. Off-the-shelf test instruments were evaluated to determine suitability for field tests. Factors which could affect tests were evaluated. Inspection techniques and equipment were developed for use in detecting and evaluating corrosion. Equipment and techniques were recommended for use in field tests. Author

N63-10096 Mechanical Technology, Inc., Latham, N.Y.

BEARING MATERIALS FOR PROCESS FLUID LUBRICANTS Progress Report

M. B. Peterson Sept. 11, 1962 41 p 53 refs

(Contract Nonr-3731(00)(FBM))

(MTI-62TR20)

Materials are being evaluated for use in bearings that can be lubricated with steam or water. Alloys of aluminum, cobalt, copper, tantalum, nickel, titanium, zirconium, iron, gold, silver, and platinum have been compared for the following characteristics: solubility, formation of soft oxide films, crystal structure, melting temperature, recrystallization temperature, thermal conductivity, and hardness. As a result of this evaluation, the alloys of cobalt, copper, platinum, and gold have been selected for further consideration. R.C.M.

N63-10125 Mechanical Technology, Inc., Latham, N.Y.

ANALYSIS OF PLAIN CYLINDRICAL JOURNAL BEARINGS IN TURBULENT REGIME Technical Report

E. B. Arwas, B. Sternlicht, and R. J. Wernick Sept. 1962 42 p 13 refs

(Contract Nonr-3731(00)(FBM))

(MTI-62TR22)

This paper presents a theoretical analysis of the steady-state load carrying capacity, attitude angle, and fluid film stiffness of plain cylindrical journal bearings operating in the turbulent regime. The calculated data on fluid film stiffnesses are included so that they can be used to calculate system critical speeds. In the analysis presented here, side leakage is neglected; however, existing published data on a 360° plain circular bearing was used to establish a correlation factor between laminar and turbulent leakage factors. Author

N63-10745 Directorate of Materials and Processes, Aeronautical Systems Div., Wright-Patterson AFB, Ohio

MATERIALS CENTRAL-ASM METALLURGICAL EDUCATIONAL LECTURES [Final] Report

M. G. Fontana, A. M. Hall, Tung Liu, B. D. McConnell, and W. Payne May 1962 104 p 21 refs

(ASD-TDR-62-396)

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3. MECHANICAL WEAR AND LUBRICATION Tung Liu and B. D. McConnell p 31-51 6 refs
4. SERVICE FAILURE ANALYSIS INVOLVING BRITTLE CRACKING MECHANISMS Lt. W. F. Payne p 53-102 15 refs

N63-10787 Rock Island Arsenal Lab., Ill.

WEAR AND CORROSION TENDENCIES OF MOLYBDENUM DISULFIDE CONTAINING GREASES Technical Report

S. Fred Calhoun Aug. 15, 1962 23 p 19 refs

(RIA-62-2752) OTS: $0.75

The tendency of molybdenum disulfide to increase the wear of greases is shown by results of laboratory tests. The extreme pressure properties of greases were increased by the addition of the molybdenum disulfide. It also promotes rusting of ferrous metals when added to grease. Author

N63-10929 Directorate of Materials and Processes, Aeronautical Systems Div., Wright-Patterson AFB, Ohio

LUBRICATION IN SPACE ENVIRONMENTS

R. L. Adamczak, R. J. Benzing, and H. Schwenker *In* Soc. of Aerospace Mater. and Process Engr. National Symp. on Effects of Space Environment on Materials, St. Louis, May 7, 8, and 9, 1962 12 p (See N63-10912 02-01)

Solid, semisolid and liquid lubricants, hydraulic fluids, heat transfer fluids, and novel lubrication techniques are discussed with respect to the current state-of-the-art and the future capabilities of these various materials and/or their application. The severe environmental conditions of space are compared against both the current and future state-of-the-art in the field of lubrication and energy-transfer media. Author

N63-10931 National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.

BEARINGS FOR VACUUM OPERATION—PHASE I

Harold E. Evans and Thomas W. Flatley *In* Soc. of Aerospace Mater. and Process Engr. National Symp. on Effects of Space Environment on Materials, St. Louis, May 7, 8, and 9, 1962 30 p 4 refs (See N63-10912 02-01) Previously processed as NASA-TN-D 1339; for abstract see N62-12330 07-17

N63-10934 Lockheed Missiles and Space Co., Palo Alto, Calif.

PERFORMANCE OF LUBRICANTS AND THERMAL CONTROL MATERIALS UNDER SIMULATED SPACE CONDITIONS

R. E. Mauri *In* Soc. of Aerospace Mater. and Process Engr. National Symp. on Effects of Space Environment on Materials, St. Louis, May 7, 8, and 9, 1962 22 p (See N63-10912 02-01)

(Contract AF 04(647)-787)

The gross effects of space environment on typical materials for spacecraft applications are briefly discussed. Equipment and experimental procedures used for testing and selecting materials in support of a typical high-reliability satellite hardware program are described. Experimental details and results on the effect of high vacuum and operating conditions on oils, greases, and dry-film lubricants for bearings are presented. Also discussed are applications of thermal control materials and results of environmental testing of solar reflectors, such as white paints, in the presence of intense ultraviolet radiation in vacuum. Author

N63-10947 Rocketdyne, Canoga Park, Calif.

INVESTIGATION OF CONDENSING VAPOR LUBRICATED SELF-ACTING JOURNAL BEARINGS Annual Report for Period 1 Oct. 1961 through 30 Sept. 1962

W. Unterberg, J. S. Ausman, and G. K. Fischer Nov. 30, 1962 p 138 16 refs

(Contract Nonr-3617(00))

(R-3911)

The operating characteristics of condensing vapor self-acting journal bearings were investigated analytically and a steam bearing experiment was initiated. Thermohydrodynamic considerations suggest the isothermal equilibrium behavior of the lubricant. "Linearized ph" analyses are carried out for an infinite and a finite heat-transfer model. For the infinite length isothermal full plain journal bearing with constant lubricant mass, the condensing vapor operation results in a bearing pressure limit at the saturation vapor pressure value. The load capacity of the condensing vapor bearing is correspondingly reduced below that of the noncondensing bearing. The experimental steam bearing rig and steam generation system and their operation are described. Author

N63-11055 Los Alamos Scientific Lab., N. Mex.

BIBLIOGRAPHY ON CORROSION BY LIQUID METALS (1957—SEPTEMBER 1962)

Helen J. Chick, comp. Nov. 23, 1962 39 p 170 refs

(Contract W-7405-eng-36)

(LAMS-2779) OTS: $1.00

N63-11163 Pennsylvania U. Electrochemistry Lab., Philadelphia

HYDROGEN EVOLUTION: THE EFFECT OF SURFACE CONCENTRATION Final Report

J. O'M. Bockris [1962] 142 p 35 refs

(Contract Nonr-551(22))

The objective of this project is the acquisition of fundamental knowledge concerning the behavior of atomic hydrogen at corrodible metal surfaces, in particular the formation and transfer of atomic hydrogen into the bulk metal. Such knowledge is a prerequisite to the control and the final elimination of hydrogen embrittlement which causes weakening and eventual breakdown of structures in corrosive environments. The problem can be resolved into two stages. First, a

knowledge of the concentration of atomic hydrogen on the surface of the corroding metal must be determined. Secondly, the rate of transfer of the hydrogen into the metal bulk under various conditions must be measured. The solution, therefore, requires first the development of new techniques whereby the necessary information may be acquired. The establishment from this data of a general theory of the kinetics of formation and transfer of atomic hydrogen into metals will then enable the development of practical methods of control of hydrogen embrittlement. Author

N63-11239 Directorate of Materials and Processes, Aeronautical Systems Div., Wright-Patterson AFB, Ohio

A REVIEW OF THE AIR FORCE MATERIALS RESEARCH AND DEVELOPMENT PROGRAM [Final Report, July 1, 1961-June 30, 1962]

Donna J. Tate Nov. 1962 256 p 442 refs
(WADC-TR-53-373, Suppl. 9)

These reports cover basic and applied research being conducted in the materials area by the Metals and Ceramics, Non-Metallic Materials, Physics, Manufacturing Technology, and Applications Laboratories of the Directorate of Materials and Processes. Author

N63-11278 National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.

MECHANICAL ELEMENTS FOR VACUUM OPERATION

Harold E. Evans, Thomas W. Flately and M. Francis Federline N. Y., Am. Rocket Soc. [1962] 12 p Presented at the ARS 17th Annual Meeting and Space Flight Exposition, Los Angeles, Nov. 13-18, 1962
(ARS Paper-2711-62) ARS: $0.50 members, $1.00 nonmembers

Included are the first two phases of a program investigating the high-speed operation of miniature ball bearings with metallic film lubrication and the first phase of an investigation for determining the "best bet" gear material combinations and methods of lubrication. Results of the bearing study indicate that both gold and silver appear promising as lubricants for vacuum operation and that the bearings exhibit: (1) an early dip in speed or initial erratic performance, which indicates that a "run-in" period is required; (2) a sudden failure, rather than a gradual decrease in speed, which makes the prediction of impending failure difficult. A stainless-steel (303) gear operating with a Delrin gear at a pitch line velocity of 942 fpm has operated for over 175 hours, without failure, in a vacuum of 10^{-7} torr; and a stainless-steel gear operating with an aluminum gear at a pitch line velocity of .8 fpm has operated for over 700 hours, without failure, in a vacuum of 6×10^{-9} torr. Author

N63-11756 Mechanical Technology, Inc., Latham, N.Y.

ELASTOHYDRODYNAMIC LUBRICATION (Interim Report on the Experimental Phases)

P. Lewis, S. F. Murray, and F. K. Orcutt Nov. 7, 1962 32 p 4 refs
(Contract NONR 3729(00)FBM)
(MIT-62TR29)

The theoretical study of elastohydrodynamic lubrication continues and the experimental phase has been initiated. The objectives of the experimental portion are to determine the surface temperature of elements undergoing rolling and sliding contacts and to investigate the non-Newtonian lubricant properties. The techniques and apparatus being used in these experiments are described. R.C.M.

N63-12017 Joint Publications Research Service, Washington, D. C.

INVESTIGATING THE PERFORMANCE OF CORRODED UNITS OF HYDRAULIC AND PNEUMATIC SYSTEMS

A. A. Mikhaylov and A. I. Lipin Jan. 23, 1963 20 p Transl. of article from Vestn. Mashinostr. (Moscow), no. 7, July 1962 p 38-41
(JPRS-17253) OTS: $1.60

Tests were conducted to determine the degree of corrosion on the surfaces of items such as cylinders, taps, and switches; methods were developed for restoring the corroded parts. The degree of corrosion was evaluated by measuring the depth of the pittings and by counting their number on a section of the surface. The average corrosive depths were in the range of 0.2 to 0.4 mm; maximum corrosive depth was 0.8 to 0.9 mm. The greater the number of pits on a portion of the surface area, the less their depths, and vice versa. It is determined that corrosion can best be removed by a solution consisting of hydrochloric acid (250 to 280 g/liter) and inhibiter PB-5 (8 to 10 g/liter). The acid residue is neutralized by a solution of potassium sodium biochromate (50 to 80 g/liter). To restore the machinery parts, following the removal of the corrosion, and to ensure a high resistance to corrosion, chroming in layer thickness up to 0.2 mm is carried out. D.B.

N63-12197 Joint Publications Research Service, Washington, D.C.

THE INFLUENCE OF HEAT TREATMENT BY A CURRENT OF HIGH FREQUENCY ON THE CORROSION OF WELDED JOINTS OF IKh 18n9T STEEL

V. A. Suprunov and V. N. Kisel'nikov Jan. 29, 1963 10 p 8 refs Transl. from Izvest. Vyssh. Ucheb. Zaved, Khim. i Khim. Tekhnol., (Moscow), v. 5, no. 2, 1962 p 336-339
(JPRS-17356) OTS: $0.50

The hardening of welded joints of a chromium-nickel austenite steel by induction heating with high-frequency current was investigated. Results indicated: (1) a pronounced increase in the corrosion resistance of the joints; and (2) an elimination of intercrystallite corrosion as well as an equalization of structure hardness within the zones adjacent to the welded seam. This method of enhancing corrosion resistance can be employed at chemical machinery-building plants where welding is used to manufacture items made of chromium austenite steels. I.v.L.

N63-12373 Aberdeen Proving Ground. Coating and Chemical Lab., Md.

EXPLORATION OF NEW METHODS FOR PREVENTING GALVANIC CORROSION BETWEEN MAGNESIUM AND STEEL

Donald K. Stelling Jan. 8, 1963 13 p 5 refs
(CCL Rept. 136) OTS: $ 0.50

An investigation was conducted to explore new methods of treating magnesium-steel couples after the two metals had been assembled and placed in electrical contact with each other. A phosphate anodizing treatment, prepared with this objective in mind, proved to be ineffective when applied to such couples. The treatment seemed to offer considerable corrosion resistance to magnesium alone when the operating conditions of the treatment were controlled within close limits. Author

N63-12591 National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio

BOUNDARY LUBRICATION CHARACTERISTICS OF A TYPICAL BEARING STEEL IN LIQUID OXYGEN

William F. Hady, Gordon P. Allen, and Robert L. Johnson Washington, NASA, Feb. 1963 16 p 10 refs
(NASA TN D-1580) OTS: $0.50

Friction and wear data were obtained with a typical bearing steel (AISI 440-C) at conditions approximating those encountered by bearings and seals in rocket engines using liquid oxygen as the lubricant. A 3/16-in.-radius hemisphere was loaded against the flat surface of a rotating disk at sliding velocities from 250 to 8000 ft/min and loads from 200 to 1500 grams. Fundamental boundary lubrication characteristics of liquid oxygen show the importance of surface-reaction films. The experiments described herein demonstrate the validity of the adhesion concept of friction and wear. Author

N63-13069 National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio

EFFECT OF SEVERAL OPERATING AND PROCESSING VARIABLES ON ROLLING FATIGUE

W. J. Anderson and E. V. Zaretsky Amsterdam, Elsevier Publ. Co. [1961] Repr. from Proc. of a Symp. on Rolling Contact Phenomena p 317-345 30 refs

Rolling contact fatigue experiments were conducted in two bench-type fatigue testers called the fatigue spin rig and the five-ball fatigue tester. Tests were run at maximum Hertz stresses to 800,000 psi and temperatures to 700° F. The effects on fatigue of load, speed, temperature, lubricant viscosity and base stock, material hardness, and fiber orientation are reported. The inverse cubic relationship between load and life, which holds true for ball bearings, was found to be true for SAE 52100 balls in the spin rig. Higher lubricant viscosity increased fatigue life. The type of lubricant had a significant effect on fatigue; life was forty times greater with a silicone than with an adipate of comparable viscosity. Relative fatigue life with various types of lubricant could be predicted from their pressure-viscosity coefficients. Increasing temperature was detrimental to fatigue life. Speed had little effect on life under conditions where hydrodynamic lubrication was not present. Fatigue life improved with higher material hardness, improvements in load capacity being of the order of 30 to 100 percent over the hardness range tested. Areas with material fibers oriented perpendicularly, or nearly so, to the surface were found to be weaker in fatigue than areas with fibers parallel to the surface. Author

N63-13086 Mechanical Technology, Inc., Latham, N. Y.

EXPERIMENTAL INVESTIGATION OF TWO-PHASE FLOW IN THRUST BEARINGS

F. K. Orcutt Jan. 1963 38 p 2 refs
(Contract Nonr-3731(00)(FBM))
(MTI-62TR40)

An analytical study is made of two-phase flow in thrust bearings. For all the operating conditions investigated, there is a sharply defined load-carrying limitation for the steam-lubricated bearing beyond which there is a sudden loss of stiffness leading to collapse of the bearing and contact of the surface. Bearing-load carrying capacity and stiffness are strongly dependent on the rate at which heat is withdrawn from the film by the bearing surfaces. Condensate in the form of droplets and streaks forms on the uncooled surface near the outer radius as the load approaches the critical load for collapse of the bearing. The performance of the experimental bearing lubricated with steam is compared with its theoretical performance using a single-phase lubricant having the properties of dry steam. Results indicate that, for a fixed inlet pressure and surface separation, a two-phase bearing has considerably lower carrying capacity. For the bearing configuration used there was very little dependence of bearing performance on rotor speed. Instability was observed occasionally when the shaft was stationary and conditions at onset were such that the bearing was close to the verge of collapse. J.R.C.

N63-13117 Rock Island Arsenal Lab., Ill.

ENZYMATIC DEOXYGENATION. A NEW CONCEPT IN CORROSION PREVENTION Technical Report No. 2

W. F. Garland Oct. 17, 1962 34 p 20 refs
(RIA-62-3441) OTS: $1.00

In an effort to improve the prototype deoxygenating packet, an investigation was initiated into increasing the rate of reaction and shelf life. Three surfactants were evaluated in a saturated buffered glucose solution with a view toward increasing its absorption on the molecular sieves, and the capacity and rate of oxygen absorption of the deoxygenating medium. Surfactant A proved to be the most effective wetting agent used, increasing both the capacity and rate of the original mixture. Four forms of molecular sieves (1/16 in, 1/8 in, powdered, and "improved") a second synthetic zeolite and activated alumina were investigated as substrate material for the deoxygenating liquid. Of the several materials tested, activated alumina provided the best balance of substrate properties, inert, highly absorbant, and inexpensive. An improved deoxygenating packet utilizing activated alumina as the substrate material for the deoxygenating liquid is described. Author

N63-13326 Frankford Arsenal. Pitman-Dunn Labs., Philadelphia, Pa.

COMPATIBILITY OF LUBRICANTS WITH MISSILE FUELS AND OXIDIZERS

Kurt R. Fisch (ASD. Materials Central, Wright-Patterson AFB), Louise Peale, Joseph Messina, and Henry Gisser Repr. from ASLE Trans., v. 5, 1962 p 287-296 11 refs Presented at the Annual Meeting of the Amer. Soc. of Lubrication Engineers (ASLE), St. Louis, May 1962 (Rept. A62-13)

Various compounds were studied to determine their suitability as lubricants in the presence of fuels and oxidizers used in missile systems. The classes of compounds studied were the halogenated aliphatic and aromatic hydrocarbons, the silicon and perfluorocompounds, esters, ethers, and compounds containing nitrogen. The fuels and oxidizers included ethyl alcohol, hydrocarbon fuel, unsymmetrical dimethylhydrazine, diethylenetriamine, a mixture of the latter two, hydrogen peroxide, inhibited red fuming nitric acid, and liquid oxygen. The most promising compounds were studied for their extreme pressure, antiwear, volatility, and viscometric properties. Three compounds were found to be completely inert (unreactive and insoluble) with all the fuels and oxidizers. One was a liquid (perfluorotributylamine) and the other two were solids (polytetrafluoroethylene and tetrafluoroethylene-hexafluoropropylene copolymer). The perfluorotributylamine exhibited adequate lubrication properties except for excessive volatility. The preparation of higher homologs of this compound is expected to remedy this shortcoming. The polytetrafluoroethylene and the copolymer may find application as components of a grease-type lubricant. Author

N63-13457 Lockheed Missiles and Space Co., Sunnyvale, Calif.

LUBRICATION UNDER SPACE/VACUUM CONDITIONS Technical Report

Francis J. Clauss Oct. 1962 69 p refs
(Contract AF 04(647)-787)

The effects of space environment on friction, wear, and the selection of lubricants and self-lubricating materials for spacecraft mechanisms are discussed, with special emphasis on the ultrahigh vacuum of space. Experimental studies have demonstrated the feasibility of using selected oils and greases to lubricate loaded ball bearings without replenishment for periods of over one year under the following conditions of operation: speeds of 8000 rpm, temperatures of 160° to 200° F, and vacuum of 10^{-8} torr. Over one-half year of successful operation has been achieved under similar operating conditions with self-lubricating retainers of reinforced Teflon, provided that the loads were light. Bonded films of molybdenum disulfide have given shorter lifetimes and poor reproducibility. Metal-to-metal slip-ring contacts introduce excessive electrical noise into circuits when operated in vacuum of 10^{-7} torr. The noise (as well as the friction and wear) can be markedly reduced by providing a small amount of oil vapor, sufficient to maintain a pressure on the order of 10^{-6} torr, or by incorporating molybdenum disulfide into the brush material. Author

N63-13487 South Carolina U., Columbia

AN INVESTIGATION OF OIL FILM THICKNESS BETWEEN INVOLUTE GEAR TEETH Final Report, October 11, 1960 through October 11, 1962

I. O. Mac Conochie, L. C. Hsu, and E. C. Woodward, Jr. [1962] 36 p 27 refs
(Grant DA-ORD-31-124-61-G30)
(AROD-2458-41)

Research was conducted to formulate an analytical description of relaxation effects in lubricants. Attempts were made to correlate experimental data of percent boundary operation with a dimensionless grouping of the load, speed, and viscosity. This report contains the results and conclusions of a study of the four basic factors (surface deformation, surface roughness, squeeze films, viscoelasticity) which influence gear lubrication and load-carrying capacity. A review of the technique used in these investigations is included. Author

N63-13498 General Electric Co. Vallecitos Atomic Lab., San Jose, Calif.

REMARKS CONCERNING MATERIALS FOR NUCLEAR SUPERHEAT FUEL CLADDING

H. H. Klepfer, D. L. Douglass, W. V. Cummings, M. B. Reynolds, and K. C. Antony AEC Div. of Tech. Inform., Sept. 4, 1962 46 p 23 refs

(Contract AT(04-3)-189)

(GEAP-4060) OTS: $1.00

Recent studies on the metallurgical and mechanical stability of alloys in the nuclear superheat environment are summarized to point out areas for further experimentation. The summary includes studies on corrosion, physical metallurgy, and radiation effects. The results of these studies cast doubt on the use of precipitation-strengthened nickel-base alloys as superheat fuel-cladding and indicate that studies on Inconel, Incalloy, and low-interstitial stainless alloys should be continued. R.C.M.

N63-13545 Thompson Ramo Wooldridge, Inc. Tapco Div., Cleveland, Ohio

AN INVESTIGATION OF THE CORROSION RESISTANCE OF METALLIC MATERIALS TO MOLTEN LITHIUM HYDRIDE AT CYCLIC ELEVATED TEMPERATURES

E. J. Vargo and D. B. Cooper June 1962 159 p 25 refs

(NASA Contract NAS5-462)

(ER-4774)

The corrosive effects of lithium hydride, lithium, and varying mixtures of lithium hydride and lithium upon various structural metals were investigated. These materials included iron-base, nickel-base, cobalt-base and refractory-base alloys as well as unalloyed molybdenum and titanium in the form of tubing. Sealed metal capsules of different designs containing the corrosive medium were used as test specimens. Multimetallic combinations of several of these metals were also employed in these tests. The tests were conducted in air, argon, and hydrogen atmospheres for periods up to 3008 hours, and were either conducted at static temperatures of 1500° or 1600° F or were cycled between the temperatures of 1165° and 1600° F. The relative permeability to hydrogen was also determined for these materials. Various coatings were evaluated for their effectiveness as hydrogen diffusion barriers. Author

N63-13677 General Electric Co. Flight Propulsion Lab. Dept., Cincinnati, Ohio

LOW VISCOSITY BEARING STABILITY INVESTIGATION Space Power Operation First Quarterly Project Status Report for period ending Feb. 9, 1962

[1962] 65 p 16 refs

(NASA Contract NAS3-2111)

OTS: $6.60 ph, $2.15 mf

The program objective is to select and develop bearing configurations that promise stable operation up to the high speeds typical of space turbomachinery (35,000 r.p.m.). A high-speed test rig, which is precision made for interchangeability of a large variety of bearing configurations and rotors, will be used to record rotor and bearing motions, as well as other parameters affecting bearing operation. The testing will be carried out at close to room temperature with lubricants which simulate the low viscosity and lubricity of liquid metals at operating temperatures. The experimental testing will be supplemented by analytical studies necessary to select the most promising bearing configurations, and to reduce test results to dimensionless parameters. B.J.C.

N63-13750 Mechanical Technology, Inc. Latham, N.Y.

EXPERIMENTAL INVESTIGATION OF SURFACE TEMPERATURE IN ROLLING—SLIDING CONTACTS

F. K. Orcutt Jan. 31, 1963 22 p 10 refs

(Contract Nonr-3729(00) (FBM))

(MTI-63TR3)

A study was made of surface temperature in rolling-sliding contacts using elastohydrodynamic lubrication in an effort to extend machine life and reliability. Use of thermocouples to obtain temperature measurements of a surface in concentrated rolling-sliding contact proved satisfactory. Overall electrical noise level in the thermocouple circuit was reduced to a level equivalent to 1° to 2° F temperature difference so that a dynamic measurement sensitivity of the order of 2° or 3° F could be predicted with confidence. For the low loads and rolling speeds used in the experiments to date (20,000 psi max. contact pressure, 600 rpm), there was no detectable surface temperature rise in the contact zone except at very high sliding-rolling speed ratios (as high as 90%). J.R.C.

N63-13822 Joint Publications Research Service, Washington, D.C.

NEW STEELS AND ALLOYS

A. S. Kaplan, N. N. Kozlova, and A. R. Krylove May 28, 1962 7 p Transl. from Standartizatsiya (Moscow), no. 2, Feb. 1962 p 50-52

(JPRS-13987) Distributed by OTS

The new steels and alloys available in the Soviet Union are discussed along with their applications. The discussion includes corrosion-resistant, heat-resistant, and high-temperature groups. R.C.M.

N63-14376 Union Carbide Research Inst., Tarrytown, N.Y.

RESEARCH ON PHYSICAL AND CHEMICAL PRINCIPLES AFFECTING HIGH TEMPERATURE MATERIALS FOR ROCKET NOZZLES Quarterly Progress Report [Jan. 1-Mar. 31, 1963]

Robert Lowrie Mar. 31, 1963 85 p 20 refs

(ARPA Order 34-63; Contract DA-30-069-ORD-2787)

Physical and chemical principles affecting high-temperature materials for rocket nozzles are reviewed. (1) New data are reported on: the oxidation of TiC, HfC, HfB_2, and TaB_2 by CO_2 at 2250° C brightness temperature; the corrosion of ZrO_2, TiC, ZrC, NbB_2, and TaB_2 by HCl at 2250° C brightness temperature; and the corrosion of ZTA graphite in CO_2 at 2250° C brightness temperature. (2) The products obtained when a molecular beam of oxygen impinges on a hot tungsten filament have been determined for filament temperatures from 800° C to 2200° C brightness temperature. With increasing temperature, the predominant tungsten-bearing ions detected mass spectrometrically are in turn $(WO_3)_3^+$, $(WO_3)_2^+$, WO_3^+, WO_2^+, and W^+. (3) The thermal expansion of TaC has been measured by an X-ray method to 2044° C, and a value has been obtained for the expansion of NbC at 2031° C. Measurements of the thermal expansions of solid solutions have been made on 25 TiC/75 ZrC up to 1771° C. (4) A discussion is given, in terms of band models, of the galvanomagnetic measurements which have been made on various refractory carbides, nitrides, and solid solutions between them. (5) A new method for calculating upper and lower bounds for the elastic moduli of a randomly oriented polycrystalline body from the elastic constants of a single crystal of the material has been applied to single-crystal data previously obtained for TiC and ZrC. The resulting

upper and lower limits are very close, and average values are reported for the shear moduli, Young's moduli, and Poisson's ratios of these compounds. (6) Tungsten has been successfully brazed to tungsten and this method of brazing will be used to prepare specimens for measurements of the elastic constants of tungsten single crystals to 1800° C. (7) Creep tests on two large-grained specimens of ZrC resulted in brittle features during or shortly after the applications of load increments at 1623°C and 1815°C. I.v.L.

N63-14653 Rock Island Arsenal Lab., Ill.

EFFECT OF STORAGE ON LUBRICATING GREASE COMPATIBILITY Technical Report

F. S. Meade and R. L. Young Jan. 9, 1963 53 p 17 refs
(RIA-63-88) OTS: $1.50

The compatibility of binary mixtures of twelve types of lubricating greases, when mixed in the three component ratios, 10% to 90%, 50% to 50%, and 90% to 10%, and after storage for eighteen months was determined. Approximately 15% of the grease mixtures were reexamined for compatibility after three-years' storage. The greases studied included soap thickened, nonsoap thickened, and an organic thickened product. Both mineral oil and synthetic fluid types were represented. Approximately 64% of the binary grease mixtures were compatible after an eighteen-month-storage period. As the storage period was increased to three years, the number of compatible mixtures was decreased. More grease mixtures were incompatible after eighteen months' and after three-years- storage than were incompatible immediately after preparation. In only a very few instances did grease mixtures, which were incompatible immediately after preparation, become compatible after storage. Author

N63-14813 Oak Ridge National Lab., Tenn.

THE EFFECT OF HIGH ALPHA RADIATION ON THE CORROSION OF METALS EXPOSED TO CHLORIDE SOLUTIONS

R. D. Baybarz Apr. 10, 1962 9 p 2 refs
(Contract W-7405-eng-26)
(ORNL-3265) OTS: $0.50

No direct effects of alpha radiation at a level of 2 watts/liter on corrosion of several alloys and glass were found. Secondary effects were noted for Hastelloys B and C and titanium 45A, these effects being attributed to the presence of H_2O_2 produced by radiolysis of water. Under some conditions, the corrosion rates of Hastelloys B and C were increased and those of titanium drastically decreased by the alpha radiation. Corrosion rates of glass and tantalum were <1 mpy, under all conditions tested, and of Zircaloy-2, <10 mpy. Author

N63-14815 Mechanical Technology, Inc., Latham, N.Y.

SOME THERMAL EFFECTS IN EHD LUBRICATION WITH TEMPERATURE DEPENDENT VISCOSITY OF SLIDING SURFACES

C. W. Ng Feb. 1963 34 p 9 refs
(Contract Nonr 3729(00) (FBM))
(MTI-62TR41)

The influence of two dependent variables in elastohydrodynamics, pressure, and temperature are mathematically analyzed to estimate the significance of various thermal and pressure effects and to formulate an analysis for the related thermoelastic problem The results are readily adaptable to numerical calculation D.E.R

N63-14816 Mechanical Technology, Inc., Latham, N. Y.

BEARING MATERIALS FOR PROCESS FLUID LUBRICANTS Progress Report II

M. B. Peterson Feb. 1963 42 p 23 refs
(Contract Nonr-3731(00)(FBM))
(MTI-63TR8)

In this phase of the investigation, materials selected on the basis of the various criteria for sliding effectiveness were evaluated in low-speed friction tests for their surface-damage characteristics. The following results were obtained: (1) For all the materials tested, except iron, very little difference could be detected in the sliding characteristics in water, wet steam, dry steam, or air; this permits extrapolation of data obtained in air. (2) The criteria of nonsolubility and formation of soft oxide films appeared to be the most suitable criteria for material selection (3) Of the materials suitable for use at 500° F, gold gave the least surface damage and merits further consideration for development of solft bearing materials. (4) A wide variety of other materials are available for use as bearing materials or sliding components based on the specific bearing design and operating conditions (5) A low yield point will result in a lower surface-operating temperature This, however, does not necessarily mean less tendency to fail Author

N63-15249 General Electric Co. Flight Propulsion Lab. Dept., Cincinnati, Ohio

LOW VISCOSITY BEARING STABILITY INVESTIGATION Second Quarterly Project Status Report for Period Ending May 9, 1962

[1962] 70 p 5 refs
(NASA Contract NAS3-2111)
OTS: $6.60 ph, $2.30 mf

Seven types of turbomachinery bearings have been investigated on a high-speed test rig to determine which configurations satisfy the spaceflight requirements of long-term unattended operation with low viscosity lubricants under zero g conditions. Zero-load radial-film stiffness and static load-carrying ability were studied for the following configurations: (1) two-groove cylindrical bearing; (2) preloaded cylindrical bearing (nut cracker); (3) orthogonally displaced elliptical bearing; (4) compound cylindrical bearing; (5) three-lobe bearing; (6) tilting pad bearing; and (6) Rayleigh step bearing. The effect of arbitrary load vector position relative to bearing geometry was also included in these studies. M.P.G.

N63-15272 General Plastics Corp. Bloomfield, N.J.

PRODUCTION OF THIN POLYTETRAFLUOROETHYLENE RESIN (TEFLON) COATINGS BY ELECTRODEPOSITION METHODS Final Report, Mar. 19, 1962 to Mar. 19, 1963

Robert W. Logan [1963] 76 p 33 refs
(Contract Now-62-0600-C)

An electrodeposition method of applying thin polytetrafluoroethylene resin ("Teflon") coatings has been developed which allows the application of crack-free films up to 0.001 in. thick in one coating operation Polytetrafluoroethylene (TFE) coatings applied by this method are intended to supplement sprayed TFE coatings in lubricating, without the use of oils or greases, a wide variety of military equipment. Electrodeposited TFE coatings possess a very low coefficient of friction on steel, are smooth and free from blisters, cracks, coagulated particles and other surface defects, and exhibit adhesion (under simulated dry-lubricant conditions) comparable to sprayed TFE coatings. The electrodeposition process will allow the coating of parts or equipment that heretofore were difficult, if not impossible, to spray. In addition, due to the generally favorable edge in the economics of the electrodeposition process vs. the spray process, TFE may now be applied to parts which previously were not economically feasible to coat. The main limitation of the electrodeposition process is that only those metals which are anodically corrodible and which can withstand the 700° to 750° F sintering temperature can be coated This eliminates aluminum, stainless steel, and zinc, among others. Author

N63-15502 Atomic Energy Commission. Chicago Operations Office, Ill.

PROCEEDINGS OF THE NUCLEAR SUPERHEAT MEETING—NO. 7, SEPTEMBER 12, 13, AND 14, 1962, SIOUX FALLS, SOUTH DAKOTA

AEC Div. of Tech. Inform., Oct. 30, 1962 203 p 162 refs
(TID-7658) OTS: $3.00

The papers presented covered the following areas: out-of-pile, superheat, cladding corrosion-erosion and coolant chemistry tests; superheater fuel fabrication, irradiation, and activation results; BORAX-V operating results; superheat reactor physics; superheat in-core instrumentation development; steam-water separation and heat transfer; and reactor design and construction. R.C.M.

N63-15512 Bureau of Mines, Washington, D.C.

HIGH-TEMPERATURE CORROSION STUDIES. NICKEL AND COBALT IN AIR AND OXYGEN

Robert M. Doerr 1963 24 p 23 refs
(BM-RI-6231)

Isothermal oxidation kinetics were determined for three grades of Ni and for 99.99 percent Co in O_2 and in air from 800° to 1,200° C. The oxidation reactions followed approximately the parabolic rate law. For 99.99 percent Ni in O_2 at 1,200° C, the parabolic rate constant was 2 mg cm^{-2} $hr^{-1/2}$. For 99.99 percent Co in dry air, the constant ranged from 1 mg cm^{-2} $hr^{-1/2}$ at 800° C to 18 mg cm^{-2} $hr^{-1/2}$ at 1,200° C; for 99.99 percent Co in O_2 the constant was 2 mg cm^{-2} $hr^{-1/2}$ at 800° C and 10 mg cm^{-2} $hr^{-1/2}$ at 1,000° C. For 99 percent Ni in dry air, the constant ranged from 0.2 mg cm^{-2} $hr^{-1/2}$ at 800° C to 3 mg cm^{-2} $hr^{-1/2}$ at 1,200° C. By X-ray diffraction measurements, only divalent oxides were found in the scales. Author

N63-15552 Hanford Atomic Products Operation, Richland, Wash.

HEAT TREATMENT, TENSILE PROPERTIES, AND CORROSION RESISTANCE OF Zr-2a/o Nb-2a/o Sn ALLOY

J. J. Holmes Apr. 25, 1963 23 p 8 refs
(Contract AT(45-1)-1350)
(HW-71023) OTS: $0.50

Some mechanical properties of zirconium base alloy (Zr-2a/o Nb-2a/o Sn alloy) are investigated so as to determine the use of this alloy in water cooled nuclear reactor systems as a high-strength cladding material. It is found that the heat treatability, strength, ductility, and other tensile properties of the Zr-2a/o Nb-2a/o Sn alloy make it acceptable for use as cladding material, but the corrosion resistance is so poor as to eliminate its candidacy. D.E.R.

N63-15769 National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio

INFLUENCE OF MICROSTRUCTURAL INCLUSIONS ON FRICTION AND WEAR OF NICKEL AND IRON IN VACUUM TO 10^{-9} MILLIMETER OF MERCURY

Donald H. Buckley and Robert L. Johnson Washington, NASA, May 1963 25 p 14 refs
(NASA TN D-1708) OTS: $0.75

Friction, wear, and welding characteristics of three binary alloy systems were studied at ambient pressures from 760 to 10^{-9} millimeter of mercury. Studies were conducted with nickel-oxygen, nickel-tin, and iron-sulfur alloys. Friction and wear studies were made with a hemispherical (3/16-in. rad.) rider, which slides in a circumferential path on the flat surface of a rotating metal disk of the same material. The specimens were tested at various ambient pressures with a load of 1000 grams (2.2 lb), a sliding velocity of 28 to 1800 feet per minute, and a temperature of 75° F. The incorporation of nickel oxide (1.35 to 7.50 percent) in electrolytic nickel resulted in friction and wear properties in vacuum for nickel, which were characteristic of that experienced for nickel-base alloys in air at atmospheric pressure. The addition of tin (optimum 20-percent tin) to electrolytic nickel reduced friction and wear of nickel in vacuum by a factor of 10. The fundamental lubrication mechanism, however, is not the same for the two alloy systems. The addition of various percentages of sulfur (present as ferrous sulfide) to electrolytic iron (0.01- to 0.45-percent sulfur) reduced friction, wear, and welding of electrolytic iron in vacuum (10^{-9} mm Hg). Author

N63-15790 Battelle Memorial Inst., Columbus, Ohio

EFFECT OF HEAT TRANSFER ON CORROSION OF FERROUS ALLOYS IN BOILER WATERS

Warren E. Berry and Frederick W. Fink Apr. 16, 1963 33 p 98 refs
(Contract W-7405-eng-92)
(BMI-1626) OTS: $0.75

A survey has been made of the effect of heat transfer on the corrosion behavior of ferrous alloys in boiler waters, particularly as applied to liquid-metal-heated steam generators. The results have shown that ferrous-alloy boiler tubes may fail during operation—from general corrosion, oxygen pitting, on-load pitting, caustic embrittlement, chloride stress-corrosion cracking, or corrosion fatigue. All of these forms of corrosion, except on-load pitting, can be avoided by appropriate changes in design, operation, or boiler-water treatment. On-load pitting appears to be related to heat-transfer conditions, but its cause is not yet known. Heat transfer appears to affect corrosion behavior by raising the metal surface temperature, concentrating corrosive solids in the boiler water, releasing corrosion-promoting gases from solution, or providing thermal gradients in the metal and protective oxide film. Author

N63-15859 Mechanical Technology, Inc., Latham, N.Y.

APPLICATION OF ROLLING ELEMENT COASTDOWN TECHNIQUES TO THE DETERMINATION OF LUBRICANT PROPERTIES

S. F. Murray Apr. 8, 1963 30 p 2 refs
(Contract Nonr-3729(00)(FBM))
(MTI-63TR13)

Coastdown characteristics were measured for lubricated ball bearings in order to evaluate the lubricants. As a previous study was made of oils of high viscosity, emphasis was placed on oils of a more reasonable bulk viscosity. Heavier rotors were used to increase the inertia of the rotating members, but this did not contribute to the accuracy of the data. Radial rather than thrust loaded bearings were used, but this made very little difference in the results obtained. Windage losses were eliminated by evacuating the system during the coastdown period. This increased the coastdown time. J.A.J.

N63-15883 Bendix Corp. Bendix Products Aerospace Div., South Bend, Ind.

MATERIALS PROPERTY DATA Phase I Quarterly Progress Report No. 4; Phase II Twelve Month Summary Report

James W. Yates Apr. 1962 50 p
(Contract AF 33(616)-8086)

The data contained in this report cover the areas of high-temperature-high-friction materials, corrosion-resistant materials, and high-temperature protective coatings. Author

N63-15897 Rock Island Arsenal Lab., Ill.

EFFECT OF CURE CONDITIONS ON WEAR LIFE AND CORROSION PROTECTION OF A RESIN-BONDED SOLID FILM LUBRICANT

F. S. Meade and G. P. Murphy Mar. 26, 1963 21 p 9 refs
(RIA-63-959) OTS: $0.50

A resin-bonded solid-film lubricant was applied to grit blasted steel, zinc phosphatized steel, and preheated zinc phosphatized steel. The coating was then cured at temperatures from 200° F to 500° F for times ranging from 10 to 180 minutes. The effect of these cure conditions on wear life and corrosion protection was

determined. The following information was obtained from this investigation: (1) Grit blasted steel is inferior to the other two substrates. (2) At cure temperatures above 300° F, the resin-bonded solid-film lubricant does not prevent the loss of water of hydration from the zinc phosphate coating and the resultant loss in corrosion protection. (3) No one set of cure conditions gives optimum wear life and corrosion protection. (4) Wear life increases with increasing cure time and temperature. (5) Corrosion protection increases with decreasing cure time and temperature. (6) Cure conditions depend on the application for which the resin-bonded solid-film lubricant is to be used. Author

N63-16109 Massachusetts Inst of Tech Surface Lab., Cambridge
FRICTION AND WEAR AT ELEVATED TEMPERATURES [Interim Report]
Ernest Rabinowicz and Masaya Imai Wright-Patterson AFB, Ohio, Directorate of Materials and Processes, Mar 1963 41 p 16 refs
(Contract AF 33(616)-7648)
(WADC-TR-59-603, Pt IV)

Measurements have been carried out of the friction coefficient as a function of temperature using surfaces of stainless steel covered by low-melting metals and nonmetals applied in powder form. Some work has also been done with a few other metal and nonmetal surfaces. In cases where the interaction between the low melting substance and sliding surface is high, as revealed by the occurrence of wetting, the friction reaches a peak just below the melting temperature of the substance, and then drops to considerably lower values just above the melting point. The peak below the melting temperature is associated with the formation of large adhering fragments of the low melting substance on the sliding surface. When there is no wetting, the low-melting substance has, either below or above its melting point, essentially no effect on the friction. Author

N63-16314 Mechanical Technology, Inc., Latham, N Y.
INVESTIGATION OF COMPLEX BEARING AND/OR LUBRICATION SYSTEMS First Quarterly Progress Report [May 1, 1962-Aug. 1, 1962]
P. Lewis, S. F. Murray, and M. B. Peterson Aug 5, 1962 67 p 7 refs
(Contract AF 33(657)-8666)
(MTI-62TR14)

Progress is reported in evaluating complex bearing and/or lubrication systems for flight accessory equipment that operates at temperatures from −60° to 1500° F, in high vacuum or normal atmosphere, and during exposure to nuclear radiation. Two systems have been selected for further study on the basis of materials availability and adaptability to the combined-system concept: (1) the solid-lubricated rolling element bearing and (2) the externally pressurized gas bearing. M P G

N63-16774 Garrett Corp. AiResearch Mfg Div., Phoenix, Ariz
A COMPARISON BETWEEN A "SLIPPERY TABLE" AND A "SLICK TABLE" FOR HORIZONTAL VIBRATION TESTING
C. J. Mc Kenzie *In* Defense Dept Office of the Director of Defense Research and Engineering, Washington, D C [Papers from] 31st Symp. on Shock, Vibration and Assoc Environments Part II, Phoenix, Ariz., Oct 1-4, 1962 Mar 1963 p 303 305 2 refs
(See N63-16750 14-01)

An approach that uses grease instead of the usual oil film as a lubrication medium and the benefits of the derived "slick table" operation in horizontal vibration testing in reducing vertical flexure are described. Results of this operation are that: vertical "cross-talk" of the slider plate is reduced in the frequency range of 5 to 2000 cps; the slider plate and driver plate are easy to align, wear rates are reduced, slider plates can be fabricated from aluminum or magnesium materials, the "slick table" is capable of supporting a heavier payload than the "slippery table" without breakdown of the film; exciter power requirements are comparable for shearing an oil film or a grease lubricant, and a cleaner testing area environment is experienced. D E R

N63-17460 General Electric Co. Vallecitos Atomic Lab., San Jose, Calif
CORROSION MECHANISM OF ZIRCONIUM AND ITS ALLOYS – DIFFUSION OF OXYGEN IN ZIRCONIUM DIOXIDE
D. L. Douglass Washington, AEC Div. of Tech. Inform., July 27, 1962 27 p 24 refs
(Contract AT(04-3)-189)
(GEAP-3999) OTS: $0.75

The diffusion rate of oxygen in anion-deficient zirconia, $ZrO_{1.994}$, has been determined by the interface migration of stoichiometric oxide, and is represented by the equation

$$D = 0.055 \exp(-33{,}400 \pm 3100/RT).$$

A comparison was made with other processes which occur in the metal and the oxide. Excellent agreement was noted between activation energies of oxygen diffusion in $ZrO_{1.994}$ and those for parabolic or cubic oxidation in both air and water. It appears that oxygen diffusion in the oxide is rate-controlling during oxidation of the metal. The corrosion and oxidation behavior of zirconium and some alloys are discussed in terms of the oxide-defect structure and the electrical-conduction behavior in the oxide. A speculative mechanism for corrosion transition to linear rates was suggested on the basis of preferential oxidation of a grain-boundary metallic phase. The nature of this phase and of its formation and elimination are discussed. Author

N63-17476 Hanford Atomic Products Operation, Richland, Wash
THE DEVELOPMENT OF A DRAWING LUBRICANT
Frank B. Quinlan June 4, 1963 10 p
(Contract AT(45-1)-1350)
(HW-77291) OTS: $0.50

A high melting, asphalt lubricant for metal forming has been developed. With or without a superficial coating of another lubricant, it can be used to protect exotic metals from scoring during a cold-forming operation. Unlike conversion coats (oxides, fluorides, and phosphates) the first coat of this lubricant is very thin, as well as inexpensive to apply and to remove. In some cases, the initial application of the lubricant will last through several deforming operations, such as successive wire drawing reductions or tube sinking passes. Author

N63-17683 Mechanical Technology Inc., Latham, N Y.
INVESTIGATION OF COMPLEX BEARINGS AND/OR LUBRICATION SYSTEMS Second Quarterly Technical Progress Report, Aug. 1-Nov. 1, 1962
P. Lewis, S. F. Murray, and M. B. Peterson Nov. 6, 1962 47 p 5 refs
(Contract AF 33(657)-8666)
(MTI-62TR34)

Research on complex bearing and/or lubrication systems for flight accessory equipment that operates at temperatures from −65° F to 1500° F, in high vacuum or in normal atmosphere, and while exposed to nuclear radiation, is summarized. The rolling element system was selected as the most promising for meeting the requirements of this program. The bearing

materials will be a metallic for temperatures below 1000° F, and a ceramic or carbide above 1000° F: Stellite or René 41 below 1000° F, and titanium carbide or aluminum oxide above 1000° F. Solid lubricant powders were selected for lubrication use. Thus far, powders which form molybdates, tungstates, and silicates have been selected; these reaction films form low-shear-strength adherent films. The evaluations thus far have been made on films formed by an initial application of lubricant. It will be necessary to determine the life expectancy of these films and the supply requirements. A built-in solid lubricant circulating system is felt to provide the most versatile lubricant supply system. The most critical problem is that of getting the powder into suspension. Switching from one bearing system to the other is to be accomplished by means of an expanding spacer. N.E.A.

N63-17684 Mechanical Technology, Inc., Latham, N.Y.
INVESTIGATION OF COMPLEX BEARING AND/OR LUBRICATION SYSTEMS Third Quarterly Progress Report [Nov. 1, 1962-Feb. 4, 1963]
P. Lewis, S. F. Murray and M. B. Peterson Feb. 12, 1963 45 p (Contract AF 33(657)-8666)
(MTI-24(1-63); MTI-63TR5)

Research was conducted on the development of complex bearings and lubrication systems for flight accessory equipment that will operate at temperatures from −65° F to 1500° F, in high vacuum or normal atmosphere, and while exposed to nuclear radiation. The target specifications are for a self-contained bearing system that will operate at 30,000 rpm. Two types of materials were selected for bearing use: metals for below 100° F and ceramics for above 100° F. It appears that two separate solid lubricants will be required, one for the metal bearing and one for the ceramics bearing. For the low-temperature metal bearing, a carbon-graphite retainer looks like an interesting possibility in conjunction with molybdenum disulfide. But this system lacks protection from oxidation. In the high-temperature bearing, the complex oxides appear to be promising. The major problem in this system is to find a suitable retainer material which will provide any supplementary oxide desired and will still have suitable oxidation resistance. C.L.W.

N63-17810 Atomic Energy of Canada Ltd., Chalk River
RESEARCH ON THE CORROSION OF ZIRCONIUM ALLOYS IN WATER AND STEAM AT HIGH TEMPERATURE AND PRESSURE
A. A. Kiselev, V. A. Myshkin, A. V. Kozhevnikov, S. I. Korolev, and E. G. Shorina Apr. 1963 38 p 10 refs Transl. from the Proc. of the IAEA Conf. on Corrosion of Reactor Materials, Salzburg, Austria, Vol. II, June 4–8, 1962 p 67–104
(AECL-1724) Available from Scientific Document Distribution Office, AEC of Canada Ltd., Chalk River, Ontario, $1.00

This paper presents the corrosion kinetics for zirconium–niobium alloys used in reactor construction. The data were obtained by tests in high-pressure, high-temperature water or steam in static autoclaves, over periods of 14,000 to 22,000 hours. The Zr 1 wt% Nb alloy corrodes rapidly at first, but the rate soon decreases. In water at 350° C, a parabolic rate law is obeyed from 500 to 22,000 hours: $\log \Delta m = 0.2 + 0.5 \log t$, where Δm is the weight increase in mg/dm^2 and t the time in hours. Deviations from the mean value are primarily a function of the surface treatment. Data are presented on the mechanical properties of various alloys as a function of corrosion testing for periods up to 18,000 hours. The pickup of hydrogen and the manner in which this affects the mechanical properties is discussed. Rate equations are also given for the corrosion kinetics of "Ozhennite 0.5" and Zr 2.5 wt% Nb. The long-term corrosion behavior of zirconium with 0.25 to 1.5 wt% niobium and with iron, nickel, and tin has been investigated. The corrosion resistance of zirconium is very inconsistent; however, by addition of 0.25 to 1.5 wt% niobium or small quantities of iron a consistent product is achieved, the corrosion resistance of which is similar to that of the best pure zirconium. These alloying additions result in a decrease in hydrogen pickup; nickel also improves the corrosion resistance, but enhances the rate of hydrogen pickup. Author

N63-17826 Southwest Research Inst., San Antonio, Tex.
THE THREE-BALL/CONE FATIGUE TESTER
H. E. Staph and B. B. Baber [1963] 9 p 4 refs Presented at the 1963 USAF Aerospace Fluids and Lubricants Conf., Session VI-A, San Antonio, Tex., Apr. 16–19

This paper describes a new bench-type research fatigue tester, utilizing a cone specimen in rolling contact with a cluster of three equally spaced balls. The tester is designed to operate over a wide range of conditions of temperature, load, and speed. Other features are a closed recirculating lubrication system, the ability to vary the specimen spin-to-roll ratio, and the ability to measure torque. The paper concludes with a brief discussion of some design problems, stressing the importance of alignment. Author

N63-17829 Thompson Ramo Wooldridge, Inc. TAPCO Div., Cleveland, Ohio
TRENDS IN SPACE POWER AND ANTICIPATED LUBRICATION NEEDS
P. T. Angell [1963] 9 p 4 refs Presented at the 1963 USAF Aerospace Fluids and Lubrications Conf., Session I, San Antonio, Tex., Apr. 16–19
(Sponsored by NASA; AEC; Dept. of Defense)

The important characteristics of representative turbopower systems being developed to meet the increased needs for propulsive and auxiliary power for future space missions are described; and problems and approaches to lubrication of these systems are discussed. The working fluids used in both closed or open cycle power systems are chosen on the basis of the power level and operating temperature sought. Alkali metals are preferable for higher temperature operation, but problems of heat transfer, corrosion, and structural design must be solved before systems using these fluids are available. Mercury is used at lower operating temperatures, and hydrogen–oxygen mixtures for shorter-time open-cycle applications. The requirements placed on the bearings and lubricants by closed-cycle systems are determined by considering the pressures and temperatures associated with the operating cycle. The Rankine operating cycle operates with a fluid in the temperature range where there is a liquid-vapor phase change, whereas the Brayton cycle operates with the fluid entirely in the vapor or gas phase. The use of the working fluid as the lubricant is desirable to eliminate seals and lubricate the bearings within the system pressure and temperature range. This concept dictates the use of fluid film bearings, and although some operating and application problems remain, the success demonstrated by the SNAP I/SPUD 2500 hr test and repeated endurance tests of the Sunflower turbomachine shows that there are no fundamental problems that will prevent achievement of one-year life. M.P.G.

N63-17830 General Electric Co. Flight Propulsion Div., Cincinnati, Ohio
LUBRICANT REQUIREMENTS FOR ADVANCED FLIGHT PROPULSION
D. C. Berkey [1963] 12 p Presented at 1963 USAF Aerospace Fluids and Lubricants Conf., Session I San Antonio, Tex., Apr. 16–19

The lubricant requirements of present and future jet and rocket aircraft engines are summarized. While present needs are met with existing lubricants, future (Mach 2.5 to 3.5) engines will need fluids with improved thermal and oxidation stabilities, acceptable low-temperature viscosities, and higher spontaneous ignition temperatures. The need for a good supersonic transport engine lubricant and for a solid lubricant for extended operation above 1000° F is emphasized. D.E.R.

N63-17831 General Dynamics/Fort Worth, Tex
ANTICIPATED LUBRICATION REQUIREMENTS FOR ADVANCED AIRCRAFT AND SPACE VEHICLE FRAMES
R. E. Adams [1963] 11 p Presented at 1963 USAF Aerospace Fluids and Lubricants Conf., Session I San Antonio, Tex., Apr. 16–19

Anticipated requirements of lubricants and lubricating systems for advanced aircraft and space vehicle frames are discussed. The general scope of lubricating problems has increased in variety, and complicating factors have arisen in terms of interaction between and variation of these variables. A space vehicle may encounter one type of corrosive environment as it leaves the earth's atmosphere on the start of its mission and be subjected during its midcourse phase to the corrosive environments of space, and much later, at the end of its mission, enter a planetary atmosphere. Associated with each one of these phases of the mission are widely varying temperatures. High-temperature requirements of lubricants and lubricating systems have grown from 165° F in the 1930's to 2500° F in the 1960's and will grow to 5000° F in the 1970's. Lubricants will need to have the capability of performing well in environments of liquid hydrogen and helium which have temperatures of −450° F and in vacuums of 10^{-10} torr to 10^{-12} torr. Longer life of lubricants will be necessitated with advanced space missions. Lubricant life requirements of three to five years will be reached in the 1970's. C.L.W.

N63-17832 Frankford Arsenal. Pitman-Dunn Labs., Philadelphia, Pa.
GREASE-TYPE LUBRICANTS COMPATIBLE WITH MISSILE FUELS AND OXIDIZERS
J. Messina and H. Gisser 13 p 13 refs Presented at the 1963 USAF Aerospace Fluids and Lubricants Conf., Session VII-A, San Antonio, Tex., Apr. 16–19

A thickening of mixed perfluorotrialkylamines (alkyl = C_4–C_6) with tetrafluoroethylene polymers, mol wt 2000 to 30,000, was studied in connection with the development of grease-type lubricants for liquid-fuel-powered missiles. Grease-type mixtures were obtained which were stable to shear stresses, showed no separation on standing (up to periods of one year), and showed little separation in the cone tests at 100° C. The greases were not reactive with and insoluble in ethyl alcohol, JP-4 fuel, unsymmetrical dimethylhydrazine, diethylenetriamine, a 60:40 mixture of the last two, a 50:50 mixture of unsymmetrical dimethylhydrazine and hydrazine, 90% hydrogen peroxide, and inhibited red fuming nitric acid. There was no explosive reactivity in impact tests with liquid oxygen or nitrogen tetroxide. Although N_2O_4 is somewhat soluble in the perfluorotrialkylamine, the greases showed no reactivity or observable solubility with N_2O_4, and when the N_2O_4 was permitted to evaporate from its mixture with the greases, the latter appeared unchanged. A typical grease exhibited antiwear and extreme pressure properties (4-ball tests) comparable to conventional petroleum greases, and did not attack most of the conventional elastomers. The tetrafluoroethylene polymers used had 0.20% chlorine or less. Greases made of tetrafluoroethylene polymers having 0.5 to 1.0 percent chlorine showed some reactivity with the amines. Average particle size of the polymers was 5 microns. Author

N63-17833 Pennsylvania State U. Petroleum Refining Lab., University Park
A STUDY OF THE CRITICAL PROPERTIES OF GYRO-BEARING LUBRICANTS
E. E. Klaus [1962] 13 p 7 refs Presented at the 1963 USAF Aerospace Fluids and Lubricants Conf., Session VII-A, San Antonio, Tex., Apr. 16–19

The purpose of this paper is to discuss the properties which appear to influence lubricant behavior under operational environments. These properties include volatility, oxidative behavior, viscosity, and boundary lubricity. Optimization of the lubricant properties for use in typical gyro bearings is discussed for superrefined mineral oil- and polyester-base lubricants. Properties of these improved lubricants are presented. The use of carefully selected lubricants is proposed as an analytical technique for the determination of the mechanism of gyro-bearing failure. Author

N63-17835 Fairchild Stratos Corp., Bay Shore, N.Y.
POWDER LUBRICATION OF ROLLING CONTACT BEARINGS AT VERY HIGH SPEEDS AND TEMPERATURES
A. L. Schlosser [1963] 7 p Presented at the 1963 USAF Aerospace Fluids and Lubricants Conf., Session VII-A, San Antonio, Tex., Apr. 16–19
(Contract AF 33(616)-6589)

Testing under high-speed and high-temperature conditions with both of the powder-lubricant mixtures revealed (usually after about 25 to 50 hours of operation) a wavy pattern on the inner-race running track. The number of wave peaks varied from ten to eighteen, and the pattern was formed without any apparent correlation to speed, number of balls, thrust-load vibration, test-rig shaft, velocity of carrier gas, or rate of lubricant feed. It is believed that the wave pattern contributed substantially to the high drive-torque requirement. The weight and compressed volume of powder lubricant, and the weight of the required quantity have been calculated to lubricate a pair of bearings for 100 hours. Author

N63-17844 Aeronautical Systems Div., Air Force Systems Command, Wright-Patterson AFB, Ohio
AIR FORCE GREASE RESEARCH PROGRAMS
John B. Christian [1963] 7 p Presented at the 1963 USAF Aerospace Fluids and Lubricants Conf., Session IV-A, San Antonio, Tex., Apr. 16–19

The Air Force is conducting research leading to new and improved grease-like materials capable of providing lubrication under those environments and probable operating conditions imposed upon Air Force aerospace vehicles. Some of those environments and probable operating conditions being considered are high temperatures, low temperatures, high speeds, heavy loads, high pressures, deep vacuums, and extremely long periods of operation without lubrication. Author

N63-17845 Aeronautical Systems Div., Air Force Systems Command, Wright-Patterson AFB, Ohio
HAS YOUR OIL TASTED DIFFERENT LATELY?
Kerry L. Berkey [1963] 8 p Presented at the 1963 USAF Aerospace Fluids and Lubricants Conf., Session II-A, San Antonio, Tex., Apr. 16–19

Performance efficiency and failure of aircraft engine oils are discussed. Operating problems were experienced by the T-34 turbo-prop engine on the C-133 aircraft, by the T-56 turbo-prop engine on the C-130 aircraft, by the B-52H constant speed drive, by the J-57 engine in the KC-135 aircraft, by the X-15 aircraft, and by the nozzle hydraulic pump on the J-79 engine in the F104G aircraft. All of these failures resulted from some deficiency in lubrication. The two most common

causes of failure are that the oil is not suitable for the equipment and that different brands of oil are mixed in the equipment. Low-gear load-carrying ability of oils and lubricants was suggested as one of the causes for failure. The failure which occurred in the T-56 aircraft was found to result from oil-seal failure and oil jet- and screen-plugging. Design change in the oil system of the B-52H constant speed drive, which provided additional cooling, resulted in better reliability for this system. C.L.W.

N63-17846 Southwest Research Inst., San Antonio, Tex.
LABORATORY TESTS FOR EVALUATING SUPERSONIC TRANSPORT ENGINE LUBRICANTS
B. B. Baber, J. P. Cuellar, and C. W. Lawler [1963] 19 p 11 refs Presented at the 1963 USAF Aerospace Fluids and Lubricants Conf., Session II-A, San Antonio, Tex., Apr. 16–19
(Contract AF 33(657)-9248)

The development of lubricant screening tests, and the evaluation of candidate lubricants for advanced gas turbine engines for the commercial supersonic transport are presented and discussed. In an effort to develop the required lubricant screening tests, strong reliance was placed on the experience gained from lubricant screening tests developed for the past and current generations of gas turbine engines, but with due recognition of future requirements. These considerations led to the decision to develop the following tests: (1) lubricant oxidation-corrosion test, (2) lubricant deposits and degradation test, (3) gear load-carrying capacity test, and (4) rolling-contact fatigue test. Results of the tests are presented. Author

N63-17847 Bureau of Naval Weapons, Washington, D.C.
NAVY TURBOSHAFT AND TURBOPROP ENGINE OIL PROGRAM
T. Mc Gee and A. Lockwood (Naval Air Materials Center, Aeronautical Engine Lab., Philadelphia, Pa.) [1963] 10 p Presented at the 1963 USAF Aerospace Fluids and Lubricants Conf., Session II-A, San Antonio, Tex., Apr. 16–19

A U.S. Navy program covering development of a specification for a synthetic lubricating oil intended for use in turboprop and turboshaft engines and helicopter transmissions is described. The viscosity of the oil is restricted to the five centistoke range (0 to 210° F), and the load-carrying capacity and high-temperature stability are established at higher levels than the current service oils. Low-temperature viscosity requirements have been established at a −40° F range in lieu of the standard −65° F range to permit use of heavier oil-base stocks. Tests for controlling shear stability and thermal decomposition are incorporated in the specification. Oils are required to pass a 100-hour bearing test under type 1.5 test conditions prior to engine testing. Author

N63-17849 Pratt and Whitney Aircraft, East Hartford, Conn.
SERVICE EVALUATION OF SYNTHETIC LUBRICANTS
H. W. Reynolds, Jr. [1963] 13 p Presented at the 1963 USAF Aerospace Fluids and Lubricants Conf., Session II-A, San Antonio, Tex., Apr. 16-19

Methods of evaluating synthetic lubricants for aircraft turbine engines are reviewed. Increases in engine performance often adversely affect a lubricant's environment, and in some of the late-model, high-performance turbojet engines, current lubricants appear to be reaching their useful thermal and oxidative stability limits. Methods used to screen lubricants include: (1) laboratory tests of certain key oil properties such as viscosity, acidity, and lead corrosion characteristics; (2) rig tests, using devices, such as bearing rigs, to evaluate variations of oil viscosity with time as a function of temperature; gear rigs to measure the load-carrying ability or scuff resistance; and carbon seal wear test rigs; (3) stationary engine tests to obtain an indication of lubricant performance on the basis of oil system deposits, lubricant fluid degradation, and oil-related engine mechanical durability problems; and (4) field service tests in a limited number of airline flight engines. A new approach to monitoring flight engine lubricants is based on the changes in electrical conductivity of used synthetic lubricants related to the electrical conductivity of the same oil in the unused condition. A luberater device has been developed which uses an aluminum cup as both the sampling and testing container. The cup can be mailed in its own cardboard tube, thus speeding the conductivity analysis of oil samples taken from flight engines at various operating time intervals. M.P.G.

N63-17851 Rocketdyne, Canoga Park, Calif.
ALKALI METAL LUBRICATED JOURNAL BEARING EXPERIMENTS APPLICABLE TO SPACE POWER SYSTEMS
J. Hall and R. S. Siegler [1963] 25 p 6 refs Presented at the 1963 USAF Aerospace Fluids and Lubricants Conf., Session II-B, San Antonio, Tex., Apr. 16–19
(Contract AF 33(616)-8328)

Performance data have been obtained with various one-inch-diameter, pressure fed, self-acting bearings lubricated with potassium under the following operating conditions: potassium temperature to 1000° F, journal speeds to 36,000 rpm, and loads to 56 lbs. The performance data have been correlated with theoretical predictions, and good agreement has been obtained in the laminar regime, while correlation to the limited data in the turbulent regime is reasonable. Tests were conducted with room-temperature water as the lubricant, as a means of calibrating and checking the alkali-metal test bearings. Endurance tests have been conducted on one-inch-diameter, pressure fed, self-acting bearings. Results of the tests are presented. Author

N63-17852 Mechanical Technology, Inc., Latham, N.Y.
A REVIEW OF TURBULENT LUBRICATION THEORY FOR LIQUID METAL LUBRICATED JOURNAL BEARINGS
E. B. Arwas and B. Sternlicht 13 p 16 refs [1963] Presented at the 1963 USAF Aerospace Fluids and Lubricants Conf., Session II-B, San Antonio, Tex., Apr. 16–19

This paper summarizes the problems of liquid-metal lubricated bearings that are associated with the hydrodynamics of the fluid film. At the speeds required of compact space-power turbomachinery, these bearings operate in turbulent regime. The major differences between laminar and turbulent lubrication are discussed. Recent advances achieved in turbulent lubrication analysis are described, and needed future theoretical and experimental studies are outlined. Author

N63-17853 Aeronautical Systems Div. Air Force Systems Command, Wright-Patterson AFB, Ohio
REVIEW OF LIQUID METAL LUBRICATION RESEARCH PROGRAMS
J. L. Morris [1963] 9 p 6 refs Presented at the 1963 USAF Aerospace Fluids and Lubricants Conf., Session II-B, San Antonio, Tex., Apr. 16–19

Simplicity and minimum weight are maintained in space power-conversion systems by using the liquid-metal working fluids as hydrodynamic bearing lubricants. This concept has been proven feasible by a number of experiments at expected system conditions. Author

N63-17854 General Electric Co. General Engineering Lab., Schenectady, N.Y.
COMPARISON OF NO LOAD, STATIC FLUID FILM STIFFNESS AND LOAD CARRYING CAPACITIES AMONG SEVERAL BEARING TYPES
J. D. Mc Hugh [1963] 25 p 15 refs Presented at the 1963 USAF Aerospace Fluids and Lubricants Conf., Session II-B, San Antonio, Tex., Apr. 16-19
(NASA Contract NAS3-2111)

A comparison of the stiffness of different kinds of bearings under zero load conditions has been made. In order to form a fair basis of comparison, it is first necessary to establish a common design denominator among the bearing types. This has been done by comparing bearings which at zero load have the same minimum clearances between the shaft and bearing. A further criteria is obtained by comparing the load capacities of such bearings for a specified minimum film thickness and load direction. With such a basis of comparison among the bearings studied, it is found that the four pad, tilting-pad bearing studied has the highest static stiffness at zero load, at a bearing length/diameter ratio of one-half. The calculated value, in fact, is greater than the stiffness for the other bearing types at twice the L/D studied for the four-pad bearing. Moreover, as shown in the load comparison, the load capacity is comparable to that of the three-lobe bearing, and at least one-half that of the two axial groove bearing. Thus, on the basis of these two criteria, the tilting-pad bearing is the most attractive.
Author

N63-17855 Koppers Co., Inc. Metal Products Div., Baltimore, Md.
EVALUATION OF SEAL-LUBRICANT DEPOSIT FORMATIONS UNDER HIGH TEMPERATURE CONDITIONS
R. B. Spooner, J. S. Lagarias, and B. D. Pfoutz [1963] 18 p Presented at the 1963 USAF Aerospace Fluids and Lubricants Conf., Session III-A, San Antonio, Tex., Apr. 16-19

The ASD Seal-Lubricant Rig was modified to give it the capability of reaching the high operating temperatures ultimately expected in main-shift rotating air-oil seals of high Mach number gas turbine engines. On this rig, various operating methods were studied in an effort to develop repeatable methods in a stepwise approach to the ultimate high temperatures. Repeatable methods were developed for 750° F air temperature and 300° F bulk-oil temperature and, most recently, for 1050° F air temperature and 425° F bulk-oil temperature. Resulting operation at the last condition correlates well with engine test data at similar high temperatures. Author

N63-17856 Aeronautical Systems Div. Air Force Systems Command, Wright-Patterson AFB, Ohio
ENGINE PERFORMANCE VERSUS LUBRICANT DEPOSITS
L. J. De Brohun [1963] 6 p Presented at the 1963 USAF Aerospace Fluids and Lubricants Conf., Session III-A, San Antonio, Tex., Apr. 16-19

Lubricant deposit tests are being run on candidate lubricants for specification MIL-L-9236. The final acceptance tool is a J-57-59 engine which is rigged to stress the oils at a 425° F bulk temperature. Both the Wadd No. 4 bearing rig and the 100 mm Erdco bearing rig have been used for screening applicant lubricants for final testing. Data collected with both these rigs show a better correlation between the Erdco Rig and the J-57-59 engine. It is anticipated that this rig will be used as a basic tool for evaluating candidate oils for advanced turbine engine designs. R.C.M.

N63-17857 Aeronautical Systems Div. Air Force Systems Command, Wright-Patterson AFB, Ohio
MATCHING FLUID PROPERTIES WITH PROJECTED LUBRICANT REQUIREMENTS
F. J. Harsacky [1963] 8 p 5 refs Presented at the 1963 USAF Aerospace Fluids and Lubricants Conf., Session III-A, San Antonio, Tex., Apr. 16-19

The processes in the development of new, advanced gas turbine engine oils are reviewed. There are essentially five steps to the production phase of development. First, there is the basic research on new compounds performed in the chemistry laboratory. Secondly, the fluids are evaluated as to their physical, chemical, and additive properties. Thirdly, the potential lubricant is tested in a simulated engine environment. Fourthly, static engine tests are run. Finally, the lubricant is tested in flight in actual performing engines. Acceptable levels are given for the important lubricant properties, and the current status of liquid lubricant development is summarized. D.E.R.

N63-17858 Socony Mobil Oil Co., Inc., Paulsboro, N.J.
THIN FILM OXIDATION TEST
E. A. Oberright and H. L. Hepplewhite [1963] 10 p 4 refs Presented at the 1963 USAF Aerospace Fluids and Lubricants Conf., Session III-A, San Antonio, Tex., Apr. 16-19
(Contract AF 33(616)-8021)

A High Temperature Thin Film Oxidation Unit has been constructed, and test repeatability and reproducibility have been established. This equipment offers a means of measuring the oxygen absorption and maximum deposit-free temperature of operation of a lubricating oil under highly oxidative conditions for short contact times. Six high-temperature oils, supplied by ASD, have been evaluated in this equipment, and maximum deposit-free temperatures determined. Relative ratings based on cleanliness, developed by ASD from Bearing Rig and/or Engine Test data, are in agreement with test results at 575° to 600° F in the High Temperature Thin Film Oxidation Unit.
Author

N63-17862 Southwest Research Inst., San Antonio, Tex.
RECENT DATA ON THE THERMOPHYSICAL PROPERTIES OF ALKALI METALS
W. D. Weatherford, Jr. [1963] 12 p 27 refs Presented at the 1963 USAF Aerospace Fluids and Lubricants Cong., Session III-B, San Antonio, Tex., Apr. 16-19
(Contract AF 33(657)-8657 and AF 33(657)-9457)

This paper reviews the recent data on the thermophysical properties of the alkali-metal fluids, cesium, rubidium, potassium, sodium, and lithium. Correlation of these data suggests areas of doubtful accuracy, and illustrates certain anomalous properties of sodium.
Author

N63-17868 Midwest Research Inst., Kansas City, Mo.
FRICTION AND WEAR CHARACTERISTICS OF A CERAMIC-BONDED SOLID-LUBRICANT FILM
M. T. Lavik and W. L. Clow [1963] 9 p 4 refs Presented at the 1963 USAF Aerospace Fluids and Lubricants Conf., Session V-B, San Antonio, Tex., Apr. 16-19

This paper summarizes friction and wear studies of the $PbS:MoS_2:B_2O_3$ lubricant system. A review of the film preparation and evaluation techniques used in the investigation is given. The wear-life and friction performance of the films in this system are discussed. In electron micrography of film surfaces, consideration is given surface films rubbed in air and surface films rubbed in a vacuum. Results of the film performance show that (1) the film wear-life is very good in air over a limited temperature range near 1000° F and friction coefficients remain below 0.20; (2) the films exhibit useful wear and friction properties over the temperature range 80° to 1000° F in both air and vacuum ($\sim 10^{-6}$ Torr). The wear-lives are proportional to e^{-cT} and are approximately 300 percent longer in vacuum than in air. Film structure results show that (1) the films rubbed in

air at 700° F exhibit much more severe and extensive wear areas than similar films rubbed in vacuum; (2) the wear patterns of film rubbed at 700° F in vacuum are composed of closely spaced rub marks in the film areas still intact; few areas of severe wear are noted; (3) films rubbed at 1250° F in vacuum exhibit diffuse rub marks and relatively large-scale plastic deformation. N.E.A.

N63-17875 Aeronautical Systems Div., Air Force Systems Command, Wright-Patterson AFB, Ohio
AIR FORCE BEARING FATIGUE PROGRAM
G. A. Beane, IV [1963] 5 p Presented at the 1963 USAF Aerospace Fluids and Lubricants Conf., Session VII-B, San Antonio, Tex., Apr. 16–19

While there are no bearing-fatigue problems known to be occurring in present aircraft, the Air Force has undertaken a broad and long-range program to determine the influence of lubricants on bearing fatigue life. This program includes determination of thin-film lubricant rheology properties within the rolling contact region, evaluation of bulk pressure viscosity characteristics, development of simplified bench tests for studying the effects of operating variables and predicting full-scale bearing fatigue life, and full-scale bearing evaluation of the fatigue life of select lubricants of known composition which can be made readily available whenever needed in the future. By providing a common relationship between the various program phases, such as by using identical test-specimen materials and lubricants, it is felt that the resulting package of information will add substantially toward gaining an increased knowledge of the role lubricants play in affecting bearing fatigue life. Author

N63-17876 Battelle Memorial Inst., Columbus, Ohio
THE RHEOLOGICAL BEHAVIOR OF THE LUBRICANT IN THE CONTACT ZONE OF A ROLLING CONTACT SYSTEM
J. C. Bell, J. W. Kannel, and C. M. Allen [1963] 21 p 15 refs Presented at the 1963 USAF Aerospace Fluids and Lubricants Conf., Session VII-B, San Antonio, Tex., Apr. 16–19
(Contract AF 33(616)-7257)

A technique has been developed for studying the rheological behavior of the lubricating film within the contact zone of rolling-contact bodies. This is accomplished by rolling two contacting disks together with a small amount of sliding superimposed on a relatively high rolling velocity. By measuring the traction, slip-rate, and the lubricant film thickness in the elastically deformed contact, a plot of traction versus mean shear rate can be made. Data are presented for polyphenyl ether. The data depend on the disk temperature and contact pressure qualitatively as would be expected, but the observed dependencies on shear rate and rolling speed require explanation. Analysis of possible local thermal disturbances on the lubricating film, assuming a Newtonian lubricant model, indicates that, for the experiments described here, temperature changes only partially explain the observed nonlinear variations of traction with shear rate, and fall far short in accounting for variations with rolling speed. A study assuming isothermal conditions and Ree–Eyring lubricant model provides a traction theory which is flexible enough to fit the variations with shear rate, if certain parameters have advantageous values, but which appears only partially able to correlate the variations with rolling speed. Thus additional analyses which consider, say, both non-Newtonian and thermal effects, or perhaps other entities, are necessary for interpreting the data. Author

N63-18115 Hanford Atomic Products Operation, Richland, Wash.
EROSION-CORROSION OF ALUMINUM ALLOYS
R. L. Dillon and R. S. Hope Apr. 1963 33 p 9 refs
(Contract AT(45-1)-1350)
(HW-74359, REV) OTS: $0.75

A pattern of attack, qualitatively similar to groove pitting of irradiated fuel cladding, has been produced in the laboratory. The relative susceptibility to attack of X-8001 alloy aluminum in comparison to 1245 alloy aluminum is in agreement with reactor experience. Tests have shown that the laboratory-simulated groove pitting involves both mechanical and chemical components. Under the conditions studied, both must be present before observable metal removal occurs. Of the mechanical factors studied, flow rate of the water was most important. At a given flow rate, temperature, and water quality, increase in pressure on the system tended to reduce the attack. The effect of water chemistry is demonstrated by the inability to simulate groove pitting, or in fact to remove metal, in deionized water; substantial attack can be produced in process waters. The laboratory tests were largely conducted with laboratory tap water rather than reactor process water, both as a matter of availability and as a device for accelerating the corrosion process. Significant inhibition of metal removal resulted from dichromate additions and reduced pH. Author

N63-18121 Massachusetts Inst. of Tech. Instrumentation Lab., Cambridge
Monthly Progress Report [BEARING-YIELD AND LIFE-IMPROVEMENT PROGRAM]
Alfred C. Edwards May 1963 17 p
(Contract AF 33(657)-7463)
(Rept. 16; E-1349)

Progress in a bearing-yield and life-improvement program is reported. Screening tests of base line and accelerated performance of bearings were conducted. Improved retainers made of high porosity Synthane materials have been screened, and unsteady bearing operation was alleviated by reducing the total lubricant quantity by extraction with either 99% or 90% Freon with V-78 oil. Screening starts have been made with ND gyro oil G, and satisfactory life tests of ND gyro oil D terminated at about 245 hours, approximately twice the best life of other lubricants under similar test conditions. The ball lapping process has been used to produce improved finish and design B races. Sets of design A improved bearings are being screened with groove-riding and O.D. retainers. Studies of retainer dynamic behavior were made to correlate wattmeter response to small and large amplitude variations and to determine the effect of shaft interference on bearing performance. Results of a second series of tests on improved lubricants are reported. M.P.G.

N63-18122 Massachusetts Inst. of Tech. Instrumentation Lab., Cambridge
Monthly Progress Report No. 9, September 1962 [BEARING YIELD AND LIFE-IMPROVEMENT AND THERMOELECTRIC COOLING PROGRAM]
Alfred C. Edwards Oct. 1962 24 p 2 refs
(Contract AF 33(657)-7463)
(E-1222)

Progress is reported in a bearing-yield and life-improvement program and in a thermoelectric cooling program. Fourteen pairs of bearings failed when subjected to base-line screening tests. Mercury porosimeter tests were run on three Synthane variations, and V-78 oil was tested on a single bearing test machine. Ball lapping and honing of races were investigated, and the results prompted the decision to use optimized honed races in the basic factorial test plan. The effects of pretreating bearings with organic coatings were investigated, and the relationship between the electrical resistance between a pin and disc rotating at various speeds and the observed wear was studied. Screening tests of super-refined lubricants are

being conducted, and two pairs of bearings are still running in an accelerated life-testing program. Life tests on individual bismuth telluride cooling modules have continued, and static and running tests of annular bearing cooling modules were made to evaluate insulating materials, bearing support methods, and airflow through the motor and over the hot sink heat radiator. The effect of temperature on bearing life and performance is being studied in an evaluation of practical cooled bearing systems. M.P.G.

N63-18124 Massachusetts Inst. of Tech. Instrumentation Lab., Cambridge
Monthly Progress Report No. 13, January 1963 [BEARING YIELD AND LIFE-IMPROVEMENT PROGRAM AND THERMOELECTRIC COOLING PROGRAM]
Alfred C. Edwards Feb. 1963 18 p
(Contract AF 33(657)-7463)
(E-1312)

Progress is reported in screening sets of bearings in a bearing-yield and life-improvement program. The base-line and accelerated performance tests were conducted primarily with ND gyro oil D. Data were obtained on variations of ball-retainer Synthane material oil impregnation and desorption characteristics, and on abrasive tumbling finishes for bearing races. Fabrication of design A and design B improved bearing parts is progressing. Two inner-race rotating bearings were observed in an unstable operating condition in a gyro wheel, and a theoretical evaluation of the instability is presented. The effects of lubricant viscosity and of pretreatment of the metal surfaces with organic coatings were evaluated. The major problem at the present time is evaluation of the effect of surface discontinuities. Work on the thermoelectric cooling program is nearing completion. M.P.G.

N63-18267 Hanford Atomic Products Operation, Richland, Wash.
NEUTRON IRRADIATION AND COLD WORK EFFECTS ON ZIRCALOY-2 CORROSION AND HYDROGEN PICKUP
Interim Report
W. A. Burns and H. P. Maffei Dec. 1962 32 p 18 refs
(Contract AT(45-1)-1350)
(HW-76636)

Corrosion weight gains and hydrogen sorption for Zircaloy-2 specimens exposed to similar aqueous and thermal environments in- and out-of-reactor were compared to obtain quantitative information relative to the effects of a high-energy neutron flux on the processes involved. Metal specimens representing four levels of cold work were exposed in high-quality water at 540° F to fast-neutron flux intensities over the range 1.7 to 4.2 $\times$ 10^{13} nv (> 1.0 Mev.) and to a maximum integrated fast flux of 1.06 $\times$ 10^{20} nvt. In-reactor weight gains were found to be higher by an order of magnitude, and a saturation effect of flux was indicated. No significant effects of work history on corrosion were observed. Fractional pickup of corrosion hydrogen in-reactor was within the range normally expected for out-of-reactor exposure, but a trend toward reduced pickup of hydrogen by material cold worked to the extent of about 10% was observed. No effect of cold work on hydrogen pickup was observed for unirradiated specimens. Author

N63-18311 Southwest Research Inst., San Antonio, Tex
LOX-LUBRICANT IMPACT SENSITIVITY RESULTS FOR ASD COOPERATIVE TEST PROGRAM NO. 3 Special Report [Nov. 1960-Dec. 1962]
B. B. Baber and F. Chang Jan. 25, 1963 66 p 4 refs
(Contract AF 33(616)-7223)
(SRI-RS-369)

Impact sensitivity threshold values of three test samples were evaluated by ten laboratories. Seven laboratories reported results using the ABMA type impact tester, and three laboratories reported results using the RMD impact tester. Even though rather large variations in specific threshold values were reported by laboratories using the ABMA type impact tester, there was general agreement between laboratories with respect to the relative sensitivity of the three test samples evaluated. General agreement of relative sample sensitivity was also obtained by laboratories using the RMD impact tester; however, the order of sample sensitivity was different from that obtained with the ABMA type impact tester. Although the LOX-Lubricant Impact Sensitivity Cooperative Program No. 3 showed definite improvements in test reproducibility from the previous cooperative test programs, further improvement in test reproducibility still appears desireable. Author

N63-18356 Aerojet-General Corp. Solid Rocket Plant, Sacramento, Calif.
CORROSION RATES OF REFRACTORY METALS EXPOSED TO NOZZLE COOLANTS [Final Report, Aug. 2, 1961-Jan. 2, 1962]
M. J. Cramer, A. R. Stetson (Solar Aircraft Co.), and G. J. Westcoat Apr. 1, 1962 61 p 2 refs
(Contract NOrd 17017)
(Rept. 397)

This report presents the results of a program to determine the corrosion rates of unalloyed tungsten, tantalum, and molybdenum, and 90% tantalum-10% tungsten alloy, columbium-1% zirconium alloy, and C103 columbium alloy exposed to molten lithium, sodium, potassium, and magnesium. Rectilinear and Arrhenius plots of all systems are presented up to the boiling point of the molten metals at one atmosphere pressure. Data are also presented on the effects of hydrogen chloride gas on the corrosion rate of four refractory metals in an oxygen-hydrogen rocket exhaust. Author

N63-18424 Massachusetts Inst. of Tech. Instrumentation Lab., Cambridge
Monthly Progress Report for February 1963 [BEARING YIELD AND LIFE-IMPROVEMENT PROGRAM AND THE THERMOELECTRIC COOLING PROGRAM]
Alfred C. Edwards Mar. 1963 16 p
(Contract AF 33(657)-7463)
(Rept. 14; E-1317)

Investigations into the bearing yield and life-improvement program are presented. Progress is reported on the design, fabrication, and accelerated performance tests of test bearings; on development and screening of ball retainer materials along with retainer dynamic behavior; on improvement, development, and screening of lubricants and lubricant control mechanisms; on optimum mechanical interface finishing processes by screening; on screening of parameter variations by means of single bearing test devices; and on pretreatment of metal surfaces with organic coating. C.L.W.

N63-18623 Kaman Aircraft Corp. Kaman Nuclear Div., Colorado Springs, Colo.
INVESTIGATION OF THE FEASIBILITY OF AN AIRCRAFT-OIL ANALYSIS SYSTEM FOR OPERATIONAL USE IN THE FIELD, PHASE I Technical Report [Jan. 26, 1962-May 30, 1962]

Charles W. Whittle and Phillip L. Jessen Ft. Eustis, Va., Army Transportation Res. Command, May 1963 134 p 10 refs
(Contract DA 44-177-TC-789)
(KN-676-1(PR); TCREC-TR-62-91)

Data were gathered from those organizations on the North American Continent which have performed sufficient oil analyses to provide statistically significant information. Metal content of the lubricating oil for Curtiss-Wright Type R-1820-86 piston engines is compared to engine failures. The purpose of the data analysis is to determine whether or not a correlation exists between various metal contents in lubricating oil and failure of the engine. It was found that correlation exists. A survey of methods for the determination of metal content is given. Those methods that appear practical for field use are emphasized. It is concluded that good probability of failure prediction is obtainable if the amount of particular metals is measured for any given engine type. An approximate analysis of the effect of small metal particles in the magnetic field of an inductor indicates that metal concentrations of the order of 100 parts per million will be detectable. Results of the data analysis make it apparent that this metal content may be useful in the prediction of imminent failure; the device would not be sufficiently sensitive for use as maintenance test equipment.
Author

N63-18870 National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
A SURVEY OF VACUUM LUBRICATION DEVELOPMENTS
J. E. Kingsbury and E. C. Mc Kannan Apr. 1963 5 p 10 refs
Repr. from Proc. of the 1963 Annual Technical Meeting of the Inst. of Environmental Sciences, Los Angeles, Apr. 17 19, 1963 p 41-44

Current vacuum lubrication programs in eight laboratories are reviewed for several purposes, such as: (1) collecting available information in one reference and up-dating a previous effort toward this end, (2) determining the degree of coverage of probable applications and requirements by current development programs, and (3) comparing test methods and conclusions from different programs to increase the reliability in selection of specific materials and components. Some generalized conclusions have been made where there has been sufficient agreement among the programs reviewed. Author

N63-19014 Westinghouse Electric Corp. Westinghouse Research Labs., Pittsburgh, Pa.
LUBRICATION OF BEARINGS AND GEARS IN AEROSPACE ENVIRONMENTAL FACILITIES
Paul H. Bowen Arnold Air Force Station, Tenn., Arnold Eng. Develop. Center, July 1963 134 p 11 refs
(Contract AF 40(600)-915)
(AEDC-TDR-63-166)

This report presents results of screening tests of plastics, powders, and composites, along with the use of new dry powders and composites, as dry lubricants in ball bearings and gears operating in an ultrahigh-vacuum environment. Conclusions are drawn with regard to concepts of dry lubrication, lubrication techniques, and desirable composite materials in adapting bearings and gears for use in handling equipment of environmental space chambers. Author

N63-19077 Oak Ridge National Lab., Tenn.
IN-PILE RADIATION CORROSION EXPERIMENTS WITH ZIRCONIUM, TITANIUM, AND STEEL ALLOYS IN 0.17 *m* UO_2SO_4 SOLUTIONS AT 280° C
G. H. Jenks and J. E. Baker et al July 10, 1963 77 p 21 refs
(Contract W-7405-eng-26)
(ORNL-3099) OTS: $1.75

In-pile loop experiments, L-2-15 and L-4-16, were two of a series designed to test the radiation corrosion of Zircaloy-2 and other possible reactor construction materials in UO_2SO_4 solutions under various conditions of radiation intensities, temperatures, solution compositions, and velocity of flow past specimens. The mainstream temperature in the experiments ranged from 278° to 280° C. The experiments were exposed in the LITR beam holes HB-2 and HB-4, respectively. Construction material for the loops was type 347 stainless steel. Specimens of type 347 and 309SCb stainless steels, titanium-55A and -110AT, platinum, Zircaloy-2, crystal-bar zirconium, and a variety of other zirconium alloys were tested. The power density at core specimens ranged from 19.8 to 4.6 w/ml in L-2-15 and from 5.7 to 1.3 w/ml in L-4-16. For loop L-2-15, the total time of high-temperature operation with UO_2SO_4 was 792 hours during in-pile exposure, and reactor energy was 1632 mwhr; for loop L-4-16, 1032 hr and 2325 mwhr. During both experiments, most of the reactor energy was accumulated at the 3-mw power level. N.E.A.

N63-19109 Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena
HOW MATERIALS BEHAVE IN SPACE
L. D. Jaffe and J. B. Rittenhouse Repr. from Mater. Design Eng., Sept. 1962 8 p

The behavior of materials when exposed to vacuum, ions and electrons, electromagnetic radiation, and meteoroids is discussed. Vacuum, when combined with temperature increases, can cause sublimation or decomposition and loss of molecular weight. Also, materials in surface contact in space environment exhibit a very high wear rate and coefficient of friction. Ions and electrons may affect materials by both displacement and ionization, depending on the material's sensitivity to radiation. Optical transmission properties of organic and semiconductor materials may be altered by ions and electrons. In addition to causing damage, ions and gas atoms may cause sputtering in some materials. Electromagnetic radiation can also produce displacement and ionization in materials. In addition to these effects, darkening, crosslinking, and embrittlement are caused in polymers. Color centers and accompanying optical absorption are produced in inorganic insulators and glass. Meteoroids may damage materials by perforation and spalling. N.E.A.

N63-19515 Dow Chemical Co., Denver, Colo. Rockey Flats Div.
CORROSION STUDIES ON 304 STAINLESS STEEL CONTAINING ONE PERCENT BORON-10
F. E. Butler July 19, 1963 11 p
(Contract AT(29-1)-1106)
(RFP-307)

A stainless steel alloy (304L) containing 1% boron-10 is being used to poison an 18-inch diameter ion column. This ion column is to be used for recovery of plutonium from a variety of nitric acid streams and has a capacity of approximately 20 kilograms. To ensure that the alloy does not corrode at a rate which would create problems in nuclear safety, a series of tests were initiated to determine corrosion rates. The alloy was found to be resistant to 0.35N and 7N nitric acid, but substantial corrosion rates were observed when the coupons were exposed to 7N nitric acid, 0.1N in fluoride. The corrosion rate was increased one and one-half times for each 10° C increase in temperature. However, the alloy appears to be a satisfactory material for use in the 7N nitric acid, 0.1N in fluoride provided that the free fluoride is complexed with 2.5:1 atomic ratio aluminum ion. J.L.D.

N63-19933 Aeronautical Research Labs., Melbourne (Australia)
THE CORROSION OF THE HIGH STRENGTH ALUMINIUM ALLOYS
F. G. Lewis Oct. 1962 47 p 43 refs
(ARL MET-47)

This paper presents a descriptive review of the corrosion characteristics of the high-strength aluminum-copper and aluminum-zinc-magnesium alloys. The former are prone to intercrystalline and exfoliation corrosion. Although most failures in the zinc bearing alloys to date have been due to stress-corrosion cracking, once the residual and assembly stresses have been alleviated they become increasingly susceptible to intercrystalline and exfoliation corrosion, especially in integrally machined sections. Protective treatments are discussed, and it is shown that while various methods of protection are beneficial, no existing protective scheme gives satisfactory protection against stress and intercrystalline corrosion. Author

N63-20372 Armour Research Foundation, Chicago, Ill.
DETERIORATION OF SOME ALUMINUM ALLOYS IN THE PRESENCE OF MERCURY AND CESIUM Summary Report
W. Rostoker Sept. 4, 1962 19 p
(ARF-R3501-B41)

The possibilities of embrittlement and corrosive attack on Al 1100-O and 5083-O alloys have been explored. It is shown that no serious hazard exists if the 5083-O alloy as the load-bearing portion of the structure is clad with a thick surface of 1100-O alloy. It is also shown that no advantage accrues from the use of 5052-O and 5454-O alloys as a substitute for 5083-O. Some preliminary tests of Hg or Li embrittlement of austenitic stainless steel show that no hazard exists. From this viewpoint, it may be regarded as a suitable cladding for 5083-O alloy. Author

N63-20417 Southwest Research Inst., San Antonio, Tex.
TECHNIQUES FOR INVESTIGATION OF FRICTION AND WEAR IN AEROSPACE BEARINGS [Interim Report, Apr. 1, 1962-May 1, 1963]
H. E. Staph, W. A. Gunkel, J. C. Harless, G. F. Munsch, R. R. Nydegger, P. M. Ku, and G. Dameswood. Wright-Patterson AFB, Ohio, Flight Dynamics Lab., May 1963 148 p 65 refs
(Contract AF 33(657)-8653)
(ASD-TDR-63-565)

Instrumentation techniques have been developed which may be applied toward the study of several parameters believed to contribute to friction and wear in rolling-element bearings. Measurements are made on the bearings during operation. Ultimate goal for instrumentation applicability is −65° F to 1500° F bearing temperature, 10^{-9} torr vacuum, and 24,000 rpm speed. The principal instrument for performing the measurements is a platform called a "cage follower," which rotates in a plane alongside of and parallel to that of the bearing and in synchronism with the cage. Cage-mounted transducers for temperature and strain may be connected to the cage follower by fine wires. Transducer signals, a-c or d-c, may be telemetered from the moving shaft through coupling transformers. The use of the cage follower to measure ball spin is described. Ball and cage temperature measurement by infrared techniques has been studied and shows feasibility. Material transfer occurring during bearing operation is measured on the doubly curved bearing surfaces by preformed autoradiographs and scintillation counting. Literature on the effects of the presence of electric and magnetic fields on wear in rolling element bearings is summarized. Author

N63-20587 National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio
GALLIUM-RICH FILMS AS BOUNDARY LUBRICANTS IN AIR AND IN VACUUM TO 10^{-9}mm Hg
D. H. Buckley and R. L. Johnson. Repr. from ASLE Trans., v. 6, 1963 p 1-11 4 refs

The friction and wear characteristics of various materials coated with thin gallium-rich films were determined at temperatures to 1000° F in air and at room temperature in vacuum between 10^{-7} and 10^{-9} mm Hg. Evaporation rates of gallium were measured at 10^{-7} mm Hg and ambient temperatures to 1000° F. The friction and wear experiments were conducted with 3/16-inch-radius rider hemisphere sliding on a 2 1/2-inch-diameter disk at surface speeds of 28 to 4490 feet per minute and a load of 1000 gms. Utilizing a gallium-diffused film, boundary lubrication of 440-C stainless steel was obtained. The friction and wear obtained with the gallium-diffused films were lower in vacuum than in air. The use of relatively inert materials such as boron carbide and aluminum oxide as rider specimens reduced the corrosion problem normally encountered with gallium in all-metal systems. Gallium was not equally effective as a lubricant for all materials; it reduced friction and wear for several alloys (52100 and 440-C); other materials, including a nickel base alloy, were not effectively lubricated. Author

N63-20798 National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio
WEAR AND FRICTION OF MECHANICAL CARBONS IN LIQUID OXYGEN AS INFLUENCED BY TRANSFER FILMS
William F. Hady, Gordon P. Allen, and Robert L. Johnson. Repr. from ASLE Trans. v. 6, 1963 p 201-208 10 refs
(NASA-RP-5)

Experimental wear and friction studies were conducted with a series of mechanical carbons sliding against metal surfaces in liquid oxygen (−298° F), at sliding velocities to 6500 fpm, and a load of 1000 gm. High-density graphitic carbons with a greater oxidation resistance and a greater capability of forming a transfer film gave the lowest wear and friction. Metals that form the most stable oxide films promote greater adherence of the graphite to the mating surface. Impregnated carbons must be selected with caution because frictional heating generated during sliding can initiate hazardous reactions between oxygen and certain unstable organic compounds. Author

N63-21175 Hanford Atomic Products Operation, Richland, Wash.
RADIATION EFFECTS ON ALUMINUM FILMING AND CORROSION
R. B. Richman Feb. 20, 1963 18 p 34 refs
(Contract AT(45-1)-1350)
(HW-76642) OTS: $0.50

Film deposition and corrosion were measured for aluminum samples exposed to a wide range of intensities of nuclear reactor radiation in pH 7.0, treated, Columbia River water preheated with steam to 90° C. Both the amount of film deposited and the extent of aluminum corrosion increased with radiation intensity. Author

N63-21369 National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio
REQUIREMENTS FOR HIGH TEMPERATURE MATERIALS FOR SPACE VEHICLES
G. Mervin Ault [1962] 24 p 20 refs
(NASA RP-27)

High-temperature materials are required in space vehicles for components of propulsion devices and electric power generation systems, not because of their strength at high temperatures, but rather because of unique characteristics such as their electronic work functions, thermoelectric properties, or resistance to corrosion by alkali metals. The devices and their high-temperature materials requirements are described. Author

N63-21380 Oak Ridge National Lab., Tenn.
CORROSION MECHANISMS IN REFRACTORY METAL-ALKALI METAL SYSTEMS
J. R. Di Stefano and E. E. Hoffman Sept. 16, 1963 54 p 102 refs
(Contract W-7405-eng-26)
(ORNL-3424)

The use of liquid metals introduces solid–liquid metal interactions which are not primarily electrochemical, as found in systems involving aqueous media. The corrosion of solid metals by these coolants occurs as the system attempts to attain chemical equilibrium. The mechanisms by which this can occur are (a) dissolutioning, which results from the solubility relationships between the solid and liquid metals, and (b) impurity reactions, resulting from the presence of interstitial impurities, such as oxygen, nitrogen, and carbon, in the solid and liquid metals. The most significant corrosion problem involving refractory metals appears to be the influence of the impurities, oxygen, nitrogen, and carbon. The presence of small quantities of oxygen in either tantalum or niobium results in the penetration of these metals by lithium over a wide range of temperatures. It has also been found that oxygen in sodium increases its corrosion rate when in contact with niobium and other refractory metals. A method to predict the redistribution of impurities which are present in solution in either the solid or liquid metal is compared with experimental results. Author

N63-21440 General Electric Co., Lynn, Mass. Thomsom Lab.
CORROSION FATIGUE OF COMPRESSOR BLADES
J. Miller and C. E. Peaslee Dec. 10, 1962 20 p
(DF62SE106)

An analysis is made of fatigue data obtained from laboratory investigation of salt-water corrosion of compressor blades and the development of improved protection material. Corrosion of the type that occurred in the Key West engines reduced the minimum fatigue strength of the rotor blades. Nubelon and Al–Si paint did not reduce the fatigue strength of blades, but the pure Aluminum coating reduced the fatigue strength of brazed stator vanes 30%. Under laboratory conditions, GE AM355 will withstand at least three times the vibratory stress that 403 will withstand without failure under simultaneous vibration and salt spray conditions for times over 100 hours. J.R.C.

N63-22213 Royal Aircraft Establishment, Farnborough (Gt. Brit.)
EFFECTS OF GAMMA RADIATION ON FLUOROLUBE
M. J. Downey July 1963 7 p 2 refs
(RAE-TM-SPACE-19)

The many desirable properties of Fluorolube have made it an obvious choice, in the past, as a flotation and damping fluid for gyroscopes. Its usefulness in satellite gyroscopes, however, must be considered anew because of the possible effects of radiation on these properties. The preliminary study is described and, in particular, the changes in viscosity and acidity of Fluorolube 230 owing to various absorbed radiation doses. Author

N63-22221 Argonne National Lab., Ill.
VISIT TO SOVIET CORROSION CHEMISTRY INSTITUTES, JUNE 25–JULY 4, 1962
F. W. Young, Jr. (Oak Ridge Natl. Lab.) and J. E. Draley AEC. Div. of Tech. Information, Mar. 15, 1963 26 p 83 refs
(Contracts W-7405-eng-26 and W-31-109-eng-38)
(TID-17940) OTS: $0.50

A report on a visit to the U.S.S.R. to observe fundamental corrosion research in the Soviet Union is presented. Soviet research institutes visited were: (1) The Karpov Institute of Physical Chemistry, Moscow, (2) The Institute of Physical Chemistry of the U.S.S.R. Academy of Sciences, Moscow, and (3) The Institute of Electrochemistry of the U.S.S.R. Academy of Sciences, Moscow. P.V.E.

N63-22279 Philco Corp., Philadelphia, Pa. Research Lab.
CHEMICAL CORROSION OF ROCKET LINER MATERIALS AND PROPELLANT PERFORMANCE STUDIES Fifth Quarterly Technical Summary Report
R. C. Oliver, R. W. Baier, D. L. Peters, and R. W. Sprague Sept. 15, 1963 58 p 18 refs
(Contract NOw-61-0905-c; ARPA Order 22-62)
(U-2276)

Studies of the theoretical equilibria resulting from interaction of candidate refractory nozzle wall materials with various species resulting from combustion of rocket fuels have continued. Hafnium nitride, as the highest melting nitride, has been considered in detail, with composition diagrams and saturation parameters reported for its interaction at 1000 psia with AlF_3, BF_2, BF_3, BOF, BeF_2, CO, CO_2, HCl, HF, H_2, H_2O, LiF, and N_2. It is found that HfN shows very poor theoretical stability in all reactants except H_2 and N_2. Equilibria over condensed Al_2O_3 and the refractory wall materials W, TaC, HfN, and C have also been considered, showing vapor phase compositions and pressures as a function of temperature from about 1500 to 5000° K. In the cases of W, TaC and C, the presence of Al_2O_3 leads to formation of gaseous oxides which materially increase the apparent volatility of the refractory material. A preliminary study has been made of measured rates of reaction of graphitic wall materials with propellant combustion products compared to predicted rates based on a model which assumes interface equilibrium and unity Lewis and Prandtl numbers. In the example studied, it appeared that surface temperatures were not sufficiently high to expect thermochemical equilibrium at the graphite surface. As a result the simple equilibrium model gave order-of-magnitude greater rates than measured. Author

N63-22437 Rock Island Arsenal Lab., Ill.
INFLUENCE OF ATMOSPHERIC CONTAMINANTS ON CORROSION – LITERATURE REPORT
Harry C. Muffley June 13, 1963 25 p refs
(RIA-63-2041) OTS: $0.75

Literature was reviewed concerning the contaminants that contribute to atmospheric corrosion, the mechanism of atmospheric corrosion, and the techniques available for determining atmospheric contamination. Author

N63-22954 Arnold Engineering Development Center, Arnold Air Force Station, Tenn.
LUBRICATION REQUIREMENTS FOR SPACE ENVIRONMENTS
J. D. Pinson and W. F. Mc Rae Oct. 1963 45 p 16 refs
(AEDC-TDR-63-154)

This paper presents a detailed description of research in this area with special emphasis on results of tests related to operating gears and bearings in a simulated space environment. Author

N63-23098 Oak Ridge National Lab., Tenn.
TRANSURANIUM QUARTERLY PROGRESS REPORT FOR PERIOD ENDING FEBRUARY 28, 1963
W. D. Burch, comp. Oct. 8, 1963 67 p refs
(Contract W-7405-eng-26)
(ORNL-3482) OTS: $1.75

Progress is discussed in the development of separation processes for the transuranium elements, process-equipment development, high-flux isotope reactor target-fabrication development, design of the transuranium processing facility, design of development facilities, corrosion studies, and analytical research and development studies. P.V.E.

N63-23713 SKF Industries, Inc., King of Prussia, Pa.
INFLUENCE OF LUBRICATION ON ENDURANCE OF ROLLING CONTACTS Progress Report No. 6, Dec. 22, 1962-Mar. 22, 1963
W. Schmidt, J. Mc Cool, R.Valori, T. Tallian, E. F. Brady et al [1963] 47 p refs
(Contract NOw-61-0716-C)
(AL63T016)

Additonal radioactive wear tests at 150 lb load were run in a rolling four-ball testing machine. The rolling speed above which the wear is negligible, according to the radiotracer results, corresponds to the speed at which previous electrical conductivity results had indicated essentially complete hydrodynamic separation of the surfaces. Preliminary endurance tests on 1/2-in. steel balls were run in a rolling 4-ball (Barwell) testing machine under a series of loads. The purpose of these tests was to determine the load range within which the cubic load-life relationship (as found for complete ball bearings) is valid. Test results indicate that for 52100 steel balls of 62 to 64 R_c hardness, the theoretical load-life relationship is valid up to a spindle load of 182 lb on a 4-ball set of 1/2-in. balls having 40° contact angle. Author

1964
STAR ENTRIES

N64-10175* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio
THE ROLE OF ELASTOHYDRODYNAMIC LUBRICATION IN ROLLING-CONTACT FATIGUE
E. V. Zaretsky, L. B. Sibley (Battelle Memorial Inst.), and W. J. Anderson Repr from J.Basic Eng., Trans., ASME, Sept. 1963 p 439-450 refs
(NASA RP-43; ASME Paper 62-Lub-4)

The five-ball fatigue tester was used to determine the rolling-contact fatigue life of 1/2-in.-diam. M-1 steel balls with four lubricants at 300° F. Film thickness measurements were made with the rolling-contact disk machine under simulated five-ball test conditions. Under certain conditions, elastohydrodynamic lubrication was found to exist at initial, maximum, Hertz stress levels up to 800,000 psi. There appears to be a correlation among the following variables: plastically deformed profile radius of the ball specimen at ambient temperature; lubricant type; and rolling-contact fatigue. No correlation was found between contact temperature obtained with different lubricants and fatigue life. Author

N64-10648 Joint Publications Research Service, Washington, D.C.
INVESTIGATIONS ON WEAR OF ELECTRICAL CONTACTS, USSR
Oct. 16, 1963 75 p refs Transl. into ENGLISH of four articles from the book "Elektricheskiye kontakty" (Electrical Contacts—Proc. of the 26-28 Nov. 1956 Conf.) Moscow, State Publ. House of Elec. Eng., 1958
(JPRS-18926; OTS-63-21692) OTS: $2.00

The manufacturing and breaking properties of metal-ceramic electrical contacts are discussed to provide a basis for the powder metallurgical study of high-voltage breaking switches. Such contacts are found to be very useful in circuits wherein the contacts are subjected to wearing conditions or where they must suffer the effects of weldings. The study shows the alloys Ag-Cu and Ag-Si-Mg and other age-hardenable alloys capable of increasing the wear resistance of electrical contacts, but the results with an Ag-Ni alloy show that this is not always the case. D.E.R.

N64-10704 Joint Publications Research Service, Washington, D.C.
CORROSION OF REINFORCEMENT STEEL IN POROUS CONCRETE
P. Melenevs'ka 13 Feb. 1963 6 p Transl. into ENGLISH from Budivel'ni Materialy i Konstruktsii (Kiev) v. 4, no. 4, 1962 p 13-15
(JPRS-17616; OTS-63-21125) OTS: $0.50

The effectiveness of various protective coatings on steel rods used for concrete reinforcement is discussed. Sample blocks were prepared which contained rods with and without protective coatings (the steel rods to be protected were phosphated, neutralized, and covered with lacquer coatings). The samples were subjected to thermohumidity processing in a vapor chamber, aeration by a blower, and subjection to hydrochloric acid vapor and sulfurous anhydride. Good results were obtained with phosphation of the steel rods followed by coating with Kuzbas lacquer. Tests made on the strength of bonding of the concrete to the steel rods indicated that phosphated rods coated with Kuzbas lacquers were bonded to the concrete more strongly than the unprotected rods. P.V.E.

N64-11237* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
HIGH SPEED VACUUM PERFORMANCE OF GOLD PLATED MINIATURE BALL BEARINGS WITH VARIOUS RETAINER MATERIALS AND CONFIGURATIONS
Harold E. Evans and Thomas W. Flatley Washington, NASA Dec. 1963 21 p refs
(NASA TN D-2101) OTS: $0.75

Metallic film lubrication of ball bearings is a possible answer to the evaporation, radiation resistance, and contamination problems associated with conventional lubricants in satellite applications. The first phase of the program which evolved was directed toward finding an acceptable retainer material and configuration. Bearings were tested in small 10,000 rpm motors in a special multiport oil-free vacuum system which is described. Two retainer types—fully machined retainers of S-Inconel and silver plated Circle C—proved outstanding and capable of providing about 1000-hours life in conjunction with gold plated balls and races.
Author

N64-11308 Deutsche Versuchsanstalt für Luft- Und Raumfahrt, Munich (W. Germany) Inst. für Flugtreib Und Schmiestoffe
DEVELOPMENT OF A DESIGN FOR THE AGEING OF AIRPLANE ENGINE OILS AT HIGH TEMPERATURES [ENTWICKLUNG EINER ANLAGE ZUR ALTERUNG VON FLUGMOTORENOLEN BEI HOHEN TEMPERATUREN]
G. Spengler and E. K. Jantzen Sep. 1963 45 p refs In GERMAN
(DVL-287) Available from Vereinigte Universitäts—U. Fachbuchhandlungen, R.-Wagner-Str. 1, Cologne, W. Germany
The importance of aging lubricating oil and the essential aging processes are discussed. In addition, a unit for aging aircraft engine oil at high temperatures is described; this unit permits the aging of oil up to 450° C over arbitrary time periods. During the aging process, gases such as air and nitrogen can be fed into the oil. Low-temperature condensers collect by-products of aging. Some examples of aged oils are discussed, which give an insight as to the thermal- and thermal oxidation-aging processes. The unit described above permits the aging of oils at temperatures which will arise in future aircraft, and thereby establishes the premise for the investigation of the aging process in aircraft engine oils. Trans. by I.v.L.

N64-11381* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
CORROSION PROBLEMS ASSOCIATED WITH THE USE OF TITANIUM FASTENERS TO CONNECT ALUMINUM COMPONENTS
E. E. Nelson and J. G. Williamson 30 Sep. 1963 17 p
(NASA TM X-51167; MTP-P&VE-M-63-13) OTS: $1.60 ph, $0.80 mf
Corrosion studies have indicated that Ti-6A1-4V alloy fasteners can be used to connect aluminum components without significant corrosion on the aluminum component in a normal atmospheric environment. However, exacting installation procedures must be followed for adequate control of galvanic corrosion.
Author

N64-12079 Ampex Corp., Redwood City, Calif.
THE EFFECT OF EXTERNAL PRESSURIZATION ON SELF-ACTING FOIL BEARINGS
M. Wildmann and A. Wright Oct. 1963 34 p refs
(Contract Nonr-3815(00))
(RR 63-6; AD-424200)
The effects of introducing a small amount of lubricant under pressure into a self-acting foil bearing film are investigated. Foil shape and pressure distribution under the foil are obtained by combining the equilibrium equation with the Reynolds equation and solving the resulting equation. The results show that the effect of even small external pressurization in a self-acting foil bearing is very important.
Author

N64-12094 Nuclear Metals, Inc., Concord, Mass.
BERYLLIUM CORROSION Final Technical Report, 25 Apr. 1962–24 Apr. 1963
D. S. Kneppel Washington, AEC Div. of Tech. Inform., 24 Mar. 1963 95 p refs Prepared under the U.S.-EURATOM Joint Res. and Develop. Program
(Contract AT(30-1)-3012)
(MNI-1911; EURAEC-804) OTS: $2.00
An investigation of the corrosion behavior of beryllium showed that commercial-purity beryllium will survive in 343° C water without significant attack for prolonged periods. The presence of minute amounts of copper in the water has a deleterious effect on corrosion resistance. High-purity beryllium exhibits poor corrosion resistance in high-temperature water. However, the material can be improved by alloying. Heat-treated alloys containing 0.4w/o Ni, 0.2w/o Ni plus 0.2w/o Fe, or 0.5w/o Ni plus 0.5w/o Fe showed good corrosion resistance in 343° C water. Individual alloy additions to high-purity beryllium of Al, Mg, Mn, Si, Fe, Ni, or Cr in amounts comparable to their content in commericial-purity beryllium had no effect in improving the corrosion resistance.
Author

N64-12105* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio
FRICTION, WEAR, AND DECOMPOSITION MECHANISMS FOR VARIOUS POLYMER COMPOSITIONS IN VACUUM TO 10^{-9} MILLIMETER OF MERCURY
Donald H. Buckley and Robert L. Johnson Washington, NASA, Dec. 1963 30 p refs
(NASA TN D-2073) OTS: $0.75
Experiments were conducted with various polymer compositions in vacuum (10^{-9} mm Hg) to determine the friction, the wear, the decomposition mechanisms, and the evaporation rates of one of these materials. The materials included the basic polymers polytetrafluoroethylene (Teflon, PTFE), polychlorotrifluoroethylene (PCFE), and polyimide. In addition, experiments were conducted on these polymers with various fillers incorporated into their structures. Experimental results for PTFE indicate that certain fillers (glass fiber and copper powder) markedly improve the friction and wear characteristics of some polymers (PTFE) in vacuum, while others (molybdenum disulfide, MoS_2) offer essentially no improvement. The apparent nature of wear and the decomposition mechanism for polymer compositions, during the sliding process in vacuum, are considered related to the frictional heat generated at the sliding interface and the means for its dissipation. The polyimide polymer compositions were found to have relatively good friction and wear properties in a vacuum (10^{-9} mm Hg) and are stable in vacuum at ambient temperatures to 500° F.
Author

N64-12322 Massachusetts Inst. of Tech., Cambridge
RESEARCH ON BOUNDARY CONDITIONS OVER THE TOOL-METAL INTERFACE IN PLASTIC-WORKING CONDITIONS Final Report
D. Lee, T. Sata, and W. A. Backofen Jun. 1963 50 p refs
(Contract DA-19-020-ORD-4916)
(WAL-TR-620.5/11(F); AD-409167)
Conditions governing the deterioration of the lubricant film at a tool–metal interface were examined in the plastic compression of aluminum with different combinations of loading method, specimen design, and lubricant. In all cases, a peripheral lubricant failure occurred whenever tools overlapped the specimen. The initiation of a sticking zone occurred with a critical reduction of height; both the magnitude of the reduction and the subsequent growth of the zone were influenced by the nature of lubricant, but not by specimen shape or size. The

effective deformation resistance in compression may be lowered under a cyclic loading schedule. The basis of the lowering is decreased friction in the tool-specimen interface. Author

N64-12330 General Dynamics/Ft. Worth, Tex.
HYDRAULIC SYSTEM – ROYAL LUBRICANT FLUID, PARTIAL EVALUATION TEST
B. H. Mc Daniel 4 Nov. 1963 9 p
(Contract AF 33(657)-11214)
(FTDM-2907; AD-423066)

A partial evaluation was conducted to determine if Royal Lubricant Fluid, Royco 846, is a suitable alternate to Oronite 8515 in the B-58 hydraulic system. Comparisons were made between certain critical properties of Royco 846 and Oronite 8515; they showed that the fluids met applicable specification requirements with the exception of "O" ring compatibility, in which case Royco 846 had a more deleterious effect on Q2825-type "O" rings than did Oronite 8515. Results indicate that measured physical and chemical properties of Royco and Oronite are very similar and that they pass applicable specification requirements. J.R.C.

N64-12400* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
VACUUM LUBRICATION
K. E. Demorest 25 Jan. 1962 25 p refs
(NASA TM X-50798; MTP-P&VE-M-62-2) OTS: $2.60 ph, $0.95 mf

The problem of lubrication of guidance, control, and instrument-type bearings in space is under comprehensive study. This report describes the apparatus used in the study, the environment in which evaluations of inorganic dry film lubricants are being made, and a mathematical model designed to describe the failure mode observed in actual testing. The method of total problem solution is described, in actual testing. The method of total problem solution is described, and the status of current work is discussed in detail. Author

N64-12705 Frankford Arsenal, Philadelphia, Pa.
GREASES NONREACTIVE WITH MISSILE FUELS AND OXIDIZERS
Joseph Messina Sep. 1963 10 p refs Presented in part at the Natl. Symp. of the Soc. of Aerospace Material and Process Engr., Hollywood, Nov. 1962
(FA-A63-10; AD-422788)

Polytetrafluoroethylene, graphite, and silica greases have been found to be essentially inert and unreactive with fuels and oxidizers, including ethyl alcohol, hydrocarbon fuel, unsymmetrical dimethylhydrazine, diethylenetriamine, a 60-40 mixture of the latter two, a 50-50 mixture of hydrazine and unsymmetrical dimethylhydrazine, hydrogen peroxide, inhibited red fuming nitric acid, nitrogen tetroxide, and liquid oxygen. Impact tests in the presence of lox and N_2O_4 indicate nonsensitivity of the greases at high impact energy levels. The greases exhibit adequate lubricating properties, such as oxidation and mechanical stability, antiwear, extreme pressure, and they are not deleterious to many of the conventional elastomers used in missile systems. The polytetrafluorethylene grease was found to be nonexplosive with aluminum when subjected to mutual shear at high loads. Author

N64-12812 Aeronutronic, Newport Beach, Calif.
CHEMICAL CORROSION OF ROCKET LINER MATERIALS AND PROPELLANT PERFORMANCE STUDIES, VOLUME ONE OF TWO Final Technical Report
D. L. Peters 15 Dec. 1963 79 p refs
(Contract NOw-61-0905-c; ARPA Order 22-62)
(U-2384; AD-425888)

The theoretical equilibria resulting from corrosion of refractory nozzle materials by hot combustion gases have been determined for a number of systems of interest. The refractories considered have included graphite (C), tungsten (W), TaC, HfN, TiC, ZrC, ZrB_2 MgO, and HfO_2. The bulk of the corrosion studies have been performed for "pure" species of arbitrary composition, including AlF_3, BF_2, BF_3, BOF, HBO_2, BeF_2, CO, CO_2, HCl, HF, H_2, H_2O, LiF, N_2, and condensed Al_2O_3 and BeO. In general, corrosion effects have been determined for temperatures in the range 1500° to 5000° K, and for a nominal total pressure (usually 1000 psia). Tungsten (W) and graphite (C) generally rank the most resistant of those materials considered. Tungsten has an advantage over graphite for combustion systems containing oxygen or hydrogen, whereas the reverse is true for systems based upon fluorine. Tantalum carbide (TaC) also is reasonably resistant to attack by many systems. No material considered, however, was capable of withstanding high-temperature attack by severely oxidizing atmospheres, such as CO_2 and H_2O. Author

N64-13253 McDonnell Aircraft Corp., St. Louis, Mo.
EVALUATION OF DRY FILM LUBRICANTS ON ALUMINUM AND MAGNESIUM [Final Report]
M. S. Tucker 10 Dec. 1963 44 p
(Contract AF 33(657)-11215)
(A262; AD-425071)

Vendors' literature has recommended the application of dry film lubricants to various aluminum and magnesium alloys. In order to evaluate these recommendations, combinations of several dry film lubricants applied to representative aluminum and magnesium alloys with various surface preparation procedures were tested. Of the combinations tested, the optimum combination of surface pretreatment and dry film lubricant in the case of 7075-T6 aluminum alloy was found to be Electrofilm 5396 lubricant applied to a hard coated surface. When testing HK31A magnesium alloy, the optimum combination was that of Electrofilm 5396 applied to a surface pretreated with a Dow 17 Type I coating, followed by Everlube 620 lubricant applied to the same pretreated surface. Author

N64-13342 Department of Scientific and Industrial Research National Engineering Lab., East Kilbride (Gt. Brit.)
THE EFFECT OF SURFACE TREATMENT ON CORROSION- AND AIR-FATIGUE STRENGTH OF EN40c STEEL
A. C. Low Aug. 1963 39 p refs
(NEL-102)

Corrosion fatigue tests on En40c steel at a tensile strength of 125 to 130 tons/in^2 with nine different surface finishing treatments are reported. Aluminium spraying gave a fatigue-strength at an endurance of 100 million cycles much greater than that for any other treatment. Author

N64-13399* New Hampshire Ball Bearings, Inc., Peterborough
LOW TEMPERATURE MINIATURE BEARING FRICTION STUDY Final Report

Nov. 1963 233 p
(NASA Contract NAS5-2833)
(NASA CR-55268) OTS: $15.50 ph, $7.19 mf

Test data on both running and starting torque levels for lubricated bearings at 21°, −29°, and −54° C are presented. Two distinct quantity levels of both a silicone and a MIL-L-6085A lubricant were used in testing a variety of miniature-size bearings at distinct loading levels up to two pounds, at five separate speeds from starting to 10,000 rpm. The loading was applied by two different means: (1) preloading, using bearings with appropriately sized raceway-face relationships; and (2) deadweight loading of a single bearing. The relationship between viscosity and torque is shown to be considerably different for the two types of oil tested. A discussion of possible reasons why the observed torque of duplex bearing pairs is usually more than the sum of the torque of the two bearings tested separately under equal conditions at room temperature is included. M.P.G.

N64-13405* Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena
SPACE LUBRICATION PROBLEMS AT JPL
R. P. Thompson 2 Sep. 1963 16 p
(NASA Contract NAS7-100)
(NASA CR-53034; JPL-TM-33-148) OTS: $1.60 ph, $0.80 mf

The general approach of the Jet Propulsion Laboratory to spacecraft lubrication problems is presented. Several specific applications on the *Ranger*, *Mariner*, and *Surveyor* programs are discussed. A prediction of future lubrication problems on projects such as *Voyager* is made. Author

N64-13421 Joint Publications Research Service, Washington, D.C.
CORROSION STABILITY OF TITANIUM ALLOYS JOINED BY DIFFUSION WELDING
G. K. Kharchenko and L. N. Yagupol'skaya *In its* Selections on Titanium and its Alloys from Avtomat. Svarka 30 Dec. 1963 p 25–26 ref Transl. into ENGLISH of p 90 (See N64-13417 05-01) OTS: $0.75

The corrosion stability of joints of titanium alloys, made by diffusion welding, exposed to 5% hydrochloric acid was investigated. The corrosion resistance of the welded joint of the alloy did not differ from the stability of the basic metal. Increasing the welding time to more than 5 minutes at the optimum pressure did not influence the corrosion properties of the joint. R.T.K.

N64-14882 Bureau of Mines, Rolla, Mo. Rolla Metallurgy Research Center
HIGH-TEMPERATURE CORROSION STUDIES: A SENSITIVE VOLUMETRIC APPARATUS FOR DETERMINING GAS-SOLID REACTION KINETICS
Robert M. Doerr and Charles C. Myers 1964 17p refs
(BM-RI-6359)

The apparatus described was developed for determining the kinetics of gas–solid reactions at high temperatures by measuring the volume of gas consumed with respect to time. This apparatus consists essentially of a horizontal, precision-bore glass tube connecting a small reaction chamber in a furnace to a large constant-temperature reservoir. A drop of mercury in the tube separates the two sides of the system and serves as an indicator that moves at a speed proportional to the rate of gas consumption. The sensitivity of the apparatus depends inversely on both the density of the gas in the system and the cross-sectional area of the tube; with a tube having an area of 0.079 cm^2, the sensitivity for oxygen at 308 K and 0.5 atm is 20 cm/mg. The reproducibility of data with the volumetric apparatus is good. Author

N64-15226* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio
ADVANCED BEARING TECHNOLOGY
Edmond E. Bisson and William J. Anderson Washington, NASA, 1964 517 p refs
(NASA-SP-38) GPO: $1.75

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14. LUBRICATION OF BEARINGS WITH LIQUID METALS W. J. Anderson (NASA) p 469–496 refs (See N64-15240 07-18)

N64-15228* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio
BOUNDARY LUBRICATION
Edmond E. Bisson *In its* Advanced Bearing Technol. 1964 p 15–61 refs (See N64-15226 07-01) GPO: $1.75

Boundary lubrication is examined in considerable detail. The fundamental principles involved in friction are presented; the various mechanism of wear are discussed; and the effect on friction, wear, and surface damage of adsorbed gases, liquid monolayers, adsorbed and chemisorbed films, and solid solubility of the material combination is shown. Also demonstrated is the relationship of surface films of various types to the friction, wear, and surface damage of sliding metals. C.L.W.

N64-15229* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio
HYDRODYNAMIC LUBRICATION

William J. Anderson *In its* Advanced Bearing Technol. 1964 p 63–96 refs (See N64-15226 07-01) GPO: $1.75

Hydrodynamic bearing applications are considered for two broad classes of bearings—those that support radial loads and those that support thrust or axial loads. Basic hydrodynamic theory is developed, after which applications to the analysis of radial and thrust bearings are discussed. Pressure conditions are examined that must prevail to maintain flow continuity with various film configurations in an effort to evolve a physical understanding of pressure development in an oil film. Investigations are made of the dynamic loads and instabilities in journal bearings. C.L.W.

N64-15230* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio

HYDROSTATIC LUBRICATION

William J. Anderson *In its* Advanced Bearing Technol. 1964 p 97–108 refs (See N64-15226 07-01) GPO: $1.75

A discussion is given concerning the behavior of incompressible-fluid hydrostatic bearings. The characteristics of hydrostatic bearings are discussed and are followed by an analysis of the simplest type of hydrostatic thrust bearing. Compensation is explained, and a description is given of flow through compensating resistances. Determination of bearing operating conditions and of optimum bearing proportions is presented, and a general procedure for obtaining the stiffness of a bearing is given. C.L.W.

N64-15231* Litton Industries, Inc., Woodland Hills, Calif. Guidance and Control Systems Div.

GAS-LUBRICATED BEARINGS

A study is made of the problems that are presented by gas-lubricated bearings. Analysis is complex because the compressibility of gases makes the Reynolds equation nonlinear. Because of this nonlinearity, no general analytical solution to this equation has been found, and approximate methods of solution invariably rely on some means of linearizing the equation. Some methods for obtaining approximate solutions are discussed. Results are presented in forms intended to illustrate the fundamental nature and behavior of gas lubrication. Typical design curves are also given for guides. C.L.W.

N64-15233* Synthetic Fluids Service, Inc., Pacific Palisades, Calif.

LIQUID LUBRICANTS

Douglas H. Moreton *In* NASA, Lewis Res. Center Advanced Bearing Technol. 1964 p 175–201 refs (See N64-15226 07-01) GPO: $1.75

The evolution and development of lubricants is considered in terms of the demanding requirements for liquid lubricants used in aircraft and in space projects. Some important properties are discussed that affect the performance and lifetime of lubricants. These properties are: oxidation, viscosity, thermal stability, volatility, flammability, and hydrolytic stability. C.L.W.

N64-15234* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio

NONCONVENTIONAL LUBRICANTS

Edmond E. Bission *In its* Advanced Bearing Technol. 1964 p 203–257 refs (See N64-15226 07-01) GPO: $1.75

Consideration is given to nonconventional lubricants, such as solids or gases, for operation at high temperatures. The requirements for solid lubricants are discussed; the role of such lubricants in the reduction of friction and wear in operating mechanisms, and the method of application of these lubricants are included. The use of gases containing reactive atoms in the molecule is examined. The problem areas arising from use of reactive gases as lubricants are explored, and some of the solutions to these problems are indicated. C.L.W.

N64-15235* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio

FRICTION AND BEARING PROBLEMS IN THE VACUUM AND RADIATION ENVIRONMENTS OF SPACE

Edmond E. Bisson *In its* Advanced Bearing Technol. 1964 p 259–287 refs (See N64-15226 07-01) GPO: $1.75

A general discussion is given of the friction and bearing problems that result from the exposure of mechanisms to the vacuum or radiation environments of space. Some of the problems can be eliminated by design techniques, such as the use of hermetically sealed systems, but this solution is not always possible because of its complexity and weight disadvantages. The discussion concerns finding better solutions involving self-lubricating materials or limited-life lubricants. C.L.W.

N64-15236* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio

FRICTION OF METALS, LUBRICATING COATINGS, AND CARBONS IN LIQUID NITROGEN AND HYDROGEN

Edmond E. Bisson *In its* Advanced Bearing Technol. 1964 p 289–307 refs (See N64-15226 07-01) GPO: $1.75

Data from friction and wear studies on various material combinations in liquid nitrogen and in liquid hydrogen are discussed. Friction and wear data were obtained with three common metals in liquid nitrogen. These data show that, with types 304 austenitic stainless steel sliding on 304, the wear of the rider specimen is fairly high. With two other steels, type 52100 conventional bearing steel sliding on 52100 and type 440C stainless steel sliding on 440C, wear was lower than with type 304 on 304. The wear and friction properties of austenitic steel with various surface coatings in liquid nitrogen were investigated, and the results are reported. Wear and friction investigations were also conducted with solid bodies of various plastics and of impregnated carbons in liquid nitrogen and liquid hydrogen. C.L.W.

N64-15240* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio

LUBRICATION OF BEARINGS WITH LIQUID METALS

William J. Anderson *In its* Advanced Bearing Technol. 1964 p 469–496 refs (See N64-15226 07-01) GPO: $1.75

Fluids primarily considered for use as cycle working fluids are mercury and the alkali metals—rubidium, potassium, sodium, and lithium. The properties of liquid metals that can affect the performance of bearings are their low viscosity and their corrosivity. The alkali metals reduce most metal oxides, and the high mass density of mercury tends to promote erosion because of high particle inertia. The discussion includes types of bearings, bearing experiments, properties of bearing materials, properties of liquid metals, and operating problems. C.L.W.

N64-15376 Aerojet-General Corp., Azusa, Calif. Von Karman Center

STRESS-CORROSION CRACKING OF HIGH-STRENGTH ALLOYS Eleventh Quarterly Progress Report, 1 Oct.-31 Dec. 1963

R. B. Setterlund and A. Rubin Jan. 1964 21 p refs
(Contract DA-04-495-ORD-3069)
(Rept. 0414-02-2; AD-429296)

The current program status is: (1) Triplicate bent-beam U-bend specimens of RMS 200 heat number 3960523, Vascomax 250 heat number 07868, Marvac 18 heat number C56858, and Vascomax 300 heat number 07268 were exposed to aerated distilled water, aerated 3%-sodium chloride, and 140° F water-saturated air. The most severe test condition was found to be water-saturated air. All specimens of the four heats failed. (2) Ambient tests in distilled water at 120° F have been initiated on 18%-nickel maraging steel, a low-alloy martensitic steel (D6AC), and hot-worked die steel (Vascojet 1000). (3) A preliminary test for the chemical changes occurring in 18%-nickel maraging steel has been conducted on a center-notched specimen of heat 3960502. As the stresses at the crack tip increased by deadweight loading of the specimen, the metal was found to become more chemically active. (4) Three coating systems, polyurethane, zinc, and inhibited epoxy, are being evaluated on a single heat of 18%-nickel maraging steel. I.v.L.

N64-16034* Mechanical Technology Inc., Latham, N.Y.
LUBRICATION ANALYSIS IN TURBULENT REGIME Second Quarterly Report
E. B. Arwas, F. K. Orcutt, and J. H. Vohr 24 Jan. 1964 83 p refs
(NASA Contract NASw-771)
(NASA CR-55803; MTI-64TR3) OTS: $8.10 ph, $2.69 mf

Two auxiliary computer programs were written to facilitate the reduction of the dynamic-load test data. The first program uses the readings of each set of eight data points to compute the corresponding values of the eight spring and damping coefficients, for direct comparison with the theoretical values of the coefficients. The second program is based on an analysis (presented in an appendix) wherein the sets of eight spring and damping coefficients are reduced to sets of four equivalent spring and damping coefficients. An initial set of steady-state load tests were conducted with the 360° plain circular bearing with an oil-inlet feed hole at the top of the bearing. Steady-state load tests were conducted with a 4-in.-diameter, 4-in.-long, 100° partial-arc bearing with 2×10^{-3} in./in. clearance ratio, over a range of mean clearance Reynolds numbers from 1,665 to 8,314. The agreement between experimental and theoretical load capacity was generally very good and provided encouraging verification of the theory. Transition from a laminar to a vortex regime was obtained at eccentricity ratios from 0 to 0.891; the resulting data are presented. A derivation of the linearized turbulent lubrication equation is also presented in an appendix. P.V.E.

N64-16050 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.
ON THE MECHANISM OF THE PROCESS OF MAGNETICALLY TREATING WATER
A. N. Kirgintsev, V. M. Sokolov, and N. I. Burlakova 10 Oct. 1963 13 p refs Transl. into ENGLISH from Izv. Sibirsk. Otd. Akad. Nauk SSSR (Novosibirsk), no. 1, 1963 p 25–31
(FTD-TT-63-964/1+2; AD-423209)

A study was made of the kind and amounts of corrosion products that are acquired by water and of the extent to which these products affect sludge formation. R.T.K.

N64-16087 SKF Industries, Inc., King of Prussia, Pa. Engineering and Research Center
INFLUENCE OF LUBRICATION ON ENDURANCE OF ROLLING CONTACTS Progress Report No. 8, Jun. 22, 1963-Sep. 22, 1963
E. F. Brady, J. Mc Cool, L. B. Sibley, and R. Valori [1963] 73 p refs
(Contract NOw-61-0716-C)
(AL64T003; AD-430287)

Rolling 4-ball endurance conductivity, and wear tests were continued. Radiotracer wear data were obtained at low-speed (2,500 rpm) endurance test conditions. Conductivity tests were also performed at this and adjacent speeds. A blended Primol-decalin lubricant with 15.4 cs viscosity at 34° C was used. It was found that asperity contacts are not maintained through this oil at 2,500 rpm once the balls have been thoroughly run in. For this reason, a thinner oil is being blended and will be used in future tests. Author

N64-16259 Bettis Atomic Power Lab., Pittsburgh, Pa.
EFFECTS OF SILICON, NITROGEN, AND OXYGEN ON THE CORROSION AND HYDROGEN ABSORPTION PERFORMANCE OF ZIRCALOY-2
S. Kass, J. D. Grozier, and F. L. Shubert Nov. 1963 45 p refs
(Contract AT(11-1)-GEN-14)
(WAPD-283) OTS: $1.00

The corrosion properties of Zircaloy-2 have been shown to be altered by the presence of small quantities of silicon or nitrogen. Increasing nitrogen contents of the alloys are noted to produce increased total corrosion and decreased time for transition in the weight gain–time kinetics. Silicon additions tend to produce higher weight gain values but, at the same time, render the alloy less susceptible to hydrogen absorption during aqeuous corrosion exposure. The silicon additions, furthermore, minimize the very deleterious effects upon corrosion resistance that occur due to slowly cooling the alloy through or hot working in the alpha plus beta region. A marked dependence of the hydrogen absorption by Zircaloy-2 upon prior thermal treatment was also observed. Author

N64-16427 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.
THE FEASIBILITY OF THE USE OF LIQUID-METAL FUSIONS AS LUBRICANTS
A. N. Tynnyy, M. I. Chayevskiy, and V. A. Teterskiy 15 Aug. 1963 10 p refs Transl. into ENGLISH from a Russian book "Voprosy Mashinovedeniya i Prochnosti v Mashinostroyenii" Kiev, Izd. Akad. Nauk Ukr. SSR, v. 9, no. 8, 1962 p 41–46
(FTD-TT-63-574/1+2+4; AD-417413)

The use of fusions of low-melting metals as lubricants in sliding bearings and worm reduction gears is proposed. This use of fusions will eliminate the need for special devices for cooling friction components in high-temperature installations lubricated with mineral oil, and to considerably increase the efficiency of friction pairs. Author

N64-16535 Oak Ridge National Lab., Tenn.
CORROSION OF REFRACTORY METALS BY LITHIUM
James Richard Di Stefano (M.S. Thesis—Tenn. U.) Mar. 1964 92 p refs
(Contract W-7405-ENG-48)
(ORNL-3551) OTS: $2.00

Investigations were conducted on the presence of small quantities of oxygen in niobium and tantalum and the subsequent decrease of their resistance to dissolutive attack by lithium. Penetration of niobium and tantalum by lithium results in formation of a complex corrosion product in grain boundaries and crystallographic planes, reducing the tensile strength and ductility. It was shown that the addition of zirconium was effective in eliminating lithium penetration. Alloys that were heat treated in such a way that oxygen was tied up as zirconium oxide did not corrode. C.L.W.

N64-16637 General Dynamics/Fort Worth, Tex.
MATERIAL – CORROSION PROTECTION COATINGS – FOR USE IN F-111 INTEGRAL FUEL TANKS – SCREENING TESTS OF
G. M. Warren 15 Jan. 1964 5 p
(Contract AF 33(657)-11214)
(FTDM-3126; AD-430329)

The performance and reliability requirements of the F-111 airplane necessitate the use of corrosion prevention coatings in the integral fuel tanks. The coatings investigated for this purpose were screened by selected tests that simulated the F-111 fuel-tank environment, in order to eliminate the inadequate materials from the more extensive and costly evaluation tests. The coatings tested, environmental conditions, and test results are presented in tabular form. R.T.K.

N64-16763* Michigan U., Ann Arbor Lab. for Fluid Flow and Heat Transport Phenomena
CAVITATION DAMAGE MEASUREMENTS IN MERCURY BY RADIOTRACER ANALYSIS Technical Report No. 10
Willy Smith, Juan M. Nieto, and Frederick G. Hammitt Oct. 1963 78 p refs
(NASA Grant NsG-39-60; ORA Proj. 03424)
(NASA CR-53112; Rept. 03424-10-T) OTS: $7.60 ph, $2.54 mf

The development of a method of continuous measurement of the wear of metal specimens submitted to a constant cavitation field by using radiotracer techniques was attempted. Samples of type 302 stainless steel and type 1010 carbon steel were irradiated in a nuclear reactor and then placed in a cavitating venturi in a closed-loop mercury facility. It was discovered that due to the arrangement of the centrifugal pump, the radioactive particles of steel separate at once and tend to be trapped on the liquid surface of the pump sump. By dismantling this sump, about 6% of the measured weight loss of the carbon steel specimens was recovered. This radioactive material was collected and filtered, which allowed a classification by size. Differential curves obtained for the different size debris indicate that the constituents do not vary with particle size.
Author

N64-16786 Mc Donnell Aircraft Corp., St. Louis, Mo.
METALLURGICAL EXAMINATION OF HASTELLOY X FOR CORROSION
G. Morris 10 Mar. 1964 4 p
(Contract AF 33(657)-11215)
(A468; AD-431508)

Three pieces of Hastelloy X sheet material were pickled for 1 hour in a nitric–hydrofluoric solution after being cooled slowly from 2,150° F in the following manners: (1) air cooled; (2) cooled between two steel plates that were preheated to 2,150° F; and (3) cooled in a box of heated mica. Intergranular attack was evident in each of the three specimens examined. Mica appeared to produce the most severe intergranular attack. Air cooling appeared to produce the least amount of surface attack of the three cooling methods evaluated. Author

N64-16792 Mechanical Technology, Inc., Latham, N.Y.
PRELIMINARY RESULTS ON THERMAL-ELASTOHYDRODYNAMICS
H. S. Cheng 21 Oct. 1963 35 p refs
(Contract Nonr-3729-(00) (FBM))
(MTI-63TR48; MTI-23(1-63); AD-423720)

Theoretical results are obtained for the pressure, temperature, and film thickness between two lubricated rolling and sliding cylinders. The preliminary results indicate that the temperature has a significant influence upon the pressure and film shape, particularly for substantial amount of sliding. The pressure and film shapes also indicate strongly that the fatigue is more important at low speed than at high speed. Author

N64-16980 Shell Development Co., Emeryville, Calif.
BEARING LUBRICATION UNDER SEVERE CONDITIONS Bimonthly Progress Report, Dec. 1963-Jan. 1964
29 Feb. 1964 20 p
(Contract NOw-63-0466-c)
(S-13910, AD-431873)

The possibility of obtaining bearing failure (high bearing deposits) by prolonged bearing operation with an increased oil sump charge was investigated. Failure by loss of lubricant was obtained as in all previous tests with various lubricants. Increasing the lubricant charge increased the total operating time from 36 1/2 hours (148 passes) to 114 1/4 hours (224 passes), but there was practically no difference in the operation of the bearing. For a system that fails by loss of lubricant, two equations are derived that relate initial lubricant charge, termination lubricant charge, lubricant recovery rate, and lubricant flow rate with total operating time and number of lubricant passes. The experimental values of time and number of passes for the current tests are in excellent agreement with values predicted by the derived expressions. A heated dual-tank reservoir to investigate the effect of operating with a high bulk oil temperature was built and is presently in operation. Author

N64-17095 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.
TWO EXAMPLES OF MACHINING WEAR-RESISTING AND HIGH-TEMPERATURE CORROSION-RESISTANT ALLOYS
A. V. Pankin *In its* The Working of Heat-Resistant Alloys 26 Nov. 1963 p 235 250a (See N64-17076 09-17)

Descriptions are given of two specific examples of machining difficult-to-machine alloys: the first concerns the solutions of extremely difficult problems encountered in machining of components used in the aviation and automobile industries, and the second pertains to the search for the improvement of methods employed for studying and solving new problems of a theoretical or practical order that are encountered in difficult cases. In both cases it was proven that derivation of the speed-vs-service life and speed-vs-cutting depth-vs-feed relationships from the wear–time curves is more reliable than derivation of the same dependencies by employing visual criteria. In both examples the specific industrial problems, which hold both technical and economic interest for the aviation and automobile industries, were solved by using special types of hard alloys and active lubricating coolants. C.L.W.

N64-17227* Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena
WEAR ANALYSIS OF NONLUBRICATED SPUR GEARS
James Clyde Randall Jun. 1963 125 p refs
(NASA Contract NAS7-100)
(NASA CR-53197; JPL-TM-33-139) OTS: $10.10 ph, $3.95 mf

This paper establishes a method of determining wear rates for nonlubricated, fine-pitch, precision instrument spur gears. The concepts of wear and the problems associated with applying these concepts to the unique action of spur-gear surfaces are discussed. Wear data for test gears run at various loads and speeds are collected to determine the wear rates for the

most popular materials in use today. A method is proposed for using the wear data to select between two popular methods of computing dynamic load; namely, the American Standards Association Specification B6.11-1951 and Tuplin's method, both of which are slight modifications of Buckingham's original spur-gear formulas. Author

N64-17276 North American Aviation, Inc., Downey, Calif. Space and Information Systems Div.
AEROSPACE CORROSION AND MOISTURE PROBLEMS: A REVIEW OF THE RESEARCH REPORTS [1960-1964]
J. R. Linger 20 Jan. 1964 268 p 634 refs
(SID-64-11)

This report is a bibliography of research reports on corrosion and moisture problems in the Aerospace industry published from 1960 to date. Foreign language references are included. Author

N64-17565* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio
MECHANISM OF LUBRICATION FOR SOLID CARBON MATERIALS IN VACUUM TO 10^{-9} MILLIMETER OF MERCURY
Donald H. Buckley and Robert L. Johnson Repr. from ASLE Trans., v. 7, 1964 p 91-100 refs Presented at the Lubrication Conf., Rochester, N.Y., 15-17 Oct. 1963
(NASA RP-146)

The friction and wear characteristics of various carbon materials sliding on metals and aluminum oxide were determined in vacuum at ambient pressures from 760 to 10^{-9} mm Hg. The friction and wear experiments were conducted with a hemispherically tipped carbon rider, under a load of 1,000 sliding on various disks rotating at a speed of 390 fpm. The results of this investigation show that additional research on carbon in vacuum is warranted. Adsorbed surface films present on both carbons and metal, as well as the presence of oxide on metals, appreciably influenced the friction and wear obtained with carbons in vacuum. Author

N64-17691* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
A LITERATURE SURVEY OF THE CORROSION OF METAL ALLOYS IN LIQUID AND GASEOUS FLUORINE
J. H. Cabaniss and J. G. Williamson 31 Dec. 1963 31 p refs
(NASA TM X-54612; MTP-P&VE-M-63-21) OTS: $3.60 ph, $1.13 mf

A literature survey on the corrosive nature of both liquid and gaseous fluorine is presented. This paper contains general information regarding: (1) chemical reaction of fluorine with various metallic materials; (2) conditions under which these materials can be used with fluorine; (3) results of corrosion tests that have been conducted on various materials over the temperature range of −320° F (−196° C) to 1,300° F (704° C). Author

N64-17780 Hydronautics, Inc., Laurel, Md.
ON THE ROLE OF CORROSION IN CAVITATION DAMAGE
Sophia Waring, H. S. Preiser, and A. Thiruvengadam Feb. 1964 37 p refs
(Contract Nonr-3755(00) FBM)
(Tech. Rept. 233-4; AD-433061)

The interacting influence of corrosion on cavitation damage was studied quantitatively using a magnetostrictive device. The relationship between the rate of weight loss and the amplitude of oscillation for 1020 mild steel became modified as the NaCl concentration was increased. When 1100-F aluminum was used, this relationship was not affected. An attempt was made to estimate the contribution of electrochemical corrosion to total damage by four methods: (1) static polarization measurements; (2) dynamic polarization measurements; (3) short-duration pulsing technique; and (4) long-duration pulsing technique. The electrochemical corrosion rates thus estimated are very small compared to the total rate of damage. Author

N64-17840 Phillips Petroleum Co., Idaho Falls, Idaho Atomic Energy Div.
THE DESIGN OF A DYNAMIC CORROSION AND CHEMICAL CONTROL TEST LOOP AND PRELIMINARY OUT-OF-PILE TEST RESULTS
William F. Zelezny, ed. Natl. Reactor Testing Sta., 12 Jul. 1963 93 p refs
(Contract AT(10-1)-205)
(IDO-16812) OTS: $2.00

A project having the objective of developing and demonstrating in actual operation a system for the chemical control of nuclear reactors has been carried to partial completion. The design developed by this project embodies a circulating loop in the ETR, replacing one of the conventional mechanical control rods. Control of the reactor is to be effected by varying the concentration of a boric acid solution circulating through the loop. A second objective of the project is the performance of long-term corrosion tests on boric acid–aluminum alloy combinations. This report describes the overall loop design and the means by which this design was developed. These include critical facility measurements, analog computer calculations, hydraulic and heat-transfer computations, and the construction and operation of an out-of-pile mockup loop to determine the dynamic characteristics of the loop. Author

N64-17986 Bureau of Mines, Norris, Tenn.
CORROSION RESISTANCE OF DIBORIDES IN THE PSEUDOBINARY SYSTEM TiB_2-CrB_2
Gilbert M. Farrior 1964 25 p refs
(BM-RI-6418)

Tests of resistance to molten metals, to oxidation at elevated temperatures, and to various chemical reagents were made for a series of compositions in the TiB_2-CrB_2 subsystem. There was no noticeable difference in reaction with molten metals of the various compositions in the $(Ti,Cr)B_2$ series. The oxidation tests were (1) a rising-temperature test in which the specimen temperature was increased 4° C per minute to 1,200° C and (2) a constant-temperature test in which the specimen temperature was held constant at 1,000° C. Compositions near $Ti_{0.6}Cr_{0.4}B_2$ had the best oxidation resistance. The chromium-rich alloys showed marked superiority to the titanium-rich alloys in resistance to corrosion by the chemical agents investigated. The chemical reagents used were sulfuric, nitric, and hydrochloric acids and sodium hydroxide of different concentrations. Author

N64-18029 Monsanto Research Corp., Everett, Mass. Boston Lab.
EFFECTS OF SELECTED STRAINS OF MICROORGANISMS ON THE COMPOSITION OF FUELS AND LUBRICANTS Technical Documentary Report, 1 Sep. 1962-31 Aug. 1963
John O. Smith, Glenn R. Wilson, Dolph Klein, and E. C. Harrington Wright-Patterson AFB, Ohio, AF Aero Propulsion Lab., Mar. 1964 76 p refs
(Contract AF 33(657)-9814)
(RTD-TDR-63-4117, Pt. 1; AD-433250)

A total of 35 jet fuel samples, 1 lubricant, and 44 pure hydrocarbons have been screened for growth and nongrowth support for 16 aerobic bacterial cultures. Thirty of these jet

fuels, the 1 lubricant, and 11 of the pure hydrocarbons were also screened against 5 fungal cultures for growth- and non-growth-supporting properties. Only 1 of the 35 jet fuel samples completely resisted bacterial attack. The remainder varied in their growth support of the bacterial cultures. All 30 jet fuel samples, except a contaminated JP-4 sample, showed varied growth support for the 5 fungal cultures. The 1 lubricant sample completely resisted attack by 4 of the 5 fungal cultures. Only n-cetane, from among the 11 pure hydrocarbons screened (napthenes and n-cetane) supported fungal growth. Preliminary analysis of the completely bacteria-resistant jet fuel samples showed that it contained no n-alkanes. Author

N64-18337 Thompson Ramo Wooldridge, Inc., Cleveland, Ohio TAPCO Div.
SUNFLOWER SOLAR RANKINE SYSTEM: MERCURY CORROSION AND CORROSION PRODUCT SEPARATOR STATUS SUMMARY
16 Apr. 1963 42 p
(ER-5302)

Test results are presented for Sunflower package developmental test rigs fabricated from a 300 series stainless steel. It is concluded that the use of a more corrosion-resistant material throughout the system, supplemented by a preconditioning operation, and incorporating corrosion product trapping provisions, should reduce to about 0.01 in^3 the amount of corrosion products that would be generated in the system in one year's operation. Throughout all tests on the Sunflower package, no detrimental corrosion or deposition occurred in the bearing areas. The freedom from contamination and deposition of corrosion products in these areas is linked with the observation that flow restrictions occur in portions of the system where cold sections of the hardware exist in the flow stream, i.e. when the material of the restriction is colder than the flowing mercury. It is noted that whereas it is difficult to clear up blockages that have already occurred, heat applications can effectively prevent an accumulation of contaminates in the system. E.W.

N64-18701 SKF Ind., Inc., King of Prussia, Pa. Research Lab.
INFLUENCE OF LUBRICATION ON ENDURANCE OF ROLLING CONTACTS Progress Report No. 7, 22 Mar. 1963-22 Jun. 1963
T. Tallian, Y. P. Chiu, and E. F. Brady [1963] 26 p refs
(Contract NOw-61-0716-c)
(AL63TO18; AD-417518)

Conductivity tests were conducted at low and high speeds in order to determine speeds, loads, and viscosity parameters for conditions of no film and essentially complete film lubrication, respectively, at the ball-to-ball contacts in a rolling four-ball test configuration. Data from these tests are still in the process of interpretation. The dynamic two-ball tester, designed to provide X-ray measurements of lubricant film thickness and contact profiles in a two-ball rolling contact, is described. Details of the X-ray mechanism, drive system spindles, fabrication and alignment procedure, the hydraulic system, and the electrical control system are given. Author

N64-19153 Alpha Molykote Corp., Stamford, Conn.
PREVENTION OF CORROSION WHEN USING MOLYBDENUM DISULFIDE LUBRICANTS
[1964] 4 p refs
(Spec. Print 477)

Several factors were found that must be considered in the formulation of MoS_2-based, extreme-pressure greases and oils if the material is to have assured corrosion-preventive properties. First, the purity of the powder must be carefully controlled and then the factor of particle size must be evaluated. Finally, when required, the proper corrosion inhibitor or other additives must be selected and blended with the lubricant in the required proportions and compounded, not only so that the essential qualities of the lubricant are preserved but also so that the functional properties of the molybdenum disulfide are not impaired but, rather, are enhanced. Investigation of the merits of p-nonyl phenoxy acetic acid as a rust inhibitor was conducted. A low-concentration, fine-powder MoS_2 grease was selected as the subject of a corrosion test. One sample was blended with 1% of the inhibitor, and the other was used as a test control. The bearing lubricated with the inhibited grease showed no evidence of rusting, whereas the control bearing was partially corroded. It was, therefore, possible to nullify completely any rust-inducing tendencies of MoS_2 greases. R.T.K.

N64-19364* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
ADAPTATION OF A MoS_2 "IN SITU" PROCESS FOR LUBRICATING SPACECRAFT MECHANICAL COMPONENTS
Charles E. Vest *In* AIAA 5th Ann. Structures and Mater. Conf. 1964 p 120-125 refs (See N64-19359 12-01) AIAA: $7.50 members, $15.00 nonmembers

This "in situ" process consists of surface activation treatment—electrodeposition of an MoO_3 complex ion onto the substrate surface, and conversion of this film to MoS_2 in an atmosphere of H_2S gas at 400 psig pressure and 195° C, for an exposure period of 4 to 8 hours. From the work performed and the test results, it is concluded that this process is adaptable to space components. It is also concluded that: (1) the film thickness can be controlled within $\pm 35\,\mu$ inches; (2) the average coefficient of friction of this film is 0.05 or less, and is comparable to or the same as MoS_2 powder and lower than bonded MoS_2 films; (3) the film can be easily and safely deposited onto a number of common spacecraft materials; (4) the film has a better wear life than sodium silicate bonded MoS_2, slightly better wear life than a burnished MoS_2 powder, and a somewhat poorer wear life than epoxy bonded MoS_2; and (5) the film follows the surface contour and fills up the smallest crack, lap, seam, or indentation. P.V.E.

N64-19447 Joint Publications Research Service, Washington, D.C.
TRANSLATIONS ON COMMUNIST CHINA'S SCIENCE AND TECHNOLOGY, NO. 80
27 Apr. 1964 13 p refs Transl. into ENGLISH of 2 articles from K'o-hsueh T'ung-pao (Peking) no. 12, 1963 p 40-41, no. 1, 1964 p 81-82
(JPRS-24350; OTS-64-31157) OTS: $2.00

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N64-19449 Joint Publications Research Service, Washington, D.C.
MAGNIFICATION OF 18-8 STAINLESS STEEL CRYSTAL CORROSION IN LOW CHROMIUM AREAS

Hua Pao-ting, Shen Hsing-su, Tsou Chung-chien, Li Kuei-chish, and Hsi Shu-yun *In its* Transl. on Communists China's Sci. and Tech., No. 80 27 Apr. 1964 p 6-10 refs (See N64-19447 12-01) OTS: $2.00

A sample of 18-8 steel [C (0.125%), Cr-17(71%), Ni(8.2%), Mn (0.84%), and Si (0.32%)] was treated at 650° C for 2 hours, then placed in a $1NH_2SO_4$ solution at 25° C, and made to carry an electric current by maintaining a regulated potential across the specimen of +134 millivolts. Analysis of the curve of polarization showed that under the electric current, low temperature, and solution, the crystals could remain completely pure while the crystal boundaries are activated. After the experiment was completed, the surface of the steel retained its metallic luster, and no crystal corrosion was observed when the specimen was placed under a 500-X microscope. After the specimen was slightly bent, however, crystal corrosion was observed. P.V.E.

N64-19767 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.
ON THE PASSIVATION AND CORROSION RESISTANCE OF STAINLESS STEEL
Milan Prazak and Vilem Prazak 5 Mar. 1964 21 p refs Transl. into ENGLISH from Hutnicke Listy (Prague), v. 11, no. 2, 1956 p 91-97
(FTD-TT-64-20/1+2; AD-433196)

Solving the basic problems of the electrochemical corrosion mechanism and establishing corrosion-resistance conditions of refined steel with a chromium content are discussed. The causes of stainless steel corrosion resistance are given. With the method of potential polarization, it is possible to establish values for corrosion behavior of stainless steel. The resulting data are helpful in investigating corrosion resistance. Using both theory and accurate instruments, the development of corrosion-resistant alloys is greatly simplified. G.D.B.

N64-19944* General Electric Co., Cincinnati, Ohio Missile and Space Div.
MATERIALS FOR POTASSIUM LUBRICATED JOURNAL BEARINGS Quarterly Progress Report No. 2, Jul. 22, 1963-Oct. 22, 1963
R. G. Frank, ed. [1963] 40 p refs
(NASA Contract NAS3-2534)
(NASA CR-54007) OTS: $3.60 ph

NASA approved 14 materials for inclusion in the program. These include one nonrefractory alloy, two refractory metals and alloys, three nonrefractory metal-bonded carbides, four refractory metal-bonded carbides and four pure compounds. The literature search and data compilation of properties of the candidate materials was continued. Preliminary test plans for seven test programs were submitted to NASA for approval, including potassium purification and analyses, corrosion, dimensional stability, hot hardness, compression, thermal expansion, and friction and wear in vacuum, and that approval was received. Component parts of the purification train have been ordered. The design for the isothermal capsule corrosion facility was completed, and detail drawings are being prepared. The design for the dimensional stability test program was initiated. The fabrication of the vacuum chamber for the compression testing facility was completed. The design for the high vacuum friction and wear tester was completed, and detail drawings are in process. The high vacuum chamber and pumping system was checked out at 6×10^{-10} torr—cold, dry, and empty. Author

N64-19952 Baird-Atomic, Inc., Cambridge, Mass.
LUBRICATION IN SPACE
Warren A. Salmon and Henry Scammell (Little (Arthur D.), Inc.), ed. [1963] 122 p refs Proceedings of a symp. held at Cambridge, Mass., 7-9 Feb. 1962

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N64-20037 General Dynamics/Fort Worth, Tex.
MATERIALS — LUBRICATING OIL — GTO-915 — IRRADIATION UNDER STATIC AND DYNAMIC CONDITIONS — EFFECTS OF
R. H. Mc Daniel 15 Apr. 1964 25 p
(Contract AF 33(657)-11214)
(FGT-2767; AD-436701)

A dynamic pump loop system, was operated for 20 hours in a nonnuclear environment to establish base line data on functional fluid GTO-915, high-temperature jet-engine lubricating oil. The system was then subjected to operation in a nuclear environment. Dynamic and static oil samples were taken periodically during both runs to determine physical and chemical property changes of the test fluids. Average bulk oil temperature within the static and dynamic reservoirs was 300° F. System operation and fluid characteristics, with the exception of increased coking tendency at 700° F, were satisfactory during the preirradiation run. System operation was also satisfactory during the 23-hours irradiation run. Properties most adversely affected were neutralization number, thermal, and oxidation stabilities and lubricating characteristics. Moderate viscosity increases were also noted. However, the fluid displayed good flash point and shear stability characteristics during the exposure run. Degradation of GTO-915 was definitely the result of synergistic effects of operation plus irradiation. Author

N64-20043 General Dynamics/Fort Worth, Tex.
MATERIAL — STEEL SANDWICH PANELS — SILVER, COPPER, LITHIUM, BRAZED — CORROSION INHIBITOR FOR — DEVELOPMENT OF
E. W. Turns 15 Apr. 1964 21 p
(Contract AF 33(657)-11214)
(FGT-3066; AD-436735)

Test panels of Ag-Cu-Li brazed 17-7 steel were exposed to 650° F air for one week and then treated in triplicate with

10 different test corrosion inhibitors. These panels and uninhibited controls were then exposed for 6 weeks at the specified humidity. Potassium chromate, sodium-metasilicate, and phosphoric acid showed promise as inhibitors. Phosphoric acid was especially effective and eliminated virtually all corrosion. Since phosphoric acid is an active mineral acid, additional tests were conducted to determine the effects of removing the excess acid. It was shown that rinsing or neutralization treatment of the phosphoric acid inhibited panels prior to drying at 650° F removes the inhibitive effect. Author

N64-20047 General Dynamics/Fort Worth, Tex.
MATERIALS – SOLID FILM LUBRICANTS – IRRADIATION BY THE GTR AND Co^{60} SOURCES – EFFECTS ON WEAR-LIFE
J. W. Head 15 Apr. 1964 7 p
(Contract AF 33(657)-11214)
(FTDM-3006; AD-438132)

Three solid-film lubricants were tested to determine wear-life characteristics after irradiation at ambient chamber temperature in the Ground Test Reactor (GTR). No significant effects were produced. Testing was not done for effects of cobalt 60. A.W.

N64-20049 General Dynamics/Fort Worth, Tex.
MATERIALS – CERAMIC BONDED SOLID FILM LUBRICANTS – EFFECTS OF IRRADIATION AND HIGH TEMPERATURE ON
J. W. Head 15 Apr. 1964 8 p
(Contract AF 33(657)-11214)
(FTDM-3053; AD-438137)

Film A (molybdenum disulfide + lead sulfide + boric oxide) would operate with friction coefficients of 0.4 or less only at 1000 F and so was tested only at that temperature both before and after irradiation. There was no significant effect due to exposure to reactor radiation. Film B (calcium fluoride + oxide frit) was unable to carry the prescribed load at any temperature, and so was deleted from the program. No significant effects were noted from wear life determinations conducted at 600° F and 1200° F on Film C (molybdenum disulfide + graphite + sodium silicate). A.W.

N64-20192* National Aeronautics and Space Administration Lewis Research Center, Cleveland, Ohio
FRICTION AND WEAR OF NICKEL-ALUMINUM ALLOYS AND SOME SULFUR-MODIFIED STEELS IN VACUUM TO 10^{-9} MILLIMETER OF MERCURY
Donald H. Buckley and Robert L. Johnson Washington, NASA, May 1964 21 p refs
(NASA TN D-2307) OTS: $0.50

The friction, wear, and welding characteristics of 52100, 440-C stainless steel, and M-2 tool steel with and without the addition of 0.4- to 0.5-percent sulfur were studied in vacuum (10^{-9} mm Hg). Studies were also conducted with simple nickel-aluminum binary alloys in vacuum. Friction and wear studies were made with a hemispherical (3/16-in.-rad.) rider, which slides in a circular path on the flat surface of a rotating metal disk of the same metal. The specimens in vacuum had a load of 1,000 g (2.2 lb), a sliding velocity of 75 to 1960 ftpm, and a temperature of 75° F. The addition of 0.4- to 0.5-percent sulfur to 52100, 440-C, and M-2 reduced friction, wear, and welding normally encountered with these alloys in vacuum. With nickel-aluminum binary alloys friction and wear improved with the addition of aluminum to nickel. A 16.4-percent-aluminum-nickel alloy exhibited lower friction and less wear and metal transfer in vacuum than did two commercial nickel-base alloys. Author

N64-20301 Aberdeen Proving Ground, Md. Coating and Chemical Lab.
THE CORROSIVITY OF MAGNESIUM ALLOYS IN 5 AND 20 PERCENT SALT FOG ENVIRONMENTS
A. P. De Marco 13 Mar. 1964 33 p refs
(CCL-161; AD-438984) OTS: $1.00

The results and analysis of a factorial experiment are presented, undertaken to determine the corrosivity of variously protected magnesium alloys when exposed to 5% and 20% salt fog environments. The investigation considers two lots of magnesium sand castings and one lot of magnesium sheet alloy, each given two preparatory chemical pretreatments and coated with three different batches of a thermosetting epoxy resin coating using two methods of application. For cast magnesium alloy, corrosion was noted to vary widely within and between the alloy lots investigated and their pretreatments. The relative corrosivity of the exposure environments on the alloy lots depended on the pretreatment used. For the more corrosion resistant pretreatment, 20% salt fog was substantially more corrosive than 5%. For the less effective pretreatment, no significant difference in the corrosivity of the two salt fog environments was apparent. For sheet magnesium alloy, corrosion was significantly less extensive and less variable than for cast alloy in both exposure environments. Regardless of the pretreatments, coatings used, and methods of application, 20% salt fog was found substantially more corrosive than 5%. Author

N64-20577* National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio
LUBRICANTS AND MECHANICAL COMPONENTS OF LUBRICATION SYSTEMS FOR A SPACE ENVIRONMENT
Robert L. Johnson and Donald H. Buckley Washington, NASA, 1964 24 p refs Presented at the Am. Soc. of Lubricating Engr. Aerospace Council Meeting, Chicago, 28 May 1964
(NASA TM X-52031) OTS: $2.60 ph

This report concerns: (1) design criteria for rolling-contact bearings, sliding bearings, gears, and dynamic seals; (2) component designs for various types of bearings and gears; (3) materials for bearings surfaces; (4) lubrication methods and materials; (5) proof testing of lubricated components; (6) the survey and determination of vacuum evaporation characteristics for lubricated materials; and (7) a review of the state-of-the-art of lubricants and mechanical components of lubrication systems for a space environment I.v.L.

N64-20698 Hanford Atomic Products Operation, Richland, Wash. Reactor and Fuels Lab
EFFECT OF OXIDE DISSOLUTION AND HEAT TRANSFER ON THE CORROSION OF ALUMINUM FUEL CLADDING
D. R. Dickinson and R. J. Lobsinger Dec 1963 20 p refs
(Contract AT(45-1)-1350)
(HW-77529)

In-reactor corrosion rates of aluminum-clad fuel elements in high-temperature deionized water are much higher than measured in isothermal out-of-reactor tests at the same pH and surface temperature. This discrepancy is explained in terms of oxide dissolution and heat transfer. In a nonisothermal in-reactor system, the temperature, and hence the solubility, of aluminum oxide corrosion product, is greater at the fuel-element surface than at the cooler portions of the primary loop. This results in significant dissolution of the protective aluminum oxide from the fuel element and a large increase in its corrosion rate. There was good agreement between calculated dissolution rates and measured corrosion rates. In addition to promoting dissolution, heat transfer also raises the cladding

temperature and corrosion rate because of the temperature drop across the surface oxide film. Measurements of cladding temperature showed particularly high temperature drops in in-reactor tests at reduced pH where a heavy layer of crud (deposited iron oxides) was present on the fuel surface. Author

N64-20783* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio
PROCEEDINGS OF THE NASA-AEC LIQUID-METALS CORROSION MEETING, VOLUME I
Washington, NASA, 1964 292 p refs Held at Lewis Res. Center, Cleveland, Oct. 2–3, 1963
(Sponsored by NASA and AEC)
(NASA SP-41) OTS: $5.00

CONTENTS:

N64-20785* Brookhaven National Lab., Upton, N.Y.
LIQUID-METAL CORROSION AS A SOLUTION PHENOMENON
John R. Weeks *In* NASA. Lewis Res. Center Proc. of the NASA-AEC Liquid-Metals Corrosion Meeting, Vol. I 1964 p 21–26 (See N64-20783 14-01) OTS: $5.00

The driving force for liquid-metal corrosion is the equalization of chemical potential for dissolution of all solid surfaces in contact with the liquid. Several mass-transfer processes are required. In static systems of pure metals, the rate of dissolution decreases with time but does not become zero. In a dynamic loop with a ΔT, there is a steady-state concentration of solute. Mass transfer is not zero, even in isothermal systems. With alloys, the solubilities of all components are not equal, although in many liquid metals they may be in the same sequence. A.W.

N64-20786* General Electric Co., Pleasanton, Calif. Valecitos Atomic Lab.
CHEMICAL CORROSION PROCESSES
Leo F. Epstein *In* NASA. Lewis Res. Center Proc. of the NASA-AEC Liquid-Metals Corrosion Meeting, Vol. I 1964 p 27–34 (See N64-20783 14-01) OTS: $5.00

This is a discussion of the role in corrosion processes of impurities in alkali metal systems. The importance of iron-base alloys in liquid materials is noted. Examples are given of the shift from diffusion to chemical reaction processes as the determinant of solution rate. The assumption is made that whenever a trace amount of impurity has a very strong effect on corrosion, a chemical process is responsible for the behavior of the system. Refractory metals—columbium, zirconium, molybdenum, titanium, etc.—form strongly acidic oxides readily combinable with alkali oxides to form rather stable niobates, zirconates, etc. It can reasonably be predicted that corrosion will be chemically controlled in these systems, and that the effect of oxygen as an impurity will be important in determining the behavior of the system. A.W.

N64-20787* Columbia U., New York, N.Y.
MECHANISMS IN LIQUID-PHASE CORROSION. A: DIFFUSION CONTROLLED
Charles F. Bonilla *In* NASA. Lewis Res. Center Proc. of the NASA-AEC Liquid-Metals Corrosion Meeting, Vol. I 1964 p 35–43 refs (See N64-20783 14-01) OTS: $5.00

The two typical situations in which diffusion control can occur are: (1) pure molecular diffusion of the solute molecules throughout a whole quiescent body of the liquid metal; and (2) transport of the solute away from the corroding area by flowing or stirred solvent. It is necessary to arrive at the diffusivity of the solute in the solvent in correlating or predicting diffusion-controlled corrosion. Knowing this and the situation in which diffusion control can occur, one can estimate the mass-transfer coefficient for a corrosion situation. Heat-transfer correlations can be translated into mass-transfer correlations. Prediction of rate and amount of corrosion must be left to mathematical equations of dissolving and precipitating and flow transport. A.W.

N64-20788* General Electric Co., Pleasanton, Calif. Valecitos Atomic Lab.
MECHANISMS IN LIQUID-PHASE CORROSION. B: SOLUTION CONTROLLED
Leo F. Epstein *In* NASA. Lewis Res. Center Proc. of the NASA-AEC Liquid-Metals Corrosion Meeting, Vol. I 1964 p 45-47 (See N64-20783 14-01) OTS: $5.00

The author formulates quantitative relations that are equally applicable to corrosion determined by solution rates and to corrosion determined by diffusion rates. A.W.

N64-20789* Brookhaven National Lab., Upton, N.Y.
EFFECTS OF IMPURITIES. A: OXYGEN
John R. Weeks *In* NASA. Lewis Res. Center Proc. of the NASA-AEC Liquid-Metals Corrosion Meeting, Vol. I 1964 p 49-57 (See N64-20783 14-01) OTS: $5.00

In alkali metals oxygen may have either or both of two effects: (1) acceleration of corrosion by catalyzing dissolution of the solid metal atoms; or (2) become the major migrating constituent. The activity of oxygen in the liquid metal at any given temperature can be assumed equal from Henry's law to the fraction of solubility of the dissolved phase present. Calculations are made for several systems. Alkali metals tend to form spinels with many transition metals, and the stability of these spinels may add an important free-energy term in the calculations. Oxygen solubility is higher in the heavier alkali metals. It is suggested, therefore, that traces of oxygen may be more difficult to remove than had been thought. A.W.

N64-20790* Brookhaven National Lab., Upton, N.Y.
EFFECTS OF IMPURITIES. B: NITROGEN AND HYDROGEN
John R. Weeks *In* NASA. Lewis Res. Center Proc. of the NASA-AEC Liquid-Metals Corrosion Meeting, Vol. I 1964 p 59 (See N64-20783 14-01) OTS: $5.00

In alkali metals, nitrogen may either accelerate dissolution or become the migrating constituent. These effects are considered in selected alkali metals. Hydrogen embrittlement of fuel elements occurred at $T<300^{\circ}C$ in Dounreay from H_2O in cover gas. Hydrogen may also react in conjunction with oxygen in accelerating corrosion of iron by sodium. A.W.

N64-20791* General Electric Co., Pleasanton, Calif. Valecitos Atomic Lab.
EFFECTS OF IMPURITIES. C: CARBON
Leo F. Epstein *In* NASA. Lewis Res. Center Proc. of the NASA-AEC Liquid-Metals Corrosion Meeting, Vol. I 1964 p 61-65 (See N64-20783 14-01) OTS: $5.00

This is a discussion of the role of carbon as an impurity in high-temperature service in sodium. It is now thought that the behavior of carbon rather than oxygen impurity may well determine the upper-temperature limit attainable in sodium systems. Techniques for determination of carbon in sodium are wet combustion and dry combustion, but results have been disappointing in both, and the nature of carbon in alkali metals and its reactions are essentially still unknown. A.W.

N64-20792* General Electric Co., Pleasanton, Calif. Valecitos Atomic Lab.
EFFECTS OF IMPURITIES. D: INHIBITORS AND ACCELERATORS
Leo F. Epstein *In* NASA. Lewis Res. Center Proc. of the NASA-AEC Liquid-Metals Corrosion Meeting, Vol. I 1964 p 67-71 (See N64-20783 14-01) OTS: $5.00

The author discusses the manner in which dissolved titanium and zirconium inhibit the corrosion of ferrous alloys in liquid mercury, lead, and bismuth. The acceleration of corrosion processes in the alkali metals by certain trace impurities appears to be parallel to this inhibition process. The liquid metal itself is not always the sole source of the oxygen and of nitrogen impurities that bring about accelerated corrosion. The search for specific inhibitors in the alkali metals has not been extremely successful to date. At the present time, the best technique for inhibiting corrosion in these metals is elimination of oxygen in the system. A.W.

N64-20796* General Electric Co., Pleasanton, Calif. Valecitos Atomic Lab
VAPOR PHASE PHENOMENA
Leo F. Epstein *In* NASA. Lewis Res. Center Proc. of the NASA-AEC Liquid-Metals Corrosion Meeting, Vol. I 1964 p 83-86 (See N64-20783 14-01) OTS: $5.00

There has been growing interest shown in the behavior of materials in metals in the presence of vapors at high temperatures Vapor-phase corrosion is much less than that of solids in contact with the liquid metals, and it is much less severe in the common oxides. In hydrogen systems, a large amount of corrosive attack is ordinarily observed in the condensing vapor region It is important to minimize boiling instabilities and liquid carryover in order to eliminate errors in the interpretation of vapor-phase corrosion. A.W.

N64-20797* Brookhaven National Lab., Upton, N.Y.
TWO-PHASE MECHANISMS
John R. Weeks *In* NASA. Lewis Res. Center Proc. of the NASA-AEC Liquid-Metals Corrosion Meeting, Vol. I 1964 p 87-89 (See N64-20783 14-01) OTS: $5.00

In a schematic boiling loop, dissolution occurs primarily where the solute-free condensate contacts the metal surface. Slugging may cause corrosion in the superheater, and bumping may carry saturated droplets into it. Adsorption on metal surfaces may occur even in dry vapor when liquid wets solid. At the liquid-vapor interface in static reflux capsules, Gibbs adsorption isotherm predicts concentration or depletion of the solute. A.W.

N64-20798* General Electric Co., Pleasanton, Calif. Valecitos Atomic Lab.
SPECIAL TOPICS. A: DOWNSTREAM EFFECT
Leo F. Epstein *In* NASA Lewis Res. Center Proc. of the NASA-AEC Liquid-Metals Corrosion Meeting, Vol. I 1964 p 91-95 (See N64-20783 14-01) OTS: $5.00

A series of pumped loops of various steel alloys displayed isothermal regions of considerable length at various points in the flow pattern. The corrosion rate was highest near the beginning of the constant temperature zone, and decreased from this point. This is the downstream effect, the exact nature of which is still obscure, and is discussed in this paper only as an interesting example of a new discovery in what was thought to be a thoroughly explored and well-understood field. A.W.

N64-20800* General Electric Co., Pleasanton, Calif. Valecitos Atomic Lab.
SPECIAL TOPICS. C: RADIATION EFFECTS
Leo F. Epstein *In* NASA. Lewis Res. Center Proc. of the NASA-AEC Liquid-Metals Corrosion Meeting, Vol. I 1964 p 101–104 refs (See N64-20783 14-01) OTS: $5.00

Protective layers exposed to bombardment of radioactive particles spall or slough off, or suffer cracks and flaws. Quantitative evaluation of these indicates that radiation acceleration of corrosion by liquid metals is of negligible importance. A.W.

N64-20801* General Electric Co., Pleasanton, Calif. Valecitos Atomic Lab.
SUMMARY AND CONCLUSIONS
Leo F. Epstein *In* NASA. Lewis Res. Center Proc. of the NASA-AEC Liquid-Metals Corrosion Meeting, Vol. I 1964 p 105–106 (See N64-20783 14-01) OTS: $5.00

The physical and chemical origins of the basic phenomena of liquid-metal corrosion are understood. In only a very few cases are quantitative predictions of corrosion rates possible. Certain specific phenomena (e.g., the downstream effect) are still obscure. There are many aspects of sodium and bismuth and other alkali metals that require clarification. Additional experiments must be made on two-phase liquid-vapor systems. A.W.

N64-20802* General Dynamics/Astronautics, San Diego, Calif.
SURFACE ENERGY PHENOMENA AND CORROSION
Robert J. Good *In* NASA. Lewis Res. Center Proc. of the NASA-AEC Liquid-Metals Corrosion Meeting, Vol. I 1964 p 107–125 refs (See N64-20783 14-01) OTS: $5.00
(Contract AT(04-3)-297)

For two substances having the same type of cohesive forces, the free energy of adhesion should be approximately the geometric mean of the free energies of cohesion of the separate phases. This theory is discussed through the formulation and testing of specific equations. Applications are made to corrosion phenomena. Caution is urged in applying the interface theory to the corrosion of alloys. A.W.

N64-20803* Brookhaven National Lab., Upton, N.Y.
COMPATIBILITY TESTS WITH ALKALI METALS
David Gurinsky *In* NASA. Lewis Res. Center Proc. of the NASA-AEC Liquid-Metals Corrosion Meeting, Vol. I 1964 p127–252 (See N64-20783 14-01) OTS: $5.00

This paper contains the results of compatibility tests with alkali metals; capsule and loop tests were used. Questionnaires were completed as to purpose, type, fluid, major problems encountered, and analyses of results. A.W.

N64-20804* Argonne National Lab., Ill.
BOILING STABILITY
Paul A. Lottes *In* NASA. Lewis Res. Center Proc. of the NASA-AEC Liquid-Metals Corrosion Meeting, Vol. I 1964 p 257–271 (See N64-20783 14-01) OTS: $5.00

In liquid-metal corrosion tests, flow instability would upset temperature and concentration gradients, disturb impurity accumulations at liquid-vapor interfaces, affect the entrainment of liquid droplets in vapor regions, and change the location of sensitive corrosion sites in the system. In order to determine corrosion rates, steady-state flow must be insured. There are two types of boiling instability—one related to a multivalued pressure drop and the other related to momentum changes. The first type generally can be avoided by orificing, and the second type is avoided by providing a pump as well as by orificing. A.W.

N64-20805* Oak Ridge National Lab., Tenn.
HYDRODYNAMIC AND THERMAL INFLUENCES IN CORROSION STUDIES
H. W. Hoffman *In* NASA. Lewis Res. Center Proc. of the NASA-AEC Liquid-Metals Corrosion Meeting, Vol. I 1964 p 273–303 refs (See N64-20783 14-01) OTS: $5.00

Consideration is given to the influence of heat transfer and fluid mechanics on dynamic corrosion. Comments based on specific experiments are made on: (1) the role of surface shear and boundary-layer flow and development with uranyl sulfate solutions; (2) the effects of surface temperature oscillations on the mechanical integrity and corrosion resistance of an alloy metal wall in a molten-salt environment; and (3) flow and temperature phenomena that could affect corrosion in a boiling alkali-metal system. A.W.

N64-20913 Joint Publications Research Service, Washington, D.C.
CORROSION OF TITANIUM AND ITS ALLOYS
14 May 1964 69 p refs Transl. into ENGLISH of 5 articles from Korroziya Metallov i Splavov (Moscow), 1963 p 141–193 refs
(JPRS-24602; OTS-64-31258) OTS: $1.75

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2. CORROSION AND ELECTROCHEMICAL BEHAVIOR OF TITANIUM AND ITS ALLOYS WITH MOLYBDENUM V. I. Kazarin and V. V. Andreyeva p 19–32 refs (See N64-20915 14-18)
3. INVESTIGATION OF THE HYDROGEN EMBRITTLEMENT OF ALPHA-TITANIUM ALLOYS DURING CATHODE POLARIZATION N. D. Tomashov, V. N. Modestova, S. T. Glazunov, E. A. Borisova, and V. L. Zotov p 33–44 refs (See N64-20916 14-18)
4. EFFECT OF DENSITY OF CURRENT ON THE HYDROGEN EMBRITTLEMENT (HE) AND CORROSION OF TITANIUM ALLOYS N. D. Tomashov, V. N. Modestov, and A. S. Anatolev p 45–53 refs (See N64-20917 14-18)
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N64-20915 Joint Publications Research Service, Washington, D.C.

CORROSION AND ELECTROCHEMICAL BEHAVIOR OF TITANIUM AND ITS ALLOYS WITH MOLYBDENUM

V. I. Kazarin and V. V. Andreyeva *In its* Corrosion of Titanium and its Alloys 14 May 1964 p 19-32 refs (See N64-20913 14-18) OTS: $1.75

Speed of corrosion of titanium and the value of anode critical current density have a definite dependence on the concentration of sulfuric acid. There are distinct ranges of concentrations in which the dependence of these values may be described, by a relationship of the type $K = kX^n$; where K is the speed of corrosion, or anode critical current density; X is the concentration of acid; and k and n are constants. Speed of corrosion of titanium in passive state can be increased in the presence of ions of fluorine in solutions of sulfuric acid. It also is increased in the presence of nitric acid at temperatures not lower than 100° C. Alloys of titanium with molybdenum, having on their surface more protective film than titanium, possess higher corrosion stability than titanium. For alloys with high content of molybdenum there is a characteristic lowering of corrosion stability in ranges of positive potential over +0.2 v. Author

N64-20917 Joint Publications Research Service, Washington, D.C.

EFFECT OF DENSITY OF CURRENT ON THE HYDROGEN EMBRITTLEMENT (HE) AND CORROSION OF TITANIUM ALLOYS

N. D. Tomashov, V. N. Modestov, and A. S. Anatolev *In its* Corrosion of Titanium and its Alloys 14 May 1964 p 45-53 refs (See N64-20913 14-18) OTS: $1.75

The effect of density of cathode current on the formation of a hydride layer and speed of corrosion of titanium and alloy VT5 in acid and partially in alkali media was investigated. It was found that at equal time intervals (48 hr), with an increase of cathode current, the thickness of the hydride layer on titanium increases to a certain limit ($\sim 20\mu$). At further increase of current density to over 5 to 10 ma/cm^2, in connection with saturation of external surface of hydride layer by hydrogen, the thickness of the hydride layer remains almost constant. During cathode polarization of titanium in 3N H_2SO_4 with current of constant density (8 and 20 ma/cm^2), growth of the hydride layer is a parabolic function of time. On alloy VT5, the thickness of the hydride layer, at an increase of current density in 3N H_2SO_4, increases and passes through a maximum and drops. It was shown that a decrease of thickness of the hydride layer, after a maximum, is caused by an increase of the speed of corrosion at an increase of current density (the phenomenon of a negative protective effect). Author

N64-20918 Joint Publications Research Service, Washington, D.C.

BEHAVIOR OF TITANIUM ALLOYS DURING CORROSION UNDER STRESS AND THEIR HYDROGEN EMBRITTLEMENT (HE)

N. D. Tomashov and V. N. Modestov *In its* Corrosion of Titanium and its Alloys 14 May 1964 p 54-66 refs (See N64-20913 14-18) OTS: $1.75

The prolonged effect of relatively dilute solutions of acids on alloy VT5 (5.3% and 10% HCl, 7.3% and 12.9% H_2SO_4) and titanium (10% HCl) leads to the formation of a solid hydride layer, which is visible upon examination of slides under a microscope. Tensile stress promotes penetration of hydrogen into metal under the hydride layer, separation of hydrides of titanium being chiefly at the glide planes. During corrosion under stress in these relatively dilute solutions of acids, samples of alloy VT5 containing aluminum (in contrast to titanium) rupture with comparative brittleness. In accordance with the occurrence of hydrides of titanium, fissures develop chiefly along the glide plane, maintaining on a macroscale a direction perpendicular to the stress. Rupture of samples of alloy VT5 is due basically to a decrease in the cross section of samples as a result of corrosion, and also, to the formation of fissures that accelerate the onset of rupturing. The possible mechanism of the development of fissuring and the role of aluminum are also considered. Author

N64-21064* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.

ADAPTATION OF AN MoS_2 "IN SITU" PROCESS FOR LUBRICATING SPACECRAFT MECHANICAL COMPONENTS

Charles E. Vest Washington, NASA, May 1964 18 p refs Previously published as a part of AIAA Publ. CP-8; See N64-19364 12-17

(NASA-TN-D-2288) OTS: $0.50

A process was adapted to deposit a controlled thickness and a good adherent in situ MoS_2 film onto mechanical devices for spacecraft use. The devices tested were instrument bearings and gears. Results showed that the film is adherent and thickness is controllable to $\pm 50\mu$in. Also, the film has a better wear life than burnished MoS_2 powders and inorganic-bonded MoS_2 films. Author

N64-21121 Mechanical Technology, Inc., Latham, N.Y.

ELASTOHYDRODYNAMIC LUBRICATION – EXPERIMENTAL INVESTIGATION

F. K. Orcutt 27 Feb. 1964 26 p refs

(Contract Nonr-3729(00) FBM)

(MTI-64TR6; AD-432340)

The overall objective of this program is to improve the life, reliability, and load capacity of concentrated contact machine elements, such as rolling-element bearings, gears, and cams. The chosen means of accomplishing this objective are to investigate the fundamental process of lubrication in concentrated rolling-sliding contacts and to attempt, wherever possible, to relate the findings to the practical aspects of bearing, gear, and cam performance. Measurements of several of the important variables of the load zone of the rolling-sliding disk apparatus were made. Measurements of the temperature of the surface as it moves through the load region were obtained for light to moderate loads with slip ratios up to about 25 percent, using improved vapor-deposited thermocouples and the rolling-disk apparatus. Preliminary attempts were made to obtain pressure measurements in the load region, using deposited-manganin wire transducers. R.T.K.

N64-21146 Shell Development Co., Emeryville, Calif.

BEARING LUBRICATION UNDER SEVERE CONDITIONS Final Report, 1 Apr. 1963-31 Mar. 1964

J. B. Accinelli, W. M. Widlund, and W. W. Kerlin 30 May 1964 68 p

(Contract NOw-63-0466-c)

(S-13918; AD-440305)

The studies include a realistic evaluation of several lubricants in a 35-mm ball bearing rig operating at severe conditions of speed (40,000 rpm), load (400-lb thrust), and temperature (400° to 800° F). The lubricants tested were a highly refined mineral oil, a MIL-L-7808E lubricant, a MIL-L-9236B lubricant, and a polyphenyl ether (mixed 5P4E) lubricant. All valid tests were terminated because of lubricant consumption rather than by bearing distress. The best performance was obtained with the 5P4E at 600° F (66 hr), whereas, at 800° F, operation with this lubricant became critical. For a system that fails by loss of lubricant, two equations were derived that relate initial lubricant charge, termination lubricant charge, lubricant recovery rate, and lubricant flow rate with total operating time and number of lubricant passes. The experimental values of time and number of passes for the current tests are in excellent agreement with values predicted by the derived expressions. Author

N64-21147 Ampex Corp., Redwood City, Calif.
AN INVESTIGATION OF SELF-ACTING FOIL BEARINGS
Joseph T. Ma Mar. 1964 41 p refs
(Contract Nonr-3815(00))
(RR-64-3; AD-600657)

Experimental results on the interior and exit region film-thickness measurements of self-acting foil bearings are presented and discussed. These measurements were made with capacitive sensors and conductive foils. The measured and predicted values agree very well within the range of nondimensional parameters—h_o/R, from 10^{-4} to 10^{-3}; and, $T/\mu U$, from 10^5 to 10^6. Empirical expressions for predicting the constant and minimum film thickness applicable beyond these ranges are also presented. They are valid within the range of h_o/R from $5(10)^{-5}$ to 10^{-2} and $T/\mu U$ from 10^4 to 10^6. The validity of a growing sinusoidal film thickness in the exit region first predicted by Gross is evidenced from the photographs. The measured wavelengths checked with Barlow's calculated values within 6%. For a constant relative velocity, the effect of increasing tension is to decrease the film thickness, whereas for a constant tension, the effect of increasing speed is to increase the film thickness. The effect of gas compressibility becomes important for high relative velocity, and the effect of surface roughness greatly influences either the predicted or measured values for thin film thickness. Author

N64-21223 Mechanical Technology, Inc., Latham, N.Y.
A NUMERICAL SOLUTION TO THE THERMAL-ELASTO-HYDRODYNAMIC LUBRICATION OF ROLLING AND SLIDING CYLINDERS
H. S. Cheng 25 Feb. 1964 98 p refs
(Contract Nonr-3729(00) FBM)
(MTI-64TR7; AD-432339)

Existing isothermal theories of elastohydrodynamic lubrication of rollers are extended to include the effects of temperature in the fluid and in the solids due to heating from rolling, sliding, and compression of the lubricant. The two-dimensional finite difference method has been used in calculating the temperature in the fluid using local pressure–temperature-dependent viscosity. Both the compressibility effect and the heat from compression of the lubricant are considered in the solution of the Reynolds and the energy equation. Author

N64-21268* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
HIGH SPEED VACUUM PERFORMANCE OF MINIATURE BALL BEARINGS LUBRICATED WITH COMBINATIONS OF BARIUM, GOLD, AND SILVER FILMS
Thomas W. Flatley Washington, NASA, Jun. 1964 14 p refs
(NASA-TN-D-2304) OTS: $0.50

A retainer study that involved bearings with gold-plated balls and raceways resulted in the selection of fully machined retainers of "S"-Inconel and of silver-plated Circle "C." Bearings with these retainer types and six ball and race plating combinations of barium, gold, and silver were studied. They were run in pairs in small induction motors in a vacuum environment, with nominal test conditions of 10,000 rpm, no external loading, and an oil-free ambient pressure in the 10^{-7} torr range. Testing revealed only one bearing configuration worthy of further study, that involving gold-plated balls, silver-plated raceways, and the fully machined silver-plated Circle "C" retainer. In direct contrast the combination of silver-plated balls and gold-plated raceways gave consistently poor performance. Bearing lifetimes achieved with the other configurations, all involving barium plating, in general fell between these extremes. Author

N64-21297 General Electric Co., Lynn, Mass.
MATERIALS OF CONSTRUCTION FOR HYDROCARBON-AIR FUEL CELLS WITH HOT CONCENTRATED PHOSPHORIC ACID ELECTROLYTE Interim Report No. 1
P. V. Popat and A. Kucher 1 Apr. 1964 31 p
(Contract DA-44-009-AMC-479(T); ARPA Order 247)
(AD-439400)

Of all the massive metals and alloys investigated to date, the following metals and alloys appear to have sufficient resistance to chemical corrosion in nonaerated phosphoric acid at 150° C (corrosion rate less than 1 mil per year): gold; platinum; an alloy containing 40% palladium, 30% silver, and 30% gold; certain alloys of palladium (high) with nickel or chromium; chlorimet-2, tantalum; alloys of tantalum with tungsten; molybdenum; tungsten–iridium (0.1%) alloy; and certain carbides. Certain varieties of carbons manufactured primarily for fuel cell applications appear resistant to phosphoric acid corrosion under chemical as well as electrochemical (up to one volt) environments. Of the various plastic materials investigated, Teflon (FEP), Teflon (TFE) glass-filled, Teflon (TFE), and Kynar show good stability and compatibility both in hot concentrated phosphoric acid and in the hydrocarbon fuel JP-4 at 150° C. Author

N64-21691 SKF Industries, Inc., King of Prussia, Pa. Engineering and Research Center
INFLUENCE OF LUBRICATION ON ENDURANCE OF ROLLING CONTACTS Progress Report No. 9, Sep. 22–Dec. 22, 1963
E. F. Brady, J. A. Martin, R. J. Riedy, W. Schmidt, A. J. Schwartz, and L. B. Siblex [1963] 52 p refs
(Contract NOw-61-0716-C)
(AL-64T014; AD-439606)

Lubrication studies using radiotracer techniques and electrical conductivity measurements developed previously have been continued, using a rolling four-ball test machine. Data on several lubricants under different operating conditions are reported. The development of high-resolution autoradiography

techniques is described, and the results of a brief study of wear particle size in the rolling four-ball tester are given. Also given is progress in the development of a dynamic two-ball tester for the study of film thickness and lubrication effects on contact stresses at rolling contacts, using X-ray beam techniques. Author

N64-21922 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.
A STUDY OF THE WEAR-RESISTANCE OF ENAMEL COSTINGS WITH REFERENCE TO THE LIFE OF MACHINE PARTS
V. S. Lomakin and V. I. Savchenko 14 Mar. 1963 38 p refs Transl. into ENGLISH from the Book "Treniye i Iznos v Maschinakh" Moscow, Izd. Akad. Nauk SSSR, 1960 p 63-92
(FTD-TT-62-1659/1+2+4; AD-400525)

Results of this study indicate the following: (1) The resistance of enamel coatings to abrasive wear may be regarded as the result of two properties of the coating—the resistance to wear of the surface layer and the resistance to rupture of the structure of the underlying enamel. (2) The wear of enamel coatings increases with increasing grain size of the abrasive. (3) The degree of moisture of the abrasive, as is true for moisture in general, has no appreciable effect on the wear resistance of enamel coatings. (4) Nonacid-resistant enamels, when subjected to wear in an abrasive medium containing a sulfuric acid solution, possess considerably greater wear resistance than steels and a chrome coating. (5) Enameling of parts, in addition to increasing their useful life, leads, in a number of cases, to an improvement in the operational characteristics of the machine. (6) Enameling, in the majority of cases, does not require any change in design in machine parts; at the most, a few insignificant structural changes are sometimes necessary. (Parts intended for enameling are made of low-carbon steels and gray iron.) I.v.L.

N64-21932 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.
METAL-POLYMERIC FILMS ON FRICTION SURFACES OF DETAILS
M. L. Barabash, M. V. Korogodskiy, and A. S. Krayushkin 2 Jul. 1963 10 p refs Transl. into ENGLISH from the Book "Plastmassy v Mashinostroyenii i Proborostroyenii" Kiev, Gostekhizdat, 1961 p 359-366
(FTD-TT-63-564/1+2; AD-414910)

Two methods are presented: (1) for obtaining metal polymeric films containing film forming glyptal lacquer and epoxy resin base, plus fillers of colloidal metal; and (2) for applying such films on friction surfaces in order to replace worn details. Applying film that contains colloidal metal appears to be a new method of repairing worn (through friction) features, including heavily worn parts such as pistons and other components of automobile engines. P.V.E.

N64-22189 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.
INVESTIGATING PLASTIC BEARINGS WITH INVERTED FRICTION COUPLING
A. A. Lebedev 27 May 1963 9 p Transl. into ENGLISH from the Book "Plastmassy V Mashinostroyenii i Prioborostroyenii" Gostekhizdat, 1961 p 335-340
(FTD-TT-63-242/1+2; AD-409561)

A bearing with inverted friction coupling is discussed. The antifriction material— wood pulp-lamellar plastic DSP-V with crisscross arrangement of the veneer sheet— was applied on the shaft, (not on the insert). Results of experiments on these bearings include the following: (1) The work of the bearing, during lubrication with mineral lubrications of the machine-oil type, is stable and gives a minimum friction coefficient at $v = 0.7$ to 2.8 m/sec and $p = 25$ to 30 kg/cm^2. (2) There is an optimum amount of lubrication for each friction coefficient. A further increase in the amount of the delivered lubrication does not offer a temperature reduction of the most heated zone in the bearing nor a reduction in the friction coefficient. (3) The optimum angle of lubrication delivery from the viewpoint of reducing the friction coefficient and temperature of the most heated zone appears to be an angle of 180° to 210°. (4) The temperature and friction coefficients decrease with a reduction in relative gap from 0.03 to 0.012 at oil lubrication. I.v.L.

N64-22342 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.
LUBRICANT-COOLANT FLUIDS IN CUTTING METALS AND THE TECHNIQUE OF THEIR APPLICATION (SELECTED PARTS)
M. I. Klushin 9 May 1963 225 p refs Transl. into ENGLISH from the Book "Smazochno-Okhlazhdayushchiye Zhidkosti pri Rezanii Mettalov i Tekhnika Primeneniya" Moscow, Mashgiz, 1961 p 53-97, 112-141, 168-269, 280-290
(FTD-TT-63-105/1+2; AD-414935)

The following topics are discussed: (1) the effect of various lubricants and coolants on the quality of tap-cut threads; (2) the utilization of lubricant-coolant fluids in grinding operations; (3) the cooling and lubrication of cutting zones by a high-pressure fluid stream; (4) lubrications and cooling with dispersed liquids during the reaction of metals; (5) elements of the theory, construction, and exploitation of units for spraying liquids; and (6) experience in the application of sprayed coolants and lubricants in machining metals. I.v.L.

N64-22595 McDonnell Aircraft Corp., St. Louis, Mo.
INVESTIGATION OF THE EFFECT OF DRY FILM LUBRICANTS ON CORROSION RESISTANCE Final Report
10 Jun. 1964 92 p
(Contract AF 33(657)-11215)
(A753; AD-441131)

The results of this investigation indicate that both Electrofilm 2306 and Everlube 620 lubricants used on alodined 2024 and 7075 aluminum decreased the corrosion resistance of these alloys with this surface treatment by a considerable degree. The corrosion resistance of cadmium-plated 4340 steel was adversely affected by the use of Molykote X-106 lubricant. In all of the other cases tested, the lubricants did not decrease the corrosion resistance of the alloys to any great degree, and there were several instances where the lubricants acted to increase the corrosion resistance of the alloys to which they were applied. Author

N64-22596 McDonnell Aircraft Corp., St. Louis, Mo. Structures Lab.
EFFECT OF CADMIUM PLATE ON DRY FILM LUBRICANT WEAR LIFE Final Report
Billie L. Thrasher 10 Jun. 1964 15 p
(Contract AF 33(657)-11215)
(A754; AD-441132)

This test was conducted to gather data concerning the effects of cadmium plate substrate on the wear life and corrosion resistance of dry-film lubricant coated bearings. Cadmium-plated, as well as unplated, steel test cups were used. The wear life of these cups was determined, using the MacMillan lubricant tester with an 80-rpm rotary motion and a 630-lb line-contact load. The corrosion resistance was investigated by first subjecting both plated and unplated test cups to a 4-hr wear test on the MacMillan tester, then to a 24-hr 20%-salt-spray exposure. This cycle was repeated until the coefficient of kinetic friction reached 0.2 on the wear-test portion of the cycle. The cadmium plate substrate decreased the average wear life of the lubricated surface by approximately 40%. Considerable corrosion was observed on both plated and unplated test cups after the first 24-hr salt-spray exposure. Author

N64-23090 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.

AUTOMATIC POTENTIAL (VOLTAGE) REGULATOR TO PROTECT UNDERGROUND INSTALLATIONS AGAINST CORROSION

I. K. Parra and N. V. Petina *In its* Automation 14 Feb. 1963 refs p 92–95 (See N64-23080 16-17)

A static potential regulator is described that maintains the potential difference at the level required for cathodic protection of underground installations (such as pipelines) from corrosion. The circuit diagram is presented for an automatic cathodic protection station that is contactless, based on magnetic boosters and germanium diodes, and has no rotating parts. Such a system has been successful in actual application, and is particularly recommended for use in areas where stray currents are present. M.P.G.

N64-23315 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.

ANODIC ANTICORROSION PROTECTION OF STEEL

Milan Prazak 3 Mar. 1964 14 p refs Transl. into ENGLISH from Hutnicke Listy (Prague), v. 11, no. 11, 1956 p 644–648 (FTD-TT-64-21/1+2; AD-435641)

On the basis of potential polarization curves of steel in sulfuric acid solutions, the difference between cathodic and anodic methods of applying anticorrosion protection to steel materials is explained. A theoretical discussion is presented of the conditions necessary to maintain the metal in a passive state (in the zone of anodic protection). Experimental evidence is presented that demonstrates the effectiveness of anodic protection of stainless steel. R.T.K.

N64-23320 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.

COMPARATIVE INVESTIGATION OF EROSION RESISTANCE OF HIGH-TEMPERATURE CORROSION-RESISTANT MATERIALS OF GAS TURBINES OPERATING ON SOLID FUEL

K. V. Olesevich (Odessa Polytechnic Inst.) *In its* Transactions of the Seminar on Heat-Resistant Materials 1959 p 65–75 refs (See N64-23316 16-01)

The general qualitative laws governing attrition of surfaces blasted by dust-bearing gas were investigated. In carrying out the experiments, the specimen was blasted with dust-bearing gas after the gas had been heated to high temperature (650° C), and the wear resistance of the material determined by its weight loss. P.V.E.

N64-23443 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.

INVESTIGATION OF INORGANIC SALTS FOR THE PURPOSE OF USING THEM AS HIGH-TEMPERATURE LUBRICANTS

M. M. Fialko and A. I. Dintses 7 Jan. 1964 10 p refs Transl. into ENGLISH from Khim. i Tekhnol. Topliv i Masel (Moscow), no. 10, 1963 p 22–26
(FTD-TT-63-1152/1+2; AD-430146)

An evaluation of antiwear and corrosion properties was the main object testing. The antiwear test was performed on a four-ball apparatus; the balls were made of silicon–molybdenum steel and had a 12.7-mm diam. The corrosion test was performed in a quartz test tube placed in a thermostat. The salt was placed in the test tube, and after its fusion the plates of the metal to be tested were inserted. Purified air was then blown through the fusion product. The corrosion was determined by the change in the weight of the plates. A.L.B.

N64-23839 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.

X-RAY INVESTIGATION OF RESIDUAL STRESSES OF THE FIRST AND THIRD KIND DURING WEAR OF STEEL SPECIMENS IN THE PROCESS OF FRICTION

T. Karashev and Yu. S. Terminasov *In its* Use of X-rays in the Invest. of Mater. 16 Jan. 1964 p 151–173 refs (See N64-23831 16-33)

The most reliable results of investigation of residual stresses of the first and third kind during wear of steel specimens in the process of friction can be obtained using the weighing method, measurements of microhardness, and X-ray analysis. This report discusses the use of these techniques and the development of distortions of the third kind in the surface layers of metal during friction. G.D.B.

N64-23840 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.

X-RAY INVESTIGATION OF THE WEAR OF METALS WITH A PREHARDENED SURFACE

Z. M. Abdullina and Yu. Z. Terminasov *In its* Use of X-rays in the Invest. of Mater. 16 Jan. 1964 p 174–190 refs (See N64-23831 16-33)

The friction on the surface of specimens of annealed steel U8, subjected to various preliminary hardening treatments, is characterized by the development of a block structure and of microdistortions in its crystalline structures. The process of wear of hardened specimens of steel U8, subjected to various forms of hardening treatment, differs in its mechanism from the process of wear of annealed and pretreated specimens. G.D.B.

N64-23899 Grumman Aircraft Engineering Corp., Bethpage, N.Y.

A METHOD FOR THE PRODUCTION OF CONTROLLED MICROBIOLOGICAL CORROSION ON TEST SPECIMENS

Edward A. Calvelli 1 Oct. 1963 11 p refs
(ADN-09-08a-63.1)

An accelerated biological method was developed to produce corrosion on various test alloys. This method will provide corroded specimens almost as rapidly as any artificial means, and being biologically induced, it will produce more natural configurations. Two organisms are used to produce the desired

corrosion; Thiobacillus thioparus and Thiobacillus thiooxidans. These organisms are strict autotrophs (able to grow in the absence of organic matter) and therefore make the media easier to prepare and maintain. They were selected for their ability to produce sulfuric acid as a waste product and to tolerate a considerable amount of it in the media employed. Sterility is not required, and safety problems are minimized. Author

N64-24011 Rock Island Arsenal Lab., Ill.
SURFACE CHEMISTRY OF SOME LUBRICANT ADDITIVES
S. Fred Calhoun and Max T. Fisher 24 Jan. 1964 17 p refs
(Rept.-64-232; AD-434204) OTS: $0.75

Eleven compounds or combinations of compounds were studied in this investigation. They were added to white mineral oil and evaluated for their effect upon the lubricative properties of the oil. The results were a positive but varied improvement for all additives. Six of them were tritiated, and their absorption on bearing steel specimens were studied by radioactive counting. An increase in temperature and humidity resulted in variable increases in absorption. It was observed that on static storage some of the additives apparently settled in the lubricant without forming a precipitate. Others formed a visible precipitate. In either case, their effect upon the lubricant was appreciably diminished. Degreasing with trichloroethylene seemed to eliminate the lubricative ability of the additive even though radioactive counting disclosed some still to be present on the degreased test specimen. Author

N64-24014 Shell Development Co., Emeryville, Calif.
STUDY OF HELICOPTER GEAR LUBRICATION Quarterly Progress Report No. 3, Dec. 1963–Feb. 1964
S. J. Beaubien and L. Lichtman Feb. 1964 29 p
(Contract NOw-63-0557-c)
(S-131914; AD-435876)

Lubricants may be classified according to their effect on fatigue and their extreme pressure activity. Lubricants with high extreme pressure activity and low fatigue promotion are most desirable. Lubricants with fatigue promotion and high extreme pressure activity tend to produce pitting. Break-in can accelerate fatigue in a fatigue sensitive system, through contributions to the total number of stress cycles. An earlier conclusion that the cracks that proceed gear scoring may lead also to pitting was confirmed. It appears that such cracks arise from overstress of the metal in the contact zone, or from fatigue. The use of stub-tooth gears is desirable from the standpoint of strength of the teeth and scoring prevention, since those portions of the tooth that have the highest sliding velocity in a normal tooth are elimiated in the stub-tooth system. P.V.E.

N64-24152 Olin Mathieson Chemical Corp., New Haven, Conn. Organics Div.
DEVELOPMENT OF NONFLAMMABLE HYDRAULIC FLUIDS AND LUBRICANTS Bimonthly Progress Report, 18 Feb.–17 Apr. 1964
E. H. Kober, H. F. Lederle, and G. F. Ottmann 27 Apr. 1964 48 p refs
(Contract NObs-90092)
(BMPR-3; AD-437355)

Additional trimeric and tetrameric mixed substituted (aryl-1, 1-di H-polyfluoroalkyl)phosphonitrilates were prepared and evaluated. Of these, trimeric (m-ethylphenyl-1,1-di H-trifluoroethyl)phosphonitrilate had the lowest density(1.33) and tetrameric (m-fluorophenyl-1, 1-di H-heptafluorobutyl) phosphonitrilate, the lowest pour point (−45° F) obtained so far in this class of compounds. Trimeric bis(p-methoxyphenyl) phosphonitrilate and trimeric bis(p-nitrophenyl) phosphonitrilate have been prepared as intermediates for potentially water soluble or emulsifiable products. Two members of a new class of fluids, the trimeric and tetrameric mixed substituted (arylamino-polyfluoroalkoxy) phosphonitriles have been prepared and evaluated. Author

N64-24236 Air Force Systems Command, Wright-Patterson AFB, Ohio
SLIDING FRICTION OF COPPER Technical Documentary Report, May 1962 – Aug. 1963
Tung Liu Mar. 1964 28 p refs
(RTD-TDR-63-4257; AD-435675)

To satisfy future Air Force requirements, the present knowledge on the sliding friction and wear was reviewed and found to be inadequate. More experimental data with better controlled environmental conditions are needed. To fulfill this need, a versatile sliding friction apparatus has been designed, constructed, and tested. As the initial phase of the work, friction between copper specimens was investigated. The sliding friction between copper specimens was measured under atmospheric conditions under loads of 0.1 to 20 grams. With very clean surfaces, the coefficient of friction was 1.0 to 1.1 for the entire load range. With less clean surfaces, the coefficient of friction obtained was about 0.4. Since the degree of cleanliness cannot be controlled quantitatively, the friction–load curve of sliding copper pairs in air exhibits a bifurcation characteristic. The higher friction value may be satisfactorily explained by adhesion theory. No sign of adhesion, however, was detectable when the friction coefficient was 0.4. All observations to date indicate that plastic deformation exists during the sliding process. Using published data on the total expended work in plastic deformation, the coefficient of friction between copper pairs was estimated to be about 0.2. When adhesion is negligible, based on the plastic deformation mechanism, one may deduce that the friction coefficient depends largely on the properties of the softer material of the two specimens and that, upon repeated sliding, a slight drop in friction may be observed. Author

N64-24267 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.
IMPORTANCE OF CORROSION BY HYDROCHLORIC ACID IN THE HEAVY CHEMICAL INDUSTRY
Lajos Csurgai *In its* Corrosion Observer 25 Feb. 1964 p 1–2
(See N64-24266 17-07)

The uses and industrial production methods of hydrochloric acid are listed. Corrosive properties of dry and wet hydrogen chloride gas are briefly discussed, and materials for handling and storage apparatus are mentioned. Graphite impregnated with phenol and furan resins as well as polyvinyl chloride is suggested as being especially suited for handling, storing, and transporting the acid either as a gas or in solution. D.E.W.

N64-24279 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.
FORUM: CAN STEEL RUST IN REINFORCED CONCRETE?
Istvan Szilagyi *In its* Corrosion Observer 25 Feb. 1964 p 52–57 (See N64-24266 17-07)

A formalized debate is presented on the corrosion of reinforcing steel in concrete structures. It is concluded that, if normal specifications and standards are followed, the steel reinforcement will not corrode. D.E.W.

N64-24921 Lockheed Missiles and Space Co., Sunnyvale, Calif.
GEARS, BEARINGS AND LUBRICANTS FOR AEROSPACE APPLICATIONS: AN ANNOTATED BIBLIOGRAPHY
Helen M. Abbott, comp. Aug. 1963 93 p refs
(Contract AF 94(647)-787)
(SB-63-59; Rept.-3-77-63-1; AD-441583)

This compilation of 189 annotated references is divided into two parts: (1) gears and bearings, and (2) lubricants and lubrication techniques. This material provides a coverage of the literature from October 1961 through August 1963. Subject, author, and corporate source indexes are included. Author

N64-25005* General Electric Co., Cincinnati, Ohio Missile and Space Div.
POTASSIUM CORROSION TEST LOOP DEVELOPMENT Quarterly Progress Report No. 3, Jan. 15–Apr. 15, 1964
E. E. Hoffman, Ed. [1964] 80 p refs
(Contract NAS3-2547)
(NASA-CR-54081) OTS: $7.60 ph

Research effort is reported in the following areas: (1) component evaluation Test Loop I (a natural convection loop); (2) component evaluation Test Loop II (a single-phase, forced-circulation loop—design and fabrication; (3) sodium for Loop II; (4) preprototype loop design; (5) airflow pressure-drop tests on boiler inserts; (6) preprototype loop fabrication and test chamber; (7) refluxing potassium compatibility tests; (8) material procurement; (9) grain-growth studies on Cb-1Zr; (10) helium analysis system; and (11) diffusion-bonding studies. R.T.K.

N64-25356 General Electric Co., Philadelphia, Pa. Space Sciences Lab.
SURVEY OF AEROSPACE REQUIREMENTS FOR BEARINGS AND LUBRICANTS
D. G. Flom May 1964 29 p refs
(R64SD38; AD-439892)

This is a survey of the requirements for bearings and lubricants by the aerospace industry. For convenience, the conditions are separated into natural environments associated with space and induced environments associated with specific vehicles and missions. Natural environments include low pressures, temperature extremes, meteoroid impact, electromagnetic and particulate radiation, and low gravitational forces. Temperature extremes, nuclear radiation effects, and acceleration, shock, and vibration loading make up induced environments. G.D.B.

N64-25984 Houghton (E.F.) and Co., Philadelphia, Pa.
DEVELOPMENT OF FIRE RESISTANT WATER BASED HYDRAULIC FLUIDS First Bimonthly Report
Philip Rakoff, G. John Colucci, and Robert K. Smith 25 May 1964 13 p
(Contract NObs-90269)
(AD-600568)

The main objective of this study is to impart fire resistance in both a finished lubricant and the nonaqueous residue. The targets include a flash point of greater than 450° F and an autogenous ignition temperature of at least 900° F. Several water-soluble esters were synthesized, which may be utilized as fire-resistant additives in hydraulic systems. In the preliminary blending project, various formulas were established that meet the viscosity requirements of the target fluid. R.T.K.

N64-26045 Battelle Inst., Frankfurt am Main (W. Germany).
MICROGRAVIMETRIC INVESTIGATION INTO THE MECHANISMS OF CORROSION OF REACTOR MATERIALS IN THE PRESENCE OF NUCLEAR RADIATION
W. Kuhn and G. Walter Brussels, EURATOM, Apr. 1964 25 p refs
(Contract Euratom-071-61-12-RDD)
(EURAEC-874; EUR-1474.e) Available from Belgian Am. Bank and Trust Co., N.Y., Account No. 121.86: 50 Belg. Fr.

The corrosion kinetics of pure iron, 18/8 stainless steel, and zirconium were investigated by microgravimetry in the presence and in the absence of β-radiation. Corroding atmospheres were oxygen and water vapor at pressures below 1 atmosphere. The radiation source was Sr-90-Y-90, 30 curie; the absorbed dose rate amounted to approximately 10^5 rad/h. No significant difference in corrosion kinetics was observed with and without radiation. With pure iron in oxygen at room temperature the corrosion rate was less than $1.5° \ 10^{-9}$ g/cm^{2}h. At 260° C with pure iron, stainless steel, and zirconium in oxygen and water vapor the corrosion proceeds according to the equation $g = A° \ t^n$ where g = weight gain, A = a constant, t = time, the exponent n ranging between 0.5 and 0.3. The corrosion mechanism of iron at intermediate temperatures (about 200° C) seems to differ from that at high temperatures (eg., 800° C) and low temperatures (room temperature and below). Also in a few discontinuous experiments at a radiation dose rate of about 10^6 rad/h (pure iron and zirconium at 260° C, 1 atm O_2 and 15-mm Hg H_2O), no radiation effect was observed. Author

N64-26123 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.
THE ROLE OF BACTERIA IN ELECTROCHEMICAL CORROSION OF STEEL IN SEA WATER
L. A. Rozenberg 18 Jun. 1964 14 p refs Transl. into ENGLISH from Mikrobiologiya (Moscow), v. 32, no. 4, 1963 p 689–694
(FTD-TT-64-393/1+4; AD-602332)

Experiments conducted involved the effect of *Desulfovibrio desulfuricans* (sulfate-reducing bacteria) on 1X18H9T stainless steel and St-3 carbon steel, and the effect of saphrophytic bacteria—*Pseudomonas fluorescens, Bacillus mycoides*—and saphrophytic bacteria with rather low activity, on St-3 steel. The following are indicated by the results: (1) Bacteria play the role of biological depolarizers and activators in the electrochemical corrosion of steel in sea water. (2) The role of bacteria is very important in the initial period when they activate the metal surface and accelerate the formation of microgalvanic elements. (3) The weight loss of the stainless steel caused by the sulfate-reducing bacteria ranged from 0.048 to 0.135 g/m^2 for a period of 5 to 15 days, whereas the weight loss on St-3 steel reached 60 to 70 g/m^2 for a period of 30 to 40 days. (4) The weight loss due to the action of *Psuedomonas fluorescens* and *Bacillus mycoides* was much greater than that due to the sulfate-reducing bacteria. (5) Carbon steel weight

losses from *Desulfovibrio desulfuricans* for a year can be 1.6% of the metal, and with certain saphrophytic bacteria, even 8% to 9%. (6) Only bacteria that are highly prolific, and produce substantial amounts of H_2S and NH_3, cause biological corrosion. I.v.L.

N64-26186 Mechanical Technology, Inc., Latham, N.Y.
INVESTIGATION OF COMPLEX BEARING AND/OR LUBRICATION SYSTEMS FOR HIGH SPEED, HIGH TEMPERATURE OPERATION
P. Lewis, S. F. Murray, and M. B. Peterson Wright-Patterson AFB, Ohio, Flight Dyn. Lab., Jan. 1964 140 p refs
(Contract AF 33(657)-8666)
(FDL-TDR-64-12; AD-273864)

This report describes a program whose objective was to use complex or combined systems to permit operation over a wide temperature range at high speed and with a variety of ambient pressures. The program reviewed in detail the various individual items that constitute an overall system. Based upon the requirements and the results of the review, a rolling element bearing system with a solid lubricant circulating system was selected. Experimental results are presented that explore the feasibility of the elements making up the overall system. Author

N64-26279 General Dynamics/Fort Worth, Tex. Convair Div.
MATERIAL—LUBRICATING OIL—GTO-790—IRRADIATION UNDER STATIC AND DYNAMIC CONDITIONS—EFFECTS OF
R. H. Mc Daniel 15 Apr. 1964 31 p refs
(Contracts AF 33(600)-38946; AF 33(657)-11214)
(FGT-2622; AD-437238)

A dynamic pump loop system was operated for 50 hrs in a nonnuclear environment to establish base line data on the functional fluid GTO-790. The system was then subjected to operation in a nuclear environment. Dynamic and static oil samples were taken periodically during both runs to determine physical and chemical property changes of the test fluids. Average bulk oil temperature within the static and dynamic reservoirs was 285° F. System operation was satisfactory during both runs. However, the irradiation run was terminated after 19.5 hr because of decreasing flash point values. As evidenced by test results, degradation of GTO-790 was severe during this phase. Contrary to findings on dynamic irradiation of other synthetic lubricating oils and hydraulic fluids, the effects of simultaneous dynamic operation and irradiation on GTO-790 fluid were not synergistic. Author

N64-26799 Atomics International, Canoga Park, Calif.
BERYLLIUM OXIDATION RESEARCH RELATIVE TO THE SNAP 8 REACTOR
G. Ervin, Jr. and T. L. Mackay 24 Jul. 1964 48 p refs
(Contract AT(11-1)-GEN-8)
(NAA-SR-9672) OTS: $1.00

Corrosion of beryllium by high-temperature air is a potential problem in SNAP 8 ground test reactors. Presented here are results of a research study in which oxidation of beryllium, in the temperature range of 500° to 900° C, proceeds very slowly during an initial protective period, but catastrophically during a subsequent accelerating period. Analysis of oxidation kinetics during the protective period showed a parabolic rate, and a decrease in rate with pressure, proportional to the 1/5th power of the oxygen pressure, in agreement with the theory that oxidation rate is controlled by diffusion of beryllium ion vacancies in the BeO film lattice. Author

N64-27087 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.
CORROSION AND PROTECTION OF METAL STRUCTURAL MATERIALS [KORROZIYA I ZASHCHITA KONSTRUKTSIONNYKH METALLICHESKIKH MATERIALOV]
Tomashova, N., ed. 20 Mar. 1964 357 p Transl. into ENGLISH of a Collection of Articles Moscow, Gos. Nauchn.-Tekhn. Izd. Mashinostr. Lit., 1961 p 5-260
(FTD-TT-63-672/1+2; AD-600784)

This collection is devoted to problems involving the corrosion of metallic structural materials in various corrosive media and under various conditions. New methods of corsion studies and tests are described, and the results of recent studies linked with the corrosion and protection of metallic materials and certain practical designs, as well as with the corrosion of certain new alloys, are cited in a number of articles. The data incorporated in the collection are of interest to scientific and production-engineering workers concerned with the problems of corrosion and the protection of metals. Author

N64-27191 Grumman Aircraft Engineering Corp., Bethpage, N.Y.
EFFECTS OF LUBRICATION AND SURFACE FINISH ON FRICTION AND SEIZURE OF PLAIN THRUST BEARING MATERIALS
Dennis J. Hearon and W. D. Craig, Jr. Mar. 1964 35 p refs
(ADR-05-06-64.1)

This investigation was made to find methods of improving the galling resistance of skewed axis wing-fold fittings and other thrust surfaces. Friction and seizure load tests were made with oscillating grease lubricated plain steel thrust bearings to determine the effect of material combinations, surface finishes, and type of lubricant. Various combinations of 4330 V, Modified, H-11, 440C, Nitralloy, and Graph-Mo steels were oscillated under load through 90°. Surface finishes used were 16 and 63 microinch roughness with and without grit blasting. Diester base greases with and without 5% MoS_2 and petroleum base grease with 70% MoS_2 were tested. With a gradual break-in using increasing loads, best performance was obtained with Graph-Mo against Graph-Mo steel and a 5% MoS_2 diester grease (MIL-G-21164). In all cases involving break-in, like materials were superior to dissimilar metal combinations. A grit blasted surface delayed the onset of galling at high loads for bearings that were not gradually broken in. Designs loads and friction ranges are shown in tabular form for various material combinations of common aircraft steels. Recommended relubrication intervals are shown. Author

N64-27228 Wissenschaftliche Gesellschaft für Luft- und Raumfahrt, Cologne (W. Germany)
LIGHT METALS AND NON-METALLIC MATERIALS Report on The First Joint Meeting of the Subcommittee [LEICHTMETALLE UND NICHTMETALLISCHE WERKSTOFFE Bericht über Die 1. Gemeinsame Sitzung der Unterausschüsse]
A. Martin et al (Leiden U.) [1963] 121 p refs Conf. Held at Bremen, 8-9 Apr 1963 In GERMAN
(WGLR-1/1964) Available from WGLR-Hauptgeschäftsstele, Martinstr. 40-42 Cologne W Germany 31 DM

Studies are reported on adhesive materials for construction, point-wise fast age-hardening of metal adhesive compounds, modern problems and experiences in the area of adhered aircraft constructions, stress distribution in metal adhesive compounds, metal adhesive compounds under corrosion, and possibilities for the nondestructive testing of metal adhesive compounds. D.E.W.

N64-27310* Midwest Research Inst., Kansas City, Mo.
RESEARCH ON BEARING LUBRICANTS FOR USE IN HIGH VACUUM Annual Summary Report, 23 Apr. 1963–22 May 1964
Vern Hopkins, D. H. Gaddis, R. D. Hubbell, and F. W. Holm 5 May 1964 49 p refs
(Contract NAS8-1540; MRI Proj. 2492-E)
(NASA-CR-58039) OTS: $4.60

The wear life of a potassium silicate binder material was increased by the addition of sodium fluoride. A solid lubricant film composed of MoS_2, graphite, gold, and potassium silicate modified with sodium fluoride exhibited friction characteristics similar to those of MLF-5 and longer wear life (in air) than that of MLF-5. A description of six newly designed and fabricated wear-life testers is presented. MLF-5 exhibited friction coefficients as low as 0.04 at room temperature, in air, and at loads to 150,000 psi. An ultrahigh-vacuum apparatus was built and attained an ultimate pressure of 1.6×10^{-13} torr. The preliminary design of a multistation vacuum friction apparatus is presented and discussed. Author

N64-27311* Pratt and Whitney Aircraft, West Palm Beach, Fla. Florida Research and Development Center
RESEARCH AND DEVELOPMENT OF MATERIALS FOR USE AS LUBRICANTS IN A LIQUID HYDROGEN ENVIRONMENT Summary Report
W. C. Keathley and E. W. Dwyer 18 Jun. 1964 89 p refs
(Contract NAS8-11537)
(NASA-CR-56947; PWA-FR-986) OTS: $8.10

A program was conducted to evaluate materials that can be used as lubricants in antifriction bearings operating in a liquid hydrogen environment at DN values from 2×10^6 to 4×10^6 mm-rpm. Even though no tests were conducted in a nuclear radiation field, consideration was given to such an environment in the selection of some of the candidate materials. The program described resulted in the discovery of a material that provides a significant increase in the possible bearing life when operating under the above conditions. Author

N64-27587 Oak Ridge National Lab., Tenn. Metals and Ceramics Div.
CORROSION MECHANISMS IN REFRACTORY METAL–ALKALI METAL SYSTEMS
J. R. Di Stefano and E. E. Hoffman *In* AGARD The Sci. and Technol. of Tungsten, Tantalum, Molybdenum, Niobium and Their Alloys 1964 p 257–288 refs (See N64-27576 19-18) Pergamon: £7

The refractory metals and their alloys generally have shown sufficient corrosion resistance to be considered as structural materials for alkali metal reactors and for power conversion systems designed to operate at temperature in excess of 1,000° C. However, comparatively little quantitative compatibility information is available on specific refractory metal–alkali metal systems under a variety of test conditions. The limited data available indicate that niobium, tantalum, molybdenum, and tungsten are all less soluble in alkali metals than are constituents of conventional high-temperature alloys, such as iron, nickel, chromium, and cobalt. Molybdenum has been reported to have the lowest solubility. Interactions in refractory metal systems between two or more metals in contact with a common alkali metal have been limited to exposures involving high temperatures and long times. Phase diagrams of the metals under consideration can often be useful guides in predicting interactions of this type. No serious temperature-gradient mass-transfer effects have been detected in the limited number of nonisothermal tests of refractory metals in contact with flowing alkali metals. The most complete data are available for the molybdenum–lithium system. The most serious compatibility problems in refractory metal–alkali metal systems appear to occur as a result of impurities such as oxygen, hydrogen, nitrogen, and carbon in the system. Author

N64-27730 SKF Industries, Inc., King of Prussia, Pa. Research Lab.
INFLUENCE OF LUBRICATION ON ENDURANCE OF ROLLING CONTACTS Progress Report No. 10, 22 Dec. 1963–22 Mar. 1964
E. F. Brady, S. C. Chou, J. Martin, J. Mc Cool, W. Schmidt et al [1964] 45 p refs
(Contract NOw-61-0716-c)
(AL64T037; AD-602643)

The process developed for preparing permanent-contact autoradiograms on metallic surfaces is described, and the results from autoradiograms obtained on ball sets tested in a Shell sliding four-ball machine are presented. Both wear and conductivity tests were made A.W.

N64-27945* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio
FRICTION, WEAR, AND DYNAMIC SEAL STUDIES IN LIQUID FLUORINE AND LIQUID OXYGEN
W. F. Hady, G. P. Allen, H. E. Sliney, and R. L. Johnson Washington, NASA, Aug. 1964 17 p refs
(NASA-TN-D-2453) OTS: $0.50

Friction and wear studies were conducted with four material combinations run submerged in liquid oxygen and in liquid fluorine to determine their potential as dynamic seal components for fluorine turbopump applications. The friction and wear experiments were conducted with a 3/16-in.-radius hemispherically tipped rider sliding in a circumferential path on the flat surface of a rotating 2-1/2-in.-diam disk. The seals used in this investigation had a flame-sprayed Al_2O_3 nosepiece (0.006- to 0.008-in. thick) and were run against a mating disk of TiC cermet or a fused coating of $CaF_2 + LiF + NiF_2$ on Al_2O_3 submerged in liquid fluorine. Results indicated that the presence of a fluoride film, either as an applied fused coating ($CaF_2 + LiF + NiF_2$) or as a film formed during sliding (NiF_2 on the TiC cermet or possibly aluminum fluoride (AlF_3) on Al_2O_3) in liquid fluorine, was beneficial in reducing the friction and wear of the Al_2O_3 riders. The seal experiments in liquid fluorine showed that flame-sprayed Al_2O_3 sliding against the TiC cermet or a fused coating of $CaF_2 + LiF + NiF_2$ on Al_2O_3 are potential seal materials for fluorine turbopump applications. Author

N64-28017 Battelle Memorial Inst., Columbus, Ohio
PROGRESS RELATING TO CIVILIAN APPLICATIONS DURING JUNE, 1964
Russell W. Dayton and Ronald F. Dickerson 1 Jul. 1964 48 p
(Contract W-7405-ENG-92)
(BMI-1674-(DEL)) OTS: $1.00

Research efforts are reported in the following areas: "Reactor Materials and Components"; "Studies of Fuels"; "General Fuel-Element Development"; "Radioisotope and Radiation Applications"; "Coated-Particle Fuel Materials"; "Corrosion Studies of the Fluoride-Volatility Process"; "Long-Term Creep-Rupture Program on SAP Alloys"; "Mechanical Properties of Zirconium Alloys"; "Fission-Product Deposition Studies"; "Gas-Cooled Reactor Program"; and "Development of Small Radioisotopic Power Sources." R.T.K.

N64-28085* General Electric Co., Cincinnati, Ohio Missile and Space Div.
MATERIALS FOR POTASSIUM LUBRICATED JOURNAL BEARINGS Quarterly Progress Report No. 4, Jan. 22–Apr. 22, 1964
R. G. Frank, ed. [1964] 43 p refs
(Contract NAS3-2534)
(NASA-CR-54113) OTS: $4.60 ph

Among the items reported are these: (1) Corrosion and dimensional-stability test specimens for 13 of the 14 candidate materials were ordered, and procurement of the hot hardness, thermal expansion, and compression specimens was initiated. (2) Of 100 lb of *K* received, 24.5 lb were transferred to a modified 25-lb capacity shipping container and outgassed at 315° to 450° F in preparation for repurification. (3) Fabrication of all major components of the isothermal-capsule test facilities and the dimensional-stability test facilities was completed. One of the five isothermal-capsule test facilities was assembled and instrumented with 6Nb-1Zr alloy test capsules containing *K*, and the high-vacuum chamber was evacuated in preparation for the checkout tests. (4) The Chevenard dilatometer was modified to enable the instrument to be evacuated and backfilled with high-purity He. (5) Several design changes were incorporated in the liquid *K* friction-and-wear tester. (6) A heat-transfer analysis was initiated for the final design of the liquid *K* test rig. Critical shaft-speed calculations of the final design show a ratio of 2.03 between the first critical and maximum test speed (Ncr/4800 rpm). (7) The facility requirements for the liquid *K* friction-and-wear tester have been finalized. I.v.L.

N64-28093* National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
THE EFFECTS OF COMBINED PRIOR STRESS AND ATMOSPHERIC CORROSION ON THE FATIGUE LIFE OF ALUMINUM ALLOYS
Herbert A. Leybold Washington, NASA, Aug. 1964 18 p refs
(NASA-TN-D-2359) OTS: $0.50

Fatigue tests were conducted on 300 vibrating cantilever sheet bending specimens after the specimens were subjected to atmospheric stress corrosion for varying periods of time up to 4 years. Specimens of 2024-T3 and 7075-T6 aluminum alloy in both the bare and clad forms were tested. For comparison, companion tests were conducted indoors. The results indicate that the constant stresses applied to the specimens during the stress-corrosion portion of the investigation had no significant effect on the fatigue life. Most of the reduction in fatigue life due to atmospheric exposure occurred during the first year. The fatigue lives of 7075-T6 and 2024-T3 specimens in the bare condition were shortened by factors of 4.0 and 3.5, respectively, and the life of the 7075-T6 material in the clad condition was shortened by a factor of 1.5. No factor could be determined for the 2024-T3 clad material because of the scatter of the test results. Author

N64-28130 Olin Mathieson Chemical Corp., New Haven, Conn. Organics Div.
DEVELOPMENT OF NONFLAMMABLE HYDRAULIC FLUIDS AND LUBRICANTS Bimonthly Progress Report, Apr. 18–Jun. 17, 1964
H. F. Lederle and E. H. Kober 24 Jun. 1964 38 p
(Contract NObs-90092)
(BMPR-4; AD-601677)

A number of mixed substituted trimeric and tetrameric (arylamino-polyfluoroalkoxy) phosphonitriles were prepared. A typical representative of this new class of compounds, bis-(N-methylanilino)-hexakis (1,1-di H-trifluoroethoxy) phosphonitrile, passed the hydrolytic stability test of specification MIL-H-19457A and gave also excellent results in the Falex wear test. Another representative, bis(N-methylanilino)-tetrakis (1,1-di H-trifluoroethoxy) phosphonitrile, gave viscosities approaching those of the same specification. Catalytic reduction of trimeric bis(p-nitrophenyl) phosphonitrilate afforded bis(p-aminophenyl) phosphonitrilate in excellent yield. Ethoxylation of the latter resulted in the consumption of 10.8 moles of ethylene oxide per amino-group to give a water soluble material having potential for use in water base hydraulic fluids. Representatives of the novel class of arylthio-polyfluoroalkoxy phosphonitriles were synthesized but displayed slow hydrolytic instability and poor lubricity. Author

N64-28169 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.
STUDY OF CONTACT CORROSION IN LABORATORY AND NATURAL ATMOSPHERIC CONDITIONS
I. L. Rozenfelid, T. I. Pavlutskaya, and L. M. Lapides 14 Feb. 1964 31 p refs Transl. into ENGLISH from Tr. Inst. Fiz. Khim., Akad. Nauk SSSR (Moscow), no. 8, 1960 p 155–172
(FTD-MT-63-124; AD-602562)

A survey is presented of electrode-corrosion investigation. A general conclusion from all experimental material, both in the laboratory and in natural conditions, consists in the fact that the influence of contact on the speed of metal corrosion in atmospheric conditions is significant. This is explained by the concentration of corrosion, due to the small range of contact, directly at the borders of the metals in contact. The speed of contact corrosion, in turn, depends greatly on the composition of the atmosphere. The susceptibility of various alloys and metals to contact corrosion and methods of determining contact corrosion are discussed. I.v.L.

N64-28276 Southwest Research Inst., San Antonio, Texas
LUBRICATION RESEARCH AND TEST METHOD DEVELOPMENT FOR AEROSPACE PROPULSION SYSTEMS Technical Documentary Report, Mar. 15, 1963–Feb. 14, 1964
B. B. Baber, W. R. Blackstone, R. A. Burton, P. M. Ku, and J. A. Russell Wright-Patterson AFB, Ohio, AF Aeropropulsion Lab., May 1964 145 p refs
(Contract AF 33(657)-11088)
(APL-TDR-64-50; AD-600924)

The work performed under this program was concerned with applied research in the broad field of lubrication related to advanced primary and secondary aerospace propulsion systems. Two principal phases were investigated: impact sensitivity of materials in contact with rocket propellants, and lubrication, friction, and wear mechanisms in the cryogenic temperature range. Author

N64-28445 Joint Publications Research Service, Washington, D C.
CORROSION AND IRRADIATION
V V. Gerasimov, A I Gromova, Ye S Golovina, G S. Moskvichev, and F. S. Pavlova et al 20 Aug 1964 279 p refs
Transl. into ENGLISH of the book "Korroziya i Obluchenive" Moscow, Gosatomizdat, 1963 p 1 270
(JPRS-26020, TT-64-41290)

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1. THE INFLUENCE OF THE COMPOSITION OF WATER ON THE RESISTANCE OF CONSTRUCTION MATERIALS p 1-30 refs
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3. CORROSION RESISTANCE OF CHROMIUM STEELS p 52-78 refs

4. CORROSION BEHAVIOR OF CARBON AND LOW-ALLOY STEELS IN WATER AT HIGH TEMPERATURES p 79–94 refs

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9. RADIATION OF A NUCLEAR REACTOR p 204–235 refs

10. EFFECT OF RADIATION IN THE ELECTROCHEMICAL BEHAVIOR OF MATERIALS p 236–275 refs

N64-28506 Du Pont de Nemours (E.I.) and Co., Aiken, S.C. Savannah River Lab.

ALUMINUM CORROSION IN SUBCRITICAL AND ZERO POWER CRITICAL REACTORS

Mack E. Bergstresser Jul. 1964 13 p refs

(Contract AT(07-2)-1)

(DP-911)

Natural uranium aluminum-clad fuel slugs are subject to corrosion in low-temperature (< 100° C) water during service in subcritical and zero-power nuclear reactors. This report discusses pitting corrosion and galvanic corrosion of aluminum in such service. The use of high-purity water or the addition of chromates as inhibitors will minimize the corrosion rates. Author

N64-28887* Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena.

CORROSIVE EFFECTS OF PURE AND DISTILLED WATER

Kay Haines 16 Jan. 1964 13 p refs

(NASA-CR-58640; JPL Lit. Search-567) OTS: $1.60 ph

This contains 47 abstracts on the subject taken from books and papers, proceedings and symposia, reported in Chemical Abstracts, Corrosion Abstracts, Engineering Index, and the American Ceramic Society Journal. A.W.

N64-29023 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.

CORROSION STUDY V. MECHANISM OF CHEMICAL PASSIVATION AND CORROSION OF METALS

M. Prazak and V. Prazak 2 Jul. 1963 14 p refs Transl. into ENGLISH from the Russian book "Sbornik Chekoslovak Khimii Rabot" v. 21, 1956 p 564–570

(FTD-TT-62-1721/1+2; AD-414112)

The progress of the chemical and electrochemical passivation and corrosion of iron in nitric acid of varying concentration was compared. The oxidation and reduction processes in these reactions were expressed with the aid of partial currents, the dependence of which was measured for the electrode potential for the anodic dissolving process of the iron and for the cathodic reduction of the nitric acid, but separated in the form of a polarization curve. A diagram was set up by means of which the corrosion behavior of iron in nitric acid of a given concentration can be read. The results obtained showed that between the mechanism of the chemical and electrochemical corrosion reactions, a marked difference does not exist. Author

N64-29349 Mechanical Technology, Inc., Latham, N.Y.

EXPERIMENTAL STUDY OF ELASTOHYDRODYNAMIC LUBRICATION

F. K. Orcutt 8 Jul. 1964 44 p refs

(Contract Nonr-3729(00)(FBM))

(MTI-64-TR37; AD-602792) OTS: $3.00

This report describes direct experimental measurements of pressure distribution, surface temperature, and film shape or deformation profile that have been obtained during an investigation of elastohydrodynamic lubrication. These measurements illustrate effects of loads, rolling speed, lubricant properties, and sliding speed. Their purpose is to provide guidance and verification for the development of an elastohydrodynamic theory, which can then be generally applied to practical problems in the manner that has been described. The results agree with the thermal-elastohydrodynamic theory of Cheng in many respects, but there are also differences indicating that certain modifications in the formulation of the theory should be made. Author

N64-29508* Marlin-Rockwell Corp., Jamestown, N.Y. Research and Development Labs.

SURVEY OF FRICTIONAL PROBLEMS IN SPACECRAFT Final Report

John H. Johnson and Arthur S. Irwin 16 Feb. 1964 160 p refs

(Contract JPL-N2-150168)

(NASA-CR-58704) OTS: $11.50 ph

A survey of frictional problems in spacecraft mechanisms, conducted to determine the degree of research and development effort that is required to solve the problems introduced by the space environment, is discussed. The survey covered bearings, gears, and seals. It is concluded that research should concentrate on implementing design decisions, developing new mechanical design concepts, and basic investigations to develop materials and lubricants for the future. It is also concluded that more emphasis on lubrication is warranted. P.V.E.

N64-29693* IIT Research Inst., Chicago, Ill. Technology Center

INVESTIGATION OF SLIP-RING ASSEMBLIES Final Report, 5 Mar. 1963–5 Mar. 1964

J. C. Horton [1964] 86 p

(Contract NAS8-5251; IITRI Proj. E6000)

(NASA-CR-58666) OTS: $8.10 ph

A laboratory investigation of miniature slip-ring assemblies was conducted to determine the influence of ring, brush, and insulator materials on electrical noise and mechanical wear characteristics. Electroplated rings of soft gold and two hard gold alloys coupled with brushes of Neyoro 28A, a precious metal alloy, exhibited extremely low noise levels, particularly when tested in a drive apparatus that introduced a minimum of mechanical disturbance. Pyrolysis studies of epoxy resins indicated that the major gases given off at low temperatues were low molecular weight gases such as hydrogen, carbon monoxide,and methane. No evidence of creepage or exudation of material from epoxy resins to adjoining metalic surfaces was obtained. Sublimation experiments indicated that condensible products were formed when epoxy resins were exposed to temperature gradients. Author

N64-29772 Los Almos Scientific Lab., N. Mex.

CORROSION OF STAINLESS STEELS BY WATER BOILER REACTOR FUELS

Harold M. Busey and Ralph H. Perkins 25 Aug. 1964 27 p refs
(Contract W-7405-ENG-36)
(LA-3101) OTS: $0.50

Type 316, 316-L, 321, and 347 stainless steels were corrosion tested in both nitric- and phosphoric-acid solutions for 3 years. These tests were made at 95° C under reflux conditions in the presence of air. The 0.05 M uranyl solutions contained 0.10 M HNO_3 or 0.75 M H_3PO_4 to simulate the concentrations that might be used in aqueous homogeneous, water-boiler type, nuclear-research reactors. Each test coupon contained a weld, and metallographic examinations were made of weld, nonweld, and liquid interface regions of the coupons after the 3-year tests. Photographs of the solution–metal interface are shown. The H_3PO_4-type fuel solution was found to be much less corrosive to these stainless steels than was the HNO_3 solution. Types 316 and 316-L were corroded least by the phosphate solution. The change in concentration of corrosion-product iron in the Los Alamos Water Boiler is shown for a 15-year period. Author

N64-29813 General Dynamics/Fort Worth, Tex. Nuclear Aerospace Research Facility
EFFECTS OF REACTOR RADIATION ON MIX-BIS (MIX-PHENOXYPHENOXY) BENZENE USED AS A LUBRICANT IN A HIGH-SPEED, HIGH-TEMPERATURE BEARING-RIG
W. M. Laney, R. H. Mc Daniel, M. R. Self, and J. H. Lewis 31 Mar. 1964 84 p refs
(Contract AF 33(657)-7201)
(NARF-63-IIT; FZK-9-193; AD-603444)

A radiation effects study has been conducted on mix-bis (mix-phenoxyphenoxy) benzene—Mixed 5P4E—used as a high-speed bearing lubricant at elevated temperatures. Bearing and bulk-oil test temperatures of 550°, 600°, and 700° F were employed, with axial bearing load of 200 lb at 60,000 rpm during control and test runs. It was concluded that a gamma dose of 2×10^{10} ergs/gm(C) plus associated neutrons is approaching the useful upper limit for Mixed 5P4E as a high-speed bearing lubricant at temperatures of from 550° to 600° F. At 700° F, this limit is decreased by approximately one order of magnitude. A 0.5% concentration of the antioxidant tetraphenyltin in Mixed 5P4E appeared to improve bearing-rig performance under irradiation. Author

N64-29878 Battelle Memorial Inst., Columbus, Ohio Radiation Effects Information Center
RADIATION EFFECTS. STATE OF THE ART 1963–1964
D. J. Hamman, E. N. Wyler, R. K. Thatcher, W. H. Veazie, Jr., F. R. Shober et al 30 Jun. 1964 114 p refs
(Contract AF 33(615)-1124)
(REIC-34; AD-603708)

Reports received at the Radiation Effects Information Center during the 1963–1964 period are analyzed to determine the current state-of-the-art in the following areas: (1) electronics, particularly in the semiconductor field; (2) polymeric materials, most of which were studied in the total space environment, with polyimide and phosphonitrillic chloride polymers reported as having better radiation stability than presently used polymers; (3) lubricants, flotation, and hydraulic fluids; (4) ceramics; (5) space-radiation environment; (6) dosimetry; and (7) structural metals and alloys. A general approximation of the current status of materials development for use in various radiation environment is presented graphically. M.P.G.

N64-29890 Universidad Autonoma de San Luis Potosi (Mexico)
STUDY OF SOLID LUBRICATION [ESTUDIO SOBRE LUBRICACION]
Carlos Tellez Gallardo Aug. 1964 88 p refs In SPANISH

The principles of lubrication and the properties essential to a good lubricant are reviewed. Areas of study include these: (1) the properties of metal surfaces; (2) inertia; and (3) the reduction of friction by solid lubricants. D.E.R.

N64-30118 Oklahoma U. Research Inst., Norman
ENGINEERING SURVEY OF AIRCRAFT STRUCTURAL FAILURES CAUSED BY CORROSION, FATIGUE, AND ABRASION Final Report, Jun. 10, 1963–Jan. 31, 1964
Gene M. Nordby Fort Eustis, Va., Army Transportation Res. Command, Jul. 1964 33 p
(Contract DA-44-177-AMC-98(T))
(TRECOM-TR-64-36; AD-605325)

A survey of Army aircraft structural failures caused by corrosion, fatigue, and abrasion was made to define critical areas of future structural research. The primary source of data was the Army failure reports, "Equipment Improvement Recommendation." Analysis of all data revealed four significant problem areas: (1) corrosion and fatigue of primary airframe structure; (2) separation of metal bonded joints on rotor blades; (3) erosion of rotor blade leading edges; and (4) sustaining rotor blade balance. Author

N64-30153 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.
LUBRICATION OF TURBOJET AND TURBOPROP ENGINES
S. Szczinski and M. Lyzwinski 11 Jul. 1964 14 p Transl. into ENGLISH from Wojskowy Przeglad Lotniczy (Warsaw), no. 3, 1963 p 47–55
(FTD-TT-64-143/1+2; AD-603390)

Schematic drawings are presented of closed, open, and mixed lubrication systems. Descriptions are given of the basic components of specific oil systems for turbojet and turboprop engines. Suggestions are offered as to the proper care and maintenance of the oil systems used. A.W.

N64-30157 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.
ELECTROCHEMICAL AND CORROSION BEHAVIOR OF STEEL AND NICKEL ELECTRODES IN SOLUTIONS OF SULFURIC ACID, SUBJECTED TO A REACTION OF γ-RADIATION
Ya. Kolotyrkin, N. Ya. Bune, and G. S. Tyruikov 6 Dec. 1963 12 p refs Transl. into ENGLISH from Vses. Soveshch. Radiats. Khim., AN SSSR, Otdel Khim. Nauk (Moscow), v. 1, 1958 p 143–149
(FTD-MT-63-126; AD-602556)

The electrochemical and corrosion behavior of stainless steel and nickel in 1.0 N solutions of H_2SO_4 subjected to Co^{60} gamma radiation of 1.5×10 ev/ml-sec was investigated. The change in potential of both activated and air-oxidized steel electrodes with irradiation time is plotted; in all cases radiation resulted in displacement of the potential toward positive values. The rate of corrosion decreased considerably from the rate of corrosion in the absence of radiation. A relationship is developed for estimating the rate of corrosion on the basis of the magnitude of the potential, and it is concluded that the

radiation effect on a steel electrode is equivalent to the polarization of its anodic current. Gamma radiation also resulted in displacement of the potential of nickel electrodes toward positive values, but the magnitude of displacement remained small, and the rate of corrosion increased 2 to 3 times. These results indicate that the corrosion behavior of metals in irradiated aqueous solutions depends to a significant degree on their capability for passivation. M.P.G.

N64-30398 Bureau of Mines, Albany, Ore. Albany Metallurgy Research Center
EFFECT OF IMPURITY LEVELS OF ZIRCALOY 2 MICROSTRUCTURE, MECHANICAL PROPERTIES, AND CORROSION RATES
H. Kato, D. J. Stoops, and M. D. Carver 1964 24 p
(BM-RI-6536)

The effects of impurity elements silicon, aluminum, copper, nitrogen, and manganese, at 50 to 300 ppm, on properties of the zirconium alloy Zircaloy 2 were investigated. Variations in microstructure, mechanical properties, and corrosion behavior in some inorganic acid and salt solutions were observed with variations in level of impurity element. Corrodents were solutions of sulfuric acid, phosphoric acid, copper chloride, and iron chloride. Silicon was found to modify annealed microstructures by spheroidizing and by the dispersion of second-phase material throughout grains. Silicon or manganese improved ultimate and yield strength of the alloy without loss in ductility. All five elements affected corrosion rates of the alloy, the effect being generally different for each element. Author

N64-31310 Rock Island Arsenal Lab., Ill.
SOLID FILM LUBRICANT SUBSTRATES
G. P. Murphy and F. S. Meade 6 Feb. 1964 18 p refs
(RIA-64-1377; AD-602718) OTS: $0.50

A comparison of the wear life and corrosion protective ability of a recently developed solid-film lubricant (RIA Compound 9A) and two commercial solid-film lubricants was made. The substrates to which the solid-film lubricants were applied were: (1) grit blasted steel; (2) zinc phosphatized grit-blasted steel; (3) zinc phosphatized cadmium-plated steel; and (4) sulfuric acid anodized water-sealed aluminum. Author

N64-31482 Naval Research Lab., Washington, D.C.
LUBRICATION OF SMALL ROTATING COMPONENTS
V. G. Fitzsimmons *In* Bur. of Naval Weapons Proc. of the Rotating and Static Precision Components Symp. Apr. 1964 p 50–56 (See N64-31476 23-17) OTS: $9.40

Various problems associated with lubricating miniature precision ball bearings in devices such as gyroscopes, synchros, and servomotors are discussed in general. In particular, the problem areas associated with synchros, including the following, are outlined: (1) the use of silicon lubricants in an apparent effort to meet specification requirements for torque at low and high temperature; the lubrication behavior of silicones promotes wear and unexpected degradation when used to lubricate ferrous metals in sliding contact; (2) the effect of cleanliness on bearing life; and (3) the limiting of the amount of lubricant to a few milligrams to prevent oil migration into electrical contact areas. Such a limitation does not prevent oil from spreading and being lost from the areas needing it. P.V.E.

N64-31631 Phillips Petroleum Co., Bartlesville, Okla. Research Div.
EFFECT OF JP-5 SULFUR CONTENT ON HOT CORROSION OF SUPERALLOYS IN MARINE ENVIRONMENT Progress Report No. 1
H. T. Quigg [1962] 26 p refs
(Contract NOw-64-0443-d)
(Rept.-3824-64R; AD-603422)

An exploratory program was undertaken to indicate the effect of test variables on the hot corrosion of turbine blade and turbine nozzle guidevane materials. This program included an evaluation of the effect of low (0.0002), and high (0.40 weight percent) fuel sulfur content at six gas temperatures (1200° 1400°, 1600°, 1800°, 2000°, and 2200° F) on metal loss of six superalloys (Udimet 700, Stellite 31, Hastelloy R-235, Haynes Alloy 25, Sierra Metal 200, and Udimet 500) in the presence of 10 ppm "sea salt" in the combustor air. A cascade test-specimen holder was designed and fabricated that permitted simultaneous evaluation of the effect of sulfur on six superalloys. The results obtained showed the following: (1) fuel sulfur inhibited metal loss at gas temperatures of 1800° F and above; and (2) fuel sulfur increased metal loss for some superalloys at 1600° F and below. Author

N64-31632 Phillips Petroleum Co., Bartlesville, Okla. Research Div.
EFFECT OF JP-5 SULFUR CONTENT AND SEA WATER INGESTION ON HOT GAS CORROSION OF SUPERALLOYS Progress Report No. 3
R. M. Schirmer, H. T. Quigg, and R. A. Mengelkamp [1964] 76 p refs
(Contract NOw-63-0406-d)
(Rept.-3686-64R; AD-602152)

Specimens of two nickel-base alloys were exposed to vitiated air from the Phillips 2-in. combustor (56 air–fuel ratio) at high temperature (2,000° F), high pressure (15 atm), and high velocity (500 fps) during a 5-hr cyclic test (55 min. fuel-on and 5 min. fuel-off). A statistically designed test program was used to evaluate the effect of three sulfur concentration levels in the fuel (0.0002, 0.040, and 0.40 wt. %) at three sea salt concentration levels in the air (zero, 1.50, and 15.0 ppm), and also any sulfur X sea salt interaction. The significance of test specimen metal losses and changes in tensile properties was established by analyses of variance, made at a confidence level of 95%. Author

N64-31938 Battelle Memorial Inst., Columbus, Ohio
A STUDY OF THE INFLUENCE OF LUBRICANT ON HIGH-SPEED ROLLING-CONTACT BEARING PERFORMANCE
Jerrold Kannel, J. Clarence Bell, and C. Malcom Allen Wright-Patterson AFB, Ohio, AF Propulsion Lab., Sep. 1964 64 p refs
(Contract AF 33(657)-10494)
(ASD-TDR-61-643, Pt.IV; AD-605845)

Some effects of lubricants on the performance of rolling-contact elements have been studied experimentally and theoretically. Circumferential profiles of the contact region of lubricated rolling-contact disks have been obtained using an X-ray technique for a range of loadings, temperatures, and rolling speed with a polyphenyl ether lubricant. A method has been developed for inferring the lubricant film pressures from the measured deformations, and several profiles have been analyzed to yield pressure patterns. Also, a technique has been developed for measuring film pressures directly using a strip of a Manganin coating on a glass disk; this disk is loaded into lubricated rolling contact with a second glass disk. The change in electrical resistance of the Manganin due to the film pressure is measured. The data recorded by these techniques appear to be fairly reproducible and consistent. Author

N64-32122 Mechanical Technology, Inc., Latham, N.Y.
RESEARCH ON GAS LUBRICATION AT HIGH TEMPERATURE AND LOW FLOW RATES Fourth Quarterly Progress Report

M. Eusepi, J. Meacher, and P. Lewis 25 Jun. 1964 55 p refs
(Contract AF 33(657)-10694)
(MTI-64TR35; AD-447856)

In the program to develop nitrogen-gas-lubricated journal and thrust bearings with stable operation over a speed range, two bearing concepts were selected for experimental work—the 360° inherently compensated hybrid bearing and the flexure-mounted hybrid pad bearing. The test program and the results of tests completed to date are given for the inherently compensated bearing, and the assembly drawings for the pad bearing are presented. A complete description of the test facility is included. D.S.G.

N64-32151 Thompson Ramo Wooldridge, Inc., Cleveland, Ohio Materials Processing Dept.
HIGH TEMPERATURE EXTRUSION LUBRICANTS Final Technical Documentary Report, 1 Jul. 1962–15 Jun. 1964
Robert C. Haverstraw Wright-Patterson AFB, Ohio, AF Mater. Lab., Jul. 1964 155 p refs
(Contract AF 33(657)-9141)
(ML-TDR-64-256; AD-606243)

Numerous experimental lubricant materials were initially evaluated by three laboratory screening tests: (1) A "lubricity" test was devised to measure the lubricating characteristics under conditions simulating those found in extrusion. A total of 265 compounds and mixtures were evaluated by this test. (2) A "reactivity" test determined the relative degree of surface reaction between billet materials and candidate lubricants. Both 4340 steel and molybdenum–0.5% titanium were tested at their respective extrusion temperatures with approximately 50 candidate lubricants each. (3) An "insulation" test measured comparative thermal insulation characteristics for all candidate lubricants that exhibited superior results in the lubricity test. More than 100 extrusion trials each were conducted with 4340 steel and molybdenum–0.5% titanium billets. Objectives of these trials were threefold: establishment of confidence levels for the laboratory tests, secondary screening of the experimental lubricants found to be superior by the laboratory tests, and complete evaluation of the final remaining experimental candidate lubricants. Author

N64-32352* Mechanical Technology, Inc., Latham, N.Y.
LUBRICATION ANALYSIS IN TURBULENT REGIME First Quarterly Report
F. K. Orcutt, C. W. Ng, J. H. Vohr, and E. B. Arwas 1 Oct. 1964 87 p refs
(Contract NASw-1021)
(NASA-CR-54195; MTI-64TR57) OTS: $3.00 ph; $0.75 mf

A turbulent-flow lubrication theory for the composite tilting-pad bearing has been developed. Design data calculations have been made, and results are presented. The theoretical static-load capacity, dynamic-load properties, frictional torque, and flow are given for a wide range of conditions covering the practical operating range for a four-pad, 80° pad, arc bearing. Modifications to the dynamic-load-bearing apparatus, including the installation of a torquemeter for measurement of test bearing frictional torque, have been made. Preliminary experiments to determine the parasitic torque characteristics of the apparatus have begun, and initial results are given. The tilting-pad test bearing has been designed and fabrication is underway. Author

N64-32546 Aluminum Co. of America, New Kensington, Pa. Alcoa Research Labs.
FRACTURE TOUGHNESS, FATIGUE-CRACK PROPAGATION AND CORROSION CHARACTERISTICS OF ALUMINUM ALLOY PLATES FOR WING SKINS Quarterly Report, Jun. 3–Sep. 3, 1964
G. E. Nordmark, B. W. Lifka, and J. G. Kaufman 15 Sep. 1964 117 p refs
(Contracts AF 33(657)-11155; AF 33(615)-2012)
(AD-447686)

Fracture-toughness tests of 2024-T851, 7075-T651, 7075-T7351, and 7079-T651 are complete. Of the four alloys, 7075-T7351 has the greatest toughness and 2024-T851 has the least toughness under plane-strain or mixed-mode fracture conditions. The fatigue tests to date of center-notched and bolted-joint specimens of 7075-T651 and 7079-T651 indicate that there is no consistent difference between the fatigue strengths of the different lots of either alloy or of the two alloys themselves; the fatigue strengths of 2024-T851 are slightly lower than those of the other two alloys. All of the corrosion specimens have been placed in the test environments; some short-time data are available. Author

N64-32651 Battelle Memorial Inst., Columbus, Ohio
DEVELOPMENT OF A LONG-LIFE CONTACT SEAL FOR A HIGH-SPEED ROTATING SHAFT IN LIQUID-METAL DYNAMIC POWER SYSTEMS Quarterly Progress Report, 1 Apr.–1 Jul. 1964
S. J. Basham, C. M. Allen, and W. A. Glaeser 15 Jul. 1964 39 p
(Contract AF 33(657)-10961)
(AD-449609)

Development of materials, for rubbing-contact seals, which will form interfacial lubricating films in contact with potassium, has continued with emphasis on three promising materials, Al_2O_3, Y_2O_3, and ZrO_2, used in DTA (differential thermal analysis) and 1000-hr compatibility experiments. Experiments with Al_2O_3 indicate that this material possesses the desired properties, although the extent of the reaction appears to be dependent on the density of this metal oxide and the quantity and type of the trace impurities in the material. Experiments in the friction and wear apparatus have included runs with a Cr-Al_2O_3 material and two runs with Al_2O_3. There was a marked decrease in friction coefficient during the runs in potassium vapor in one experiment with Al_2O_3 and the experiment with the Cr-Al_2O_3 material. The other Al_2O_3 experiment showed very low friction in vacuum and potassium, behavior not noted in any other experiment. The surface film was somewhat different from that on the other Al_2O_3 specimens and is being further examined. Author

N64-32771* National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio
LUBRICATION IN DIFFICULT ENVIRONMENTS
William J. Anderson *In its* Conf. on New Technol. 1964 p 91-96 (See N64-32767 24-01) GPO: $1.00

The functions of a lubricant are reviewed briefly, and nonconventional lubrication methods are discussed. Methods developed for cryogenic applications include ball-bearing retainers made of slippery or self-lubricating materials, transfer surface films, and the use of small or hollow balls in cryogenic turbomachinery bearings. For the high-temperature range, inorganic solid lubricants and fused coatings are being developed. Bearing materials of improved purity and new forging techniques have also contributed to extending bearing life. Nonspace applications of these techniques are suggested. M.P.G.

N64-33045* IIT Research Inst., Chicago, Ill. Technology Center
INVESTIGATION OF SLIP-RING ASSEMBLIES Quarterly Report No. 5, 15 Apr.–5 Aug. 1964
O. M. Kuritza, W. H. Graft, R. E. Putscher, and D. E. Richardson [1964] 16 p
(Contract NAS8-5252)
(NASA-CR-58686; Rept.-E6000-15) OTS: $1.00 fs; $0.50 mf

Preliminary analyses of wear-debris deposits were conducted, and the basic noise characteristics demonstrated previously were verified with commercial slip-ring assemblies. Also, studies were initiated of precious-metal hardening agents for gold-plating baths, and of other basic noise parameters. The preliminary analysis of wear debris indicated that metallic constituents other than the expected gold are present. Laboratory evaluation indicated that commercial 80-circuit slip-ring assemblies exhibit the same vibration, threshold, and repeatability effects that were demonstrated by experimental capsules. A run-in test presently in progress indicates that 80° grooves may possess improved noise characteristics over the standard 90° grooves. P.V.E.

N64-33060 Du Pont de Nemours (E.I.) and Co., Aiken, S.C. Savannah River Lab.
STAINLESS STEEL INFORMATION MANUAL FOR THE SAVANNAH RIVER PLANT. VOLUME I: PROPERTIES
W. C. Rion, Jr, comp. Jul. 1964 213 p
(Contract AT(07-2)-1)
(DP-860, Vol. 1) OTS: $3.00

This paper contains data on the physical and mechanical properties of stainless steel, with regard to planning, design, fabrication, or inspection of stainless-steel equipment and its production processes. These are the main objectives of the study: "Classification and Characteristics of the Stainless Steels"; "Composition and Properties"; "Resistance to Corrosion, Oxidation, and Radiation"; "Structure"; and "Fabrication." G.G.

N64-33330* SKE Industries, Inc., King of Prussia, Pa. Research Lab.
BEARING LUBRICANT ENDURANCE CHARACTERISTICS AT HIGH SPEEDS AND HIGH TEMPERATURES Progress Report No. 8, 1 Jul.–30 Sep. 1964
C. J. Wachendorfer [1964] 53 p refs
(Contract NASw-492)
(NASA-CR-59283; AL-64T055) OTS: $3.00 fs; $0.50 mf

Four high-temperature lubricants—two hydrocarbons, an ester base oil, and a modified five-ring polyphenyl ether—were used to lubricate 20 consumable-electrode vacuum-melted (CVM) WB49 tool-steel 7205 angular-contact ball bearings at speeds up to 40 000 rpm, 365-lb-thrust load and mean temperatures up to 642° F. Several cage designs manufactured from two of the most wear-resistant materials, M-1 (Rc 55) steel and S-Monel (Rc 33), were utilized in bearings tested to aid in optimizing the cages that will be used in endurance tests. A materials screening program closely related to the high-speed high-temperature bearing program has continued in which potential cage materials are being evaluated for wear resistance when lubricated with candidate high-temperature oils in the modified flat-washer tester. Author

N64-33681* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio
CORROSION OF MATERIALS BY REFLUXING MERCURY AT TEMPERATURES ABOVE 1000°F
Coulson M. Scheuermann, Charles A. Barrett, Warren H. Lowdermilk, and Louis Rosenblum [1964] 20 p Presented at Wash. Meeting of the Electrochem. Soc., Wash., D.C., 11–15 Oct. 1964
(NASA-TM-X-54787) OTS: $1.00 fs; $0.50 mf

The compatibility of various materials with mercury was determined for their possible use in contemporary space turboelectric power systems. Twenty-four materials were selected for testing from the following categories—austenitic stainless steels, martensitic chromium steels, cobalt base alloys, nickel base alloys, and refractory metals and alloys. Test results and materials are discussed with respect to compatibility, strength, and development problems associated with space systems. Corrosion rates were determined for several alloys. These are discussed and compared with existing theory. Author

N64-33713 Pennsylvania U., Philadelphia Electrochemistry Lab.
HYDROGEN EMBRITTLEMENT RESULTING FROM CORROSION, CATHODIC PROTECTION, AND ELECTROPLATING Third Quarterly Report
L. Nanis and J. Mc Breen 1 Aug. 1964 15 p refs
(Contract N-156-44134)
(AD-446525)

The permeation rate of hydrogen through iron membranes was studied as a function of potential in various electrolytes. Graphs of permeation rate are presented for different solutions and as a function of potential, of solute concentration, of the square root of cathodic current, and of temperature. D.E.W.

N64-33849 Phillips Petroleum Co., Bartlesville, Okla. Research Div.
EFFECT OF JP-5 PROPERTIES ON HOT GAS CORROSION AND FLAME RADIATION
R. M. Schirmer and E. W. Aldrich Jun. 1964 111 p refs
(Contract NOw-63-0406-d)
(RDR-3753-64R; AD-603650)

This report summarizes results of hydrocarbon fuel performance studies. The primary effort was an experimental investigation to determine whether the maximum sulfur content of 0.4 wt.%, currently allowed in grade JP-5 aviation turbine fuel, is a safe level for protection of the superalloys used in high-performance engines when operated in a marine environment. A second phase dealt with the effect of fuel molecular structure and volatility on the total radiant energy from combustor flames, which by contributing to the operating temperature of hot section components, limits aircraft turbine engine power and durability. Author

N64-33892 Chalmers U. of Tech., Göteborg (Sweden)
SURFACE CHEMISTRY AND CORROSION
J. Arvid Hedvall Scand. U. Books, 1963 22 p refs *Its* Trans. No. 271 Available from Scand. U. Books: 6 SK

The practical importance and application of various surface reactions and the associated corrosion are treated. Diagrams, metallographic microphotographs, reaction kinetics curves, and yield curves support the nontechnical discussion. D.E.W.

N64-33976 Philco Corp., Blue Bell, Pa. Research Labs.
AN INVESTIGATION AND FEASIBILITY DEMONSTRATION OF NOZZLES FOR RESTARTABLE SOLID ROCKET MOTORS First Quarterly Technical Report
W. H. Armour, J. G. Baetz, H. M. Berkowitz, R. M. Edmiston, R. D. Hackett et al 21 Sep. 1964 146 p refs
(Contract AF 04(611)-9904)
(U-2794; RPL-TDR-64-112; AD-448114)

This program is an analytical study supported by experimental laboratory and rocket motor tests in order to define and solve the problems associated with the restart of solid rocket motor nozzles. These efforts include thermal, structural, and corrosion analysis, materials tests, and rocket motor testing. This report describes the efforts conducted to date on the

mechanisms of nozzle heating and cooling, structural response, and various other phenomena, such as corrosion, ablation, etc., occurring during nozzle heating and/or cooling. Author

1965
STAR ENTRIES

N65-10383# Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.
THE PROBLEM OF LUBRICATING JOURNAL BEARINGS WITH AN AXISYMMETRIC SUPPORTING SURFACE
I. Ya. Tokar' and P. S. Chernyakov 21 Sep. 1964 11 p refs Transl. into ENGLISH from Izv. Akad. Nauk SSSR, Otd. Tekhn. Nauk: Mekhan. i Mashinostr. (Moscow), no. 2, 1963 p 149-152
(FTD-TT-64-510/1+2+4; AD-607119)

This paper pertains to the development of formulas for the design calculations of end seals, and for axial bearings with a conic supporting surface. The steady flow of an incompressible viscous fluid between two axisymmetric surfaces, one of which is spinning and the other stationary, is examined by the application of the Navier-Stokes equations and the equation of discontinuity. Calculations for journal bearings with a conic supporting surface, and for journal bearings with a conic supporting surface and a band on the periphery, are presented. G.G.

N65-10606# California U., Livermore Lawrence Radiation Lab.
CORROSION OF BERYLLIUM OXIDE BY WATER VAPOR
A. Maimoni 4 Sep. 1964 36 p refs
(Contract W-7405-ENG-48)
(UCRL-7663)

Beryllium oxide has been used as a structural and moderating material for a number of high-temperature, air-cooled reactors; however, for open-cycle applications, its reaction with water vapor can lead to losses of moderator material from the high-temperature regions of the reactor core and to subsequent deposition in the cooler regions. A comparison is made between the calculational method and reported experimental determinations of the corrosion and deposition of BeO. The calculational scheme can predict the amount of BeO deposited as a smooth layer on the inside of the tube, although qualitative experimental results show that deposition takes place by growth of isolated crystals. The logic and operating procedure for the HOT HOLE program, written for an IBM-650, is presented. Experimental corrosion profiles are compared with HOT HOLE results and show reasonable agreement. D.S.G.

N65-10637*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio
INFLUENCE OF CRYSTAL STRUCTURE ON FRICTION CHARACTERISTICS OF RARE-EARTH AND RELATED METALS IN VACUUM TO 10^{-10} MILLIMETER OF MERCURY
Donald H. Buckley and Robert L. Johnson Washington, NASA, Nov. 1964 18 p refs
(NASA-TN-D-2513) OTS Prices: HC $0.50/MF $0.50

The friction, wear, and metal-transfer characteristics were determined for rare-earth and related metals in vacuum to 10^{-10}mm of mercury. The metals studied were lanthanum, neodymium, praseodymium, cerium, holmium, erbium, gadolinium, dysprosium, samarium, yttrium, and thallium. Friction and wear experiments were conducted with the rare-earth or related metals generally sliding against 440-C stainless steel at sliding velocities to 2000 ft/min and loads to 3000 grams. The rare-earth or related metals were the rider specimens (3/16-in.-rad. hemisphere) sliding on flat 2 1/2-in.-diam disk specimens of 440-C stainless steel. Factors studied were the effects of crystal structure and crystalline phase changes on the friction, wear, and metal-transfer characteristics of these metals in vacuum. Author

N65-10691# Battelle Memorial Inst., Columbus, Ohio
EXTRUSION
F. W. Boulger and D. E. Strohecker *In its* Surv. of Current Knowledge of Metal Deformation Process. and Deformation Characteristics of Beryllium, Refractory Metals, Superalloys, and High-Strength Steels, and Other Difficult-to-Form Metals 14 Aug. 1964 p 1-80 refs (See N65-10690 01-17)

A description of the principles, limitations, and effects of extrusion processes is given. Specifically discussed are the following: (1) hydrostatic extrusion; (2) factors affecting extrusion pressures, such as strength and reduction, friction and die shape, strain rate, and temperature distributions; (3) extrusion equipment and tooling; (4) lubrication for cold extrusion, hot extrusion, and for claddings; (5) metal flow in extrusion and effects of lubrication, extrusion ratio, and conical dies; and (6) effect of extrusion conditions on microstructure and mechanical properties. D.S.G.

N65-10788# Deutsche Versuchsanstalt für Luft- und Raumfahrt, Aachen (W. Germany) Inst. für Theoretische Gasdynamik
INSTATIONARY HYDRODYNAMIC LUBRICATION THEORY [INSTATIONARE HYDRODYNAMISCHE SCHMIERUNGSTHEORIE]
Ingolf Teipel May 1964 26 p refs *In* GERMAN; ENGLISH summary
(DLR-FB-64-01; DVL-293) Available from DVL, Munich: 11.50 DM

Wearing phenomena were observed in sliding bearings at high rotation velocities. A method was developed that makes it possible to calculate the unsteady loads on a sliding bearing at high reduced frequencies. The results are interpreted in relation to the destruction causes. Author

N65-10946# Battelle Memorial Inst., Columbus, Ohio
THE DEVELOPMENT OF TECHNIQUES TO MEASURE THE DYNAMIC FILM THICKNESS AND FILM PRESSURE IN JOURNAL BEARINGS LUBRICATED WITH LIQUID POTASSIUM Quarterly Progress Report, Feb. 15-May 14, 1964
D. R. Grieser, J. C. Smith, and C. M. Allen 5 Aug. 1964 36 p refs
(Contract AF 33(615)-1134)
(AD-451213)

The program to develop techniques for the static and dynamic measurement of liquid-potassium-lubricated journal-bearing film thickness, film pressure, and film extent has continued. Paper evaluations of a number of potential techniques to accomplish the program objectives were completed, and

experimental work was initiated to develop favorable systems. Of the techniques studied, an eddy-current and magnetic-inductance method was selected as being most favorable for the film-thickness measurement. A device based on the Villari effect is being designed for measurement of the potassium-film pressure. Paper evaluations of ultraviolet and radioisotopic radiation techniques for lubricant extent imaging were completed. Author

N65-10988# Joint Publications Research Service, Washington, D.C.
CORROSION OF MAGNESIUM ALLOYS
M. A. Timonova 19 Nov. 1964 29 p refs Transl. into ENGLISH from the book "Korroziya i Zashchita Magniyevykh Splavov", Moscow, 1964 p 53–63, 114–118, 137–139
(JPRS-27451; TT-64-51700)

Presented are brief discussions of investigations involving the following: (1) "Corrosion of Cast Alloys"; (2) "Corrosion of Alloys of the System Mg-Al-Zn-Mn"; (3) "Corrosion of Binary and Ternary Alloys, Alloyed with Rare-Earth and Other Elements"; (4) "Corrosion of Alloy VM65-1 (System Mg-Zn-Zr)"; and (5) "Corrosion of Alloys of the Systems Mg-Th-Mn, Mg-Th-Zr, and Mg-Th-Zn-Zr." P.V.E.

N65-11202# Mechanical Technology, Inc., Latham, N.Y.
EXPERIMENTAL INVESTIGATION OF A STEAM LUBRICATED JOURNAL BEARING Interim Progress Report
J. S. Meacher 1 Aug. 1964 37 p refs
(Contract Nonr-3731(00))
(MTI-64TR40; AD-605503)

Apparatus and preliminary testing for the experimental investigation of a steam-lubricated journal bearing are described. The test bearing is an externally pressurized, double-row, orifice compensated type, 3.0 inches in diameter and 3.0 inches in length. This work is a continuation of a study of process fluid lubrication wherein the performance of a steam-lubricated thrust bearing has previously been investigated and reported. The work is directed toward the development of process-fluid-lubricated bearings for shipboard application. Steam was therefore considered to be the lubricant fluid with most potential for practical application. The choice of an externally pressurized test bearing, rather than hydrodynamic type, was based on the load capacity requirements of probable shipboard applications. Preliminary tests were conducted at room temperature and at 400° F using nitrogen instead of steam as lubricant. A baseline of bearing performance was thus established for comparison with future performance with steam at various conditions. Author

N65-11393# Olin Mathieson Chemical Corp., New Haven, Conn. Chemicals Div.
DEVELOPMENT OF NONFLAMMABLE HYDRAULIC FLUIDS AND LUBRICANTS Bimonthly Progress Report, Jun. 18–Aug. 17, 1964
E. H. Kober, H. F. Lederle, and G. F. Ottmann 28 Aug. 1964 26 p refs
(Contract NObs-90092)
(BMPR-5; AD-604490)

A new type of water-soluble phosphonitrilates for potential use as water-base hydraulic fluids was synthesized by the reaction of trimeric bis(p-hydroxyphenyl) phosphonitrilate with ethylene oxide. Trimeric and tetrameric bis-(p-nitrophenyl) phosphonitrilate, a trimeric bis(m-nitrophenyl-2,2,2-trifluoroethyl) phosphonitrilate, and tetrameric bis(p-hydroxyphenyl) phosphonitrilate were synthesized as intermediates to be used in the preparation of potential water-base hydraulic fluids. Hexakis (3-pyridinyl) triphosphonitrilate was synthesized and found to be water insoluble. The chloromethylation of hexaphenyl triphosphonitrilate has finally been effected employing chloromethyl methyl ether as chloromethylating agent. Several new arylamino-polyfluoroalkoxy phosphonitriles have been isolated and characterized. Two trimeric and two tetrameric mixed substituted aryl-polyfluoro alkyl phosphonitrilates performed very satisfactorily in Falex wear tests. Author

N65-11428# Southwest Research Inst., San Antonio, Tex. Aerospace Propulsion Research Dept.
FUNDAMENTAL STUDIES OF CONTACT FATIGUE Progress Report No. 2, 24 Jul.–24 Oct. 1964
R. A. Burton and J. A. Russell 24 Oct. 1964 35 p refs
(Contract NOw-64-0460-d)
(RS-431; AD-450612)

Contact fatigue data are presented for several lubricants on 52100 tool steel in laboratory air, using oscillatory normal loading. Fatigue life for these experiments appears to be sensitive both to type of lubricant and to changes in stress characteristics. As far as may be determined from the preliminary data, the lubricant effects may not be similar to those in rolling contact. Preliminary hardness measurements on selected specimens have shown insignificant variation in substrate hardness for the unfailed specimens, and definite patterns of work hardening for failed specimens. Detailed statistical analysis is given for all fatigue data. Also, the technique to be applied in the calculation of stresses for near-Hertzian stress distributions is outlined. Author

N65-11499*# General Electric Co., Cincinnati, Ohio Missile and Space Div.
MATERIALS FOR POTASSIUM LUBRICATED JOURNAL BEARINGS Quarterly Progress Report No. 5, Apr. 22–Jul. 22, 1964
R. G. Frank, ed. [1964] 85 p refs
(Contract NAS3-2534)
(NASA-CR-54169) OTS Prices: HC $3.00/MF $0.75

Thirteen pounds of potassium were purified, and the equipment and methods are detailed. Three separate checkout tests are reported that were performed with the isothermal-capsule corrosion test facility in the 10^{-9} torr range, and two checkout tests were conducted with the dimensional stability test facility in the same range. Checkout tests on the thermal expansion and hot hardness facilities indicate that the test environments are suitable for the evaluation of all materials in the current program. The design of the liquid-potassium friction and wear tester was reviewed extensively, and nearly all drawings were finalized. D.E.W.

N65-11604# General Motors Corp., Bristol, Conn. New Departure Div.
RESEARCH AND DEVELOPMENT OF AIRFRAME BEARINGS FOR AEROSPACE VEHICLES Progress Report, 1 Nov. 1962–31 Jan. 1963
R. J. Matt, J. B. Muratore, R. E. Murteza, and C. J. Zupkus 11 Feb. 1963 39 p refs
(Contract AF 33(657)-8431)
(PR-3; AD-602898)

A total of 153 Phase-1 tests were completed at temperatures of −100°, 1500°, 2000°, and 2500° F. Results have

demonstrated significant differences in the coefficient of friction, wear, and load-carrying ability, and some promise of satisfactory bearing materials for the entire temperature range is indicated. It was agreed to discard four of the eight original Phase-1 test materials from further testing. The Phase-2 lubricant study is currently in progress, and four of the six lubricants have been selected. Consideration is being given to two additional lubricants. The Phase-3 ultrahigh-vacuum test rig components are being fabricated, and will be installed into the test chamber. Author

N65-11656# Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.

WAYS OF USING CARBON FLUORIDES AND CARBON CHLOROFLUORIDES AS HIGHLY-STABLE INSTRUMENT OILS

G. I. Fuks and M. M. Blekherov 2 Jan. 1964 14 p refs Transl. into ENGLISH Khim. i Tekhnol. Topliv i Masel (Moscow), no. 7, 1963 p 58–62
(FTD-MT-63-158; AD-606964)

Investigated was the use of aliphatic acids as additives to carbon fluoride and chlorofluoride to improve the stability of these instrument oils. It is concluded that aliphatic acids considerably improve the antifriction and antiwear properties of the oils. Due to poor solubility, the aliphatic acids must be distributed as highly dispersed particles. A condensation method is described for obtaining colloidal solutions that assures high stability by reducing stratification. The effectiveness of these additives begins only when the particles begin to melt and free molecules appear in the system to form a boundary layer; therefore, aliphatic acid additives are effective in the temperature range from 30° to 150° C and possibly higher, depending on the molecular weight of the chosen acid. To increase the adhesion of carbon fluoride oils and prevent drop formation, the instrument surfaces should be treated with a dewetting agent. M.P.G.

N65-11897# Union Carbide Corp., Tonawanda, N.Y. Cryogenic Development Lab.

COMPATIBILITY OF MATERIALS WITH 7500 PSI OXYGEN Final Report, Jun. 1963–Jun. 1964

G. J. Nihart and C. P. Smith Wright-Patterson AFB, Ohio, AMRL, Oct. 1964 90 p refs
(Contract AF 33(657)-11686)
(AMRL-TDR-64-76; AD-608260)

A research program was conducted to develop ignition data on thread lubricants, thread sealants, fluorocarbon plastics, and metals. Spontaneous ignition temperatures were determined in both 2000-psi and 7500-psi oxygen for all the above materials except metals. The spontaneous ignition temperatures for these materials were found to be essentially the same in 7500-psi oxygen and in 2000-psi oxygen. Only three of the tested lubricants are recommended for possible use in 7500-psi systems. None of the thread sealants are recommended. Glass-filled polytetrafluoroethylene is usable only if tightly confined. The relative ease of ignition of metals and alloys was determined by promoted ignition methods in oxygen at 7500 psi. Inconel alloy 600, brass, Monel alloy 400, and nickel were found to have the highest resistance to ignition and combustion among the common alloys and metals. Of the materials tested, stainless steel and aluminum are the least satisfactory for use at oxygen pressures of 7500 psi. A test system was constructed to evaluate the hazards in rapidly charging a 65-cu-in. nickel-lined vessel with high-pressure oxygen. A series of rapid charging tests up to and as high as 8000 psi proceeded without incident. Electrostatic charges measured during the charging were negligible. Author

N65-12021*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.

AN ANALYSIS OF THE VARIATION IN WEAR LIFE OF HOT PRESSED MOLYBDENUM DISULFIDE-SILVER ELECTRICAL CONTACT BRUSHES IN VACUUM

Donald R. Ulrich 5 Oct. 1964 24 p refs
(NASA-TM-X-53146) OTS Prices: HC $1.00/MF $0.50

Compositions of hot-pressed molybdenum disulfide containing metallic additions have shown promise as materials for electrical contact brushes in vacuum; however, the wear life for a given composition has varied from specimen to specimen. The nonreproducibility of these brushes has been analyzed with the major effort being concentrated on a 55.9% MoS_2–44.1% Ag (wt) composition. The factors affecting wear duration of both the brush materials and their deposited commutator films have been studied and correlated. An optimum brush composition that should give the best combination of lubrication and electrical conduction properties is defined. The brushes are classified according to their electrical conduction behavior. Author

N65-12110# Naval Air Engineering Center, Philadelphia, Pa. Aeronautical Materials Lab.

INVESTIGATION OF ANTIMONY COATINGS, CYCLIC OXIDATION-CORROSION ENVIRONMENT Final Report

E. Taylor 22 Nov. 1963 5 p
(NAEC-AML-1819; AD-424104)

A study was made of the protective properties of antimony when plated on steel and coupled to magnesium. Steel cleats, plated with either antimony or aluminum, were riveted to magnesium alloy panels and exposed to 600° F for 16 hours, followed by exposure in a salt-spray cabinet. Each phase was photographed and observed for corrosion signs. It was found that the aluminum-plated panels with a 52.6% corrosion showed a somewhat greater resistance than the antimony-plated steel panels with 62.2% corrosion. G.G.

N65-12319*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio

MARKED INFLUENCE OF CRYSTAL STRUCTURE ON THE FRICTION AND WEAR CHARACTERISTICS OF COBALT AND COBALT BASE ALLOYS IN VACUUM TO 10^{-9} MILLIMETER OF MERCURY. II: COBALT ALLOYS

Donald H. Buckley and Robert L. Johnson Washington, NASA, Dec. 1964 11 p refs
(NASA-TN-D-2524) OTS Prices: HC $1.00/MF $0.50

The friction and wear characteristics of binary tungsten–cobalt and molybdenum–cobalt alloy systems in vacuum (10^{-9} mm Hg) were determined. The influence of the alloying agents on the crystal transformation of cobalt and the friction and wear characteristics of cobalt were determined at varying sliding velocities to 2000 fpm. Both rider specimens (3/16-in.-radius hemisphere) and disks (2 1/2-in. diameter) were of the same material. The addition of the alloying elements tungsten and molybdenum influenced the crystal transformation in cobalt. The friction and wear characteristics of hexagonal cobalt were obtained to higher sliding velocities (and therefore higher interface temperatures) with the addition of 32.6% tungsten or 25% molybdenum; both alloys delayed the transformation of cobalt from the hexagonal to the face-centered-cubic form. Author

N65-12415*# IIT Research Inst., Chicago, Ill. Technology Center

INVESTIGATION OF SLIP-RING ASSEMBLIES Quarterly Report No. 6, 5 Aug.–5 Nov. 1964

[1964] 16 p
(Contract NAS8-5251)
(NASA-CR-59710; E-6000-18) OTS Prices: HC $1.00/MF $0.50

The spectrographic analyses of wear debris conducted thus far have indicated that the primary constituent is gold from the ring surface. Some evidence of a minor hydrocarbon component has been obtained. Run-in tests of experimental capsules have demonstrated that surface lubrication is particularly effective in maintaining low noise levels and in minimizing wear of the ring and brush surfaces. A run-in test of a commercial capsule has indicated that there is a significant difference in the nature of the wear deposit that is accumulated during run-in. Experiments with various rhodium-modified gold plating baths have indicated that the hardness of the plate decreases as the concentration of rhodium ions increases. Author

N65-12647# General Electric Co., Pleasanton, Calif. Vallecitos Atomic Lab.
RESEARCH AND DEVELOPMENT PROGRAM OF THERMIONIC CONVERSION OF HEAT TO ELECTRICITY, VOLUME I Final Technical Summary Report, 31 Oct. 1963–30 Jun. 1964
R. H. Bristow, L. N. Grossman, and A. J. Kaznoff 30 Jun. 1964 175 p refs
(Contract NObs-88578; ARPA Order 219)
(GEST-2035; AD-605389) OTS: $5.00

The electrical conductivity of Lucalox alumina was measured under conditions representing the operational environment of a thermionic diode. Tungsten- and molybdenum-based coatings were developed, metallized to alumina, and tested in cesium vapor for over 2000 hours. Multilayered cermets were prepared but failed to prove electrically insulating. Alumina-to-nickel and alumina-to-niobium shim seals were prepared and tested for extended periods of time. The joining of various refractory metals to metallized alumina using diffusion bonding, brazing, and braze–diffusion bonding techniques was investigated. The cesium corrosion resistance of various materials and seals was determined at 1000° C. Author

N65-12793# Atomic Energy Commission, Washington, D.C. Div. of Technical Information
CORROSION OF METALLIC MATERIALS BY URANIUM HEXAFLUORIDE AT HIGH TEMPERATURE [CORROSION DE MATERIAUX METALLIQUES PAR L'HEXAFLUORURE D'URANIUM A HAUTE TEMPERATURE]
G. Langlois Nov. 1964 134 p refs Transl. into ENGLISH of Rept.-CEA-2385, 1963 117 p
(CEA-2385; AEC-TR-6504) OTS: $4.00

The effects of gaseous uranium hexafluoride on various metallic materials at high temperatures were investigated under conditions similar to those obtained in isotopic separation plants. The test method employed consisted in maintaining metal platelets at temperatures between 50° and 150° C in the presence of the corrosive gas in stainless steel or glass vessels for a few hundred hours, and then weighing these samples within a few micrograms. An extensive range of metals was studied in this way. Some, such as gold, platinum, nickel, Monel, and Inconel, exhibited weight variations too slight to permit them to be classified or to predict their behavior at high temperatures. It was concluded that the solution of the corrosion problem consists in raising the maximum use temperature of the metals involved by improving their purity. D.E.W.

N65-12993# MSA Research Corp., Callery, Pa. Research Div.
FACTORS AFFECTING THE COMPATIBILITY OF LIQUID CESIUM WITH CONTAINMENT METALS Technical Documentary Report, 1 Jul. 1963–15 Aug. 1964
F. Tepper and J. Greer Wright-Patterson AFB, Ohio, AF Mater. Lab., Nov. 1964 43 p refs
(Contract AF 33(657)-9168)
(AFML-TR-64-327; AD-608385)

Mechanisms associated with the corrosive attack of refractory metal alloys and superalloys by liquid cesium have been investigated. The superalloys, Haynes-25 and TD-Nickel, were exposed at 1800° F, and the refractory metal systems, Mo-1/2Ti, Cb-1Zr, Ta-10W, and Cb-25Ta-12W-1/2Zr were exposed at 2100° and 2500° F. Pure nickel and pure zirconium were employed as dissimilar metal additions in some tests. Boiling reflux tests of each alloy candidate were performed. Metal solubility studies showed the solubility of the refractory metals columbium and molybdenum to be approximately 10 to 20 ppm at 2500° F. Dissimilar metal tests showed mass transfer of metallic elements to be experienced by all couples in the presence of pure liquid cesium except Mo-1/2Ti/Zr. The solubility of carbon in cesium was determined between 600° and 1200° F, and data obtained showed no effect of carbon on the freezing point of cesium. Author

N65-13191# Rensselaer Polytechnic Inst., Troy, N.Y.
THE THERMODYNAMICS OF CORROSION IN MOLTEN CARBONATES: APPLICATION OF E-pCO_2 DIAGRAMS
M. D. Ingram and G. J. Janz Oct. 1964 27 p refs Submitted for Publication
(Contract Nonr-591-(10))
(TR-23; AD-449958)

The corrosion of metals in fused carbonates is discussed in terms of a diagrammatic presentation of the thermodynamic data. The treatment closely resembles that of Pourbaix and Littlewood; diagrams are plotted of E vs pCO_2, where E is the redox potential of the system, and pCO_2 = $-\log_{10}(CO_2)$. Each diagram is divided into three regions that mark the limits of stability at unit activity of the pure metal, metal oxide, and liquid metal carbonate. In the oxide region the metal may become passivated, but this depends on structural factors and requires experimental confirmation. The electrochemical series in molten carbonates is presented, and the significance of pCO_2 in relation to acid-base behavior is discussed. Author

N65-13316*# Franklin Inst., Philadelphia, Pa.
A COMPUTER PROGRAM FOR HYDROSTATIC BEARINGS INCLUDING THE EFFECTS OF NON-UNIFORM FILM THICKNESS AND RELATIVE VELOCITY FOR VARIOUS METHODS OF LUBRICANT SUPPLY Final Technical Report
J. G. Hinkle, V. Castelli, H. C. Rippel, and C. D. Zimmerman, Jr. Apr. 1964 102 p refs
(JPL-BP-3-211570)
(NASA-CR-59916; F-B2099) OTS Prices: HC $4.00/MF $0.75

This report describes the development and use of a computer program for the determination of the load-carrying capacity, flow requirements, and righting moments of hydrostatic bearings using an incompressible fluid, including the effects of variable film thickness, relative velocity, and method of lubricant supply. The basic equations, numerical approximations, method of solution, numerical treatment, and FORTRAN program are presented along with instructions on the use of the program and a sample problem. Author

1963
IAA ENTRIES

A63-10476
AIRCRAFT LUBRICANTS AND SPECIAL PRODUCTS. I.
Maxwell Smith (The Shell International Petroleum Co., Ltd., England).
The Society of Licensed Aircraft Engineers, Journal, vol. 11, no. 6, 1962, p. 2-12.

Discussion of new types of aircraft lubricants, and special products in current use, including piston- and turbine-engine oils, hydraulic fluids, general-purpose oils, extreme-pressure oils, a compass fluid, preservative oils, and antirust compounds (based on lanolin or petrolatum). Schematic diagrams of a portable auxiliary oil tank for applying engine preservatives are presented. British and American specification numbers of many of the lubricants are listed.

A63-10631
LUBRICANTS FOR ENGINES FOR SUPERSONIC AIRCRAFT.
N. J. Hunter (British Petroleum Co., Ltd., Research Centre, Sunbury-on-Thames, England).
Aircraft Engineering, vol. 34, Nov. 1962, p. 317, 318.

Discussion of a research and development program for high-temperature lubricants for supersonic aircraft engines. The history of the development of aircraft engines, together with their lubricant requirements, is briefly reviewed.

A63-10883
KOROZNÍ VLASTNOSTI AUSTENITICKÝCH NEREZAVĚJÍCÍCH OCELÍ CHROMMANGANOVÝCH LEGOVANÝCH NIKLEM A MOLYBDENEM [CORROSION PROPERTIES OF AUSTENITIC NICKEL AND MOLYBDENUM ALLOYED CHROME-MANGANESE STAINLESS STEELS].
F. Pobořil, M. Zezulová, and M. Pražák.
Hutnické Listy, vol. 17, no. 10, 1962, p. 705-712. 27 refs.
In Czech.

Experimental determination of the effects of the additions of nickel and molybdenum on the corrosion properties of alloyed stainless steels. From a detailed experimental investigation of Fe-Cr-Mn-N austenitic steels, two types of steels, Cr10Mn17Mo15N and Cr10Mn17Ni5N2, are developed. It is found that both steels show approximately 100% higher values of yield than other austenitic nickel-chromium stainless steels for practically equal values of ductility, area reduction, and impact strength.

A63-11058
ENGINEERING MODEL FOR WEAR.
R. G. Bayer, W. C. Clinton, C. W. Nelson, and R. A. Schumacher (IBM Corp., General Products Div., Development Laboratory, Endicott, N.Y.)
Wear, vol. 5, Sept.-Oct. 1962, p. 378-391.

Correlation of the wear produced between two metallic bodies sliding against each other with the resulting shear stress. Tests of a variety of material-lubricant combinations show that wear can be eliminated for a given moment of time if the shear stress is kept below a certain fraction of the yield point in shear of the weaker of the two metals. It is found that this fraction is a function of the material and the lubricant used. Values of this fraction determined for a large number of material combinations are tabulated.

A63-11059
THE ROLE OF FILLER GEOMETRICAL SHAPE IN WEAR AND FRICTION OF FILLED PTFE.
C. J. Speerschneider and C. H. Li (Honeywell Research Center, Hopkins, Minn.)
Wear, vol. 5, Sept.-Oct. 1962, p. 392-399.

Investigation of the wear and friction properties of pure and Al_2O_3-filled polytetrafluoroethylene (PTFE) mated to stainless steel. Spherical and irregular particles of comparable size (about 7 μ) are used as the fillers. Optical and electron-microscope observations of the mating surfaces show that the abrasive damage due to Al_2O_3 is greatly reduced when using spherical particles. The coefficient of friction is the same as for pure PTFE in the case of spherical particles but is much larger for irregular particles.

A63-11971
SLIDING CONTACTS AND FRICTION PHENOMENA IN SPACE.
F. J. Clauss, C. F. O'Hara, S. P. Drake, and F. B. Cooke (Lockheed Aircraft Corp., Lockheed Missiles and Space Co., Sunnyvale, Calif.)
(American Society of Metals, Golden Gate Conference, San Francisco, Calif., Feb. 1962.)
IN: Materials Science and Technology for Advanced Applications. Englewood Cliffs, N.J.; Prentice-Hall, Inc., 1962, p. 164-198.

Consideration of the problems anticipated for mechanisms operating in space. Available information is summarized on the applicability of various lubricants and self-lubricating materials to solve such problems as the operation of gears, bearings, and sliding electric contacts. Special emphasis is placed on obtaining long-time reliability under orbital conditions, together with minimum weight and size. The advantages and limitations of various classes of lubricants and self-lubricating materials for spacecraft applications are reviewed, and new data from current experimental studies are presented. Comparisons are made of the lubricating lifetimes provided by several oils and greases on ball bearings operating in air and in vacuum. Graphite, molybdenum disulfide, soft metals, plastics, ceramics, and cermets are among the materials evaluated.

A63-11993
CORROSION AND MASS TRANSFER IN ALKALI LIQUID METAL SYSTEMS.
John R. Weeks (Brookhaven National Laboratory, Upton, N.Y.)
(American Society of Metals, Golden Gate Conference, San Francisco, Calif., Feb. 1962.)
IN: Materials Science and Technology for Advanced Applications. Englewood Cliffs, N.J.; Prentice-Hall, Inc., 1962, p. 709-727. 20 refs.
AEC-sponsored research.

Study of the containment problem associated with both all-liquid and boiling-liquid-metal heat exchangers. Liquid alkali metals offer attractive properties as coolants for space-vehicle power sources. They are usually contained in the high-melting, body-centered cubic transition metals and their alloys (steels at temperatures below 550°C, and refractory metals at higher temperatures). Corrosion can occur by dissolution of the solid metal into the liquid alkali metal, and by a chemical (as opposed to intermetallic) reaction resulting from the presence of nonmetallic impurities in either the liquid or the solid metals. Dissolution-corrosion is a function of solubility and hydrodynamic factors. It is rare in practical alkali metal systems, except where high-Ni container alloys are used. Chemical corrosion is a function of the C, O, and N activity in both the liquid and the solid metals; it is minimized by "gettering" both the solid alloy and the liquid metal for these impurities, and/or by cold-trapping the coolant to reduce the concentration of soluble oxides. It is shown that design of liquid-vapor systems requires knowledge of the relative aggressiveness of the bulk liquid and the fresh condensate.

A63-12006
THE MANY FACES OF CORROSION.
L. H. Seabright (Amphenol-Borg Electronics Corp., Electrochemical Research Laboratory, Broadview, Ill.) and Robert J. Fabian.
Materials in Design Engineering, vol. 57, Jan. 1963, p. 85-91.

Survey of the onset and development of 13 basic types of corrosion in metals. The galvanic series of metals, anodic and cathodic, is reviewed, and the principles of galvanic corrosion are outlined. Caustic embrittlement (as a form of stress corrosion), cavitation erosion, corrosion fatigue, crevice corrosion, dezincification (loss of zinc from an alloy), direct attack by a corrosive medium, erosion corrosion, fretting corrosion, graphilization induced surface corrosion (of gray iron castings), hydrogen

embrittlement, intergranular corrosion, and stress corrosion are described. Methods for their prevention are noted. Current theories on the corrosion of metal are summarized, with reference to the electrochemical and the galvanic series.

A63-12007
EVALUATING MATERIALS FOR CORROSIVE SERVICE.
F. L. LaQue (International Nickel Co., Inc., New York, N. Y.)
Materials in Design Engineering, vol. 57, Jan. 1963, p. 93-98.

Survey of corrosion testing techniques used in the selection of materials for new applications. The simulation of a corrosive environment is discussed in terms of composition and temperature of the environment, volume of test solution, degree of immersion, length of exposure, degree of aeration, and velocity of testing media. The designing of tests is outlined for stress corrosion, corrosion fatigue, crevice corrosion, galvanic corrosion, and spray resistance. Methods used in evaluating the extent of corrosion damage are described. It is noted that usually more than one method is required.

A63-12009
CORROSION RESISTANCE DATA.
Robert J. Fabian.
Materials in Design Engineering, vol. 57, Jan. 1963, p. 106-121.

Presentation of an initial selection guide to the corrosion resistance of materials. The behavior of more than 90 engineering materials is cataloged for almost 70 of the most common atmospheres, waters, acids, solvents, and chemicals which a product is likely to encounter in service. The information is based primarily on data furnished by major materials producers. The five groups of materials covered are metals, plastics, elastomers, other nonmetallics, and coatings and linings.

A63-12287
AIRCRAFT LUBRICANTS AND SPECIAL PRODUCTS. II.
Maxwell Smith (Shell International Petroleum Co., Ltd., London, England).
Society of Licensed Aircraft Engineers, Journal, vol. 11, no. 7, p. 8-12.

Discussion of lubricants for a large number of bearings in aircraft which cannot be lubricated with oil. Specifically covered are greases - i. e., semisolid lubricants comprising a dispersion of solid gelling agents in liquid lubricants. Specifications for greases now require tests for high-temperature endurance, low-temperature torque, worked stability, water resistance, and gear wear; four-ball tests are also required. It is indicated that in the future additional tests will be needed. Engine coolants, deicing and defrosting mixtures, and antiseize materials are also briefly discussed.

A63-12400
DEPOSIT AND OIL DEGRADATION CHARACTERISTICS: REPORT OF DEPOSIT AND OIL DEGRADATION CHARACTERISTICS PANEL.
H. W. Reynolds (United Aircraft Corp., Pratt and Whitney Aircraft Div., East Hartford, Conn.)
Society of Automotive Engineers, National Aerospace Engineering and Manufacturing Meeting, Los Angeles, Calif., Oct. 8-12, 1962. Paper SP-234. p. 3-5.

Discussion of the standardization of testing devices that are capable of subjecting an aircraft lubricant to typical or simulated engine-oil environments for the documentation of its temperature-time limitations. Methods for standardizing the bearing rig and the test oil system are described, and schematic diagrams are provided. On the basis of the first tests, many modifications of equipment and procedure are made, including the use of bottled air to avoid compressor-oil carry-over, a specified heating and warmup period, minimum and maximum running periods per day, and a fixed test oil make-up rate. A demerit rating system is presented to describe oil deposits in the bearing rig, representing an average of both liquid- and vapor-phase types of deposits.

A63-12401
THE INFLUENCE OF LUBRICANTS ON BEARING FATIGUE LIFE: REPORT OF BEARING FATIGUE PANEL.
Irwin Koved (General Motors Corp., Hyatt Bearings Div., Harrison, N. J.)
Society of Automotive Engineers, National Aerospace Engineering and Manufacturing Meeting, Los Angeles, Calif., Oct. 8-12, 1962, Paper SP-234. p. 6-8.

Brief survey of the development of methods for the rating of good and poor lubricants with respect to the influence of the lubricant on bearing life. On the basis of data compiled, it is seen that the lubricants intended for aircraft gas turbine or other bearing applications should be of the highest permissible viscosity to obtain full advantage of the apparent fatigue benefits derived from an increase in bulk viscosity. Existing data on rolling-contact fatigue rigs provide criteria for a tester. Four rolling-contact lubricant test-rig designs are chosen.

A63-12411
AIRFRAME AND ACCESSORY LUBRICANTS.
Gordon Walker (Douglas Aircraft Co., Inc., Santa Monica, Calif.) and J. H. Gustafson (Marlin-Rockwell Corp., Jamestown, N. Y.)
Society of Automotive Engineers, National Aerospace Engineering and Manufacturing Meeting, Los Angeles, Calif., Oct. 8-12, 1962. Paper 583A. 8 p.

Discussion of solid-film lubricants, which are powders with lubricating properties bonded to a surface with a suitable binder to provide a low coefficient of friction and good wear-preventive action. A brief description of coating application to the base materials is given. It is suggested that solid-lubricant coatings should be considered in the design of equipment under the following conditions: (1) in oxygen systems in which only compatible coatings can be used, (2) where parts are not readily accessible for periodic lubrication, (3) where the presence of oil or grease is impractical and objectionable, (4) when pressure (vacuum) and/or temperatures are beyond the limits of conventional lubricants, and (5) where semipermanent, antiseize, threaded parts require frequent use. Two types of lubricant testers are described, and results of tests using these devices are presented. A short discussion is included which considers test techniques designed to predict the high-temperature performance, in actual service, of airframe and accessory lubricants. The discussion contains descriptions of grease-bearing tests at extremely high temperatures and under thrust and radial loads.

A63-12674
SUR LA MODIFICATION TEMPORAIRE DE VISCOSITE DES LUBRIFIANTS SOUMIS A DES CONTRAINTES DE CISAILEMENT MECANIQUE ATTEIGNANT 10^8 DYNES/CM^2 [ON THE TEMPORARY MODIFICATION OF VISCOSITY OF LUBRICANTS CONSTRAINED BY MECHANICAL SHEARING STRESSES REACHING 10^8 DYNES/CM^2].
François Lagarde, N. P. Vinh Tuong, Robert Courtel (I.S.M.C.M., Saint-Ouen, France), and Pierre Sorin (Centre National de la Recherche scientifique, Bellevue, (Seine-et-Oise), France).
Académie des Sciences (Paris), Comptes Rendus, vol. 256, no. 4, Jan. 21, 1963, p. 878-881. In French.

Experimental investigation of temporary variations in the viscosity of liquid lubricants under elevated shearing stresses. A new method of measuring the thicknesses of lubricant films, subjected to a shock, is used. On the basis of a comparison between the film thicknesses measured during the shock and those calculated, it is found that the viscosity is reduced during the shock due to the shearing constraints attained (10^8 dynes/cm^2).

A63-12906
LUBRICATION IN SPACE VEHICLES.
Earl G. Jackson (National Research Corp., Cambridge, Mass.)
Wear, vol. 5, Nov.-Dec. 1962, p. 417-434. 20 refs.

Brief overall survey of the problems, and some of the solutions, associated with lubrication of mechanical apparatus in space. The space environment and its effects on lubrication are discussed. The environment includes meteoroids, weightlessness, various forms of radiant energy, temperature extremes, and ultrahigh vacuum. It is indicated that, from a practical viewpoint, vacuum

provides the most interesting challenges in designing bearing systems. A variety of methods available for application to space-vehicle lubrication problems are considered, from the standard fluid-lubricated systems to the use of solids which have been developed for very-high-temperatures applications. One of the more useful solid lubricants is polytetrafluorethylene. This material, while subject to radiation damage in the presence of oxygen, is found to be quite stable in the high vacuum of space, has a low dry coefficient of friction, and would seem to have much application at moderate speeds, even under heavy loads. Increasing laboratory activities, aimed at producing improvements in length of life and reliability, are reviewed.

A63-12907

FRICTIONAL BEHAVIOR OF SODIUM-LUBRICATED MATERIALS IN A CONTROLLED HIGH-TEMPERATURE ENVIRONMENT.

J. W. Kissel, W. A. Glaeser, and C. M. Allen (Battelle Memorial Institute, Columbus, Ohio).

(American Society for Mechanical Engineers, Spring Lubrication Conference, Miami Beach, Fla., May 8-10, 1961.)
Wear, vol. 5, Nov.-Dec. 1962, p. 446-457. 10 refs.
Contract No. A-7405-eng-92.

Study of the frictional behavior between sliding-contact specimens over a temperature range of 80° to 1,300°F. Speed and load are about 0.2 mm/sec and 10,000 psi, respectively. Experiments are performed in argon-swept vacuum, both dry and with molten sodium at the specimen interface. Materials studied include molybdenum, tungsten, tungsten carbide, and titanium carbide. It is found that chemisorbed films are produced on the specimen surfaces, and the composition of these is largely determined by the type and duration of environmental exposure. The relationship between the observed stick-slip behavior and the presence of surface films of specific compositions is discussed.

A63-12908

FRICTION, WEAR AND LUBRICATION OF PLASTICS.

G. V. Vinogradov and M. D. Bezborodko (Academy of Sciences, Institute of Petrochemical Synthesis, Moscow, USSR).

Wear, vol. 5, Nov.-Dec. 1962, p. 467-477. 15 refs.

Description of some simple methods of studying friction and wear of plastics at high loads, and the effect of lubricating media on the processes involved. The possibility of estimating the efficacy of lubricating media in metal-plastic friction tests of short duration is shown. It is indicated that the modifying (primarily chemical) action of the lubricating medium and its components on the metal surface contacting the plastic may be responsible for reducing friction and wear. Of practical interest is the high antifriction activity and strong antiwear action displayed by glycols, and especially glycerine, in tests of friction between plastics and hardened steel.

A63-13635

THE CORROSION OF NICKEL-BASE MATERIAL IN GAS-TURBINE AND BOILER ATMOSPHERES.

E. J. Bradbury, P. Hancock, and H. Lewis (International Nickel Co., (Mond), Ltd., Development and Research Dept. Laboratory, Clydach, Glamorganshire, Wales).

Metallurgia, vol. 67, Jan. 1963, p. 3-14. 14 refs.

Discussion of the various aspects of the high-temperature corrosion of nickel-base heat-resisting materials, with particular attention to gas-turbine and boiler conditions, in which contamination by various gases and ash deposits may break down the otherwise adequate oxidation resistance of these alloys. The nature and extent of the attack is illustrated by reference to plant experience and/or laboratory tests in which the various types of corrosion are reproduced. Reference is made to oxidation and carburization, to sulphur attack by hydrogen sulphide and sulphur dioxide, and to corrosion by deposits formed during combustion of oil, coal, peat, and leaded fuels. Consideration of the behavior of selected materials in various corrosive environments permits some recommendations on the choice of materials for particular applications.

A63-13855

RAZRUSHENIE NAGRETYKH METALLOV I SPLAVOV V VOZDUSHNOM POTOKE SVERKHZVUKOVYKH SKOROSTEI [CORROSION OF HEATED METALS AND ALLOYS IN A SUPERSONIC AIRSTREAM].

L. Ia. Nesgovorov and V. I. Prosvirin (Institut Inzhenerov Grazhdanskogo Vozdushnogo Flota, Riga, Latvian SSR).

Inzhenerno-Fizicheskii Zhurnal, vol. 6, Feb. 1963, p. 44-51. 12 refs. In Russian.

Investigation of high-temperature oxidation of metals and alloys in a high-velocity airstream, involving disintegration due to corrosion and erosion, and culminating in the burning of the sample. A special apparatus constructed for the tests and the procedures followed are discussed. The average rate of disintegration over a temperature range of 1,073°-1,273°K is established as a function of the time of heating, sample temperature, and position of the sample in the airstream. Results obtained for burning iron-based and heat-resistant alloys are compared.

A63-13898

THE MAGNETOHYDRODYNAMIC FINITE STEP SLIDER BEARING.

W. F. Hughes (Carnegie Institute of Technology, Pittsburgh, Pa.)

(American Society of Mechanical Engineers, Lubrication Symposium, Miami, Fla., June 4-6, 1962, Paper 62 - LubS-15.)
ASME, Transactions, Series D, Journal of Basic Engineering, vol. 85, Mar. 1963, p. 129-135; Discussion, Dennis C. Kuzma, p. 136; Author's Closure, p. 136.

Theoretical analysis of the finite step slider bearing, using an electrically conducting liquid-metal lubricant in the presence of a magnetic field applied both tangentially and transversely to the fluid film. The electrical terminal characteristics are discussed. For the transverse field, it is found that only a slight increase in pressurization can be effected on open-circuit conditions and that the short-circuit condition is adverse. For the tangential field the effect is adverse for both open and short circuit. By supplying electrical power from an external source, however, significant increases in load-carrying capacity can be achieved for both field geometries. Various curves of normalized load vs Hartmann number and pressure contour plots are presented.

A63-14911

ANLAUFREIBUNG UND STICK-SLIP BEI GLEITPAARUNGEN [STATIC FRICTION AND STICK-SLIP OF METALS].

G. Niemann and K. Ehrlenspiel (Technische Hochschule München, Institut für Allgemeine Gestaltungst lehre und Maschinenelemente, Munich, West Germany).

VDI Zeitschrift, vol. 105, Feb. 1963, p. 221-233. In German.

Theoretical and experimental investigation to devise methods for reducing the static friction and stick-slip which occur during the starting of machines and gear assemblies. It is found that both friction and stick-slip are best overcome by using an optimum material-lubricant combination. Stick-slip can be reduced by employing a small normal force or a highly rigid connection lead to the driving clutch. When the mass of the gliding body is large, the stick-slip is also reduced.

A63-14968

THE OXIDATION CHARACTERISTICS OF NIOBIUM-1 ZIRCONIUM ALLOY.

E. J. Delgrosso, R. C. Krutenat, C. E. Carlson, and J. S. Carta (United Aircraft Corp., Pratt and Whitney Aircraft Div., Connecticut Aircraft Nuclear Engine Laboratory (Canel), Materials Laboratory, Middletown, Conn.)

Journal of the Less-Common Metals, vol. 5, Feb. 1963, p. 57-77. 10 refs.
Contract No. AT(30-1)-2789.

Experimental investigation of the oxidation of niobium-1 zirconium alloy by continuous weight gain measurements in the temperature range 400° - 2,200°F. The majority of the tests are conducted in flowing, dry air, although several tests are made in argon atmospheres contaminated with room air at levels of 1% and 5% oxygen. Oxidation rates, kinetic relationships, total oxygen contamination values, and temperature coefficients of the linear oxidation rates are presented in tabular and graphical form. The

effects of specimen geometry and physical condition of the alloy are examined by testing specimens of various shapes in the cast, cold-reduced, and recrystallized conditions. The results are compared with previous work on pure niobium.

A63-15024
EIGENSCHAFTEN VON NICKEL-CHROM-MOLYBDÄN-LEGIERUNGEN UND IHRE VERBESSERUNGSMÖGLICHKEITEN [PROPERTIES OF NICKEL-CHROMIUM-MOLYBDENUM ALLOYS, AND THEIR IMPROVEMENT POSSIBILITIES].
Hubert Gräfen (Badischen Anilin- & Soda-Fabrik, AG, Ludwigshafen/Rhein, West Germany).
(Verfahrens-Ingenieure, Annual Meeting, Mainz, West Germany, Oct. 7-10, 1962.)
Chemie-Ingenieur-Technik, vol. 3, Mar. 1963, p. 229-235. 12 refs. In German.

Discussion of the chemical resistance of Ni-Mo-Cr alloys, with particular reference to Hastelloy C. It is shown that the intercrystalline corrosion which occurs at the welding seams and heated spots of such alloys, as a result of sigma-phase precipitation at the grain boundaries, can be successfully removed by heat treatment at 1,220°C followed by quenching in water. The tendency toward sigma-phase precipitation can also be reduced by changing the alloy composition; thus, silicon-free alloys will lend themselves to welding without preceeding heat treatment, and they will not show intercrystalline corrosion when annealed in a solution and allowed to cool in air.

A63-15682
SYNTHETIC LUBRICATING OILS FOR AIRCRAFT GAS TURBINES.
Society of Licensed Aircraft Engineers, Journal, vol. 11, no. 11, 1963, p. 8, 9.

Description of some of the properties of synthetic oils for lubricating aircraft gas-turbine engines, covering both the U.S. and British products. The chief requirements for a synthetic oil for gas-turbine engines are presented and discussed in view of their applications.

A63-15990
ION ENGINE RELIABILITY AS AFFECTED BY CORROSION OF MATERIALS.
P. M. Winslow (Hughes Aircraft Co., Culver City, Calif.)
American Institute of Aeronautics and Astronautics, Electric Propulsion Conference, Colorado Springs, Colo., Mar. 11-13, 1963, Paper 63032. 14 p.

Presentation of detailed corrosion data on 50- and 500-hr exposure tests of a number of ion-engine structural metals in both cesium vapor and liquid. The structural metals tested for corrosion included the 300 series stainless steels, Sicromo, and Inconel, as well as a titanium-vanadium alloy. Tests on tantalum, tungsten and a possible oxygen getter alloy were also run. Important aspects of the impurities study are the effects of oxygen in cesium on corrosion as well as on potential degradation of the ionizer. The most formidable problems associated with oxygen relate to the measurement of the oxygen level in cesium. Analytical methods used for oxygen in other alkali metals are not entirely satisfactory for cesium.

A63-16183
LONG TERM OPERATION AND PRACTICAL LIMITATIONS OF DRY, SELF-LUBRICATED BEARINGS.
D. J. Boes (Westinghouse Research Laboratories, Pittsburgh, Pa.)
Lubrication Engineering, vol. 19, Apr. 1963, p. 137-142.

Description of three series of experiments which demonstrate the ability of a completely dry ball bearing to function satisfactorily for long periods of time under various combinations of load, speed, temperature, and atmospheric environment. This capability is achieved by equipping the standard ball bearing with a ball separator, or cage, that is fabricated from a material possessing inherent lubricating properties. The cage material used is reinforced polytetrafluoroethylene. The bearings operate from 1×10^{-5} torr to atmospheric pressure.

A63-16507
INFLUENCE DE LA TRANSFORMATION EN PHASE α DE L'AUSTENITE VOISINE DES JOINTS DE GRAINS SUR LA FORME DES COURBES DE POLARISATION, DANS LE DOMAINE D'ACTIVITE, POUR DES ACIERS CONTENANT 18% DE CHROME ET 8% DE NICKEL [INFLUENCE OF THE α-TRANSFORMATION PHASE OF AUSTENITE IN THE REGION OF GRAIN BOUNDARIES ON THE POLARIZATION CURVES IN THE ACTIVITY DOMAIN FOR STEELS CONTAINING 18% CHROME AND 8% NICKEL].
Jacques Voeltzel and Jean Plateau (Institut de Recherches Sidérurgiques, Saint-Germain-en-Laye, France).
Académie des Sciences (Paris), Comptes Rendus, vol. 256, no. 10, Mar. 4, 1963, p. 2156-2158. In French.

Investigation of austenitic steel samples to find the regions most susceptible to corrosion, for steels containing various amounts of carbon, chrome, nickel, and titanium. Austenitic steels studied include (a) one containing 18% chrome, 9% nickel, and 0.07% carbon, and (b) one containing 17% chrome, 12% nickel, 0.5% titanium, and 0.07% carbon. On the basis of the polarization curves that are presented, it is concluded that, for the steels studied, the curves depend on an α-phase at the grain boundaries.

A63-16837
K VOPROSU O FIZICHESKOI SUSHCHNOSTI KAVITATSIONNOGO RAZRUSHENIIA MATERIALOV [CONCERNING THE PHYSICAL NATURE OF THE CAVITATIONAL DESTRUCTION OF MATERIALS]
A. M. Frid.
Aviatsionnaia Tekhnika, no. 1, 1963, p. 126-130. In Russian.

Experimental investigation of the phenomenon of cavitation, to define the mechanisms of cavitation both by corrosion and erosion. The results indicate that the cavitational degradation of metals is caused by the presence on the metal surface of microcracks and pores, containing air. The rate of degradation is seen to depend upon the weight charge of the air inside the pores and microcracks, and to attain a maximum at a certain value of this charge. It is shown that the resistance to cavitation of materials depends not only on the microvolumetric properties of a material, but also on its melting point, heat resistance, and corrosion stability at high temperatures.

A63-17415
ROLLING CONTACT PHENOMENA.
Edited by Joseph B. Bidwell (General Motors Corp., Research Labs., Engineering Mechanics Dept., Warren, Mich.)
(Symposium on Rolling Contact Phenomena, 4th, Warren, Mich., Oct. 10, 11, 1960.)
New York, Elsevier Publishing Co., Inc., 1962. 450 p. $18.00.

Collection of papers dealing with the metallurgical, chemical and physical phenomena which occur in rolling contacts. Studied are contacting bodies of varied geometry undergoing rolling or combined rolling and sliding while subjected to loads in many environments. The papers are intended for the applications engineer and for academic studies, and they represent the results of investigations of kinematics, elasticity, energy losses, fatigue, friction, and lubrication of rolling elements. The papers are individually abstracted and indexed in this issue.

A63-17428
EFFECTS OF LUBRICANTS AND SURFACE COATINGS ON LIFE AS MEASURED ON THE FOUR-BALL FATIGUE TEST MACHINE.
F. G. Rounds, Jr. (General Motors Corp., Research Labs., Warren, Mich.)
(Symposium on Rolling Contact Phenomena, 4th, Warren, Mich., Oct. 10, 11, 1960.)
IN: Rolling Contact Phenomena. New York, Elsevier Publishing Co., Inc., 1962, p. 346-362; Discussion, p. 362-364. 20 refs.

Experimental determination of the effects of lubricants and surface coating on the fatigue life of SAE 51100 steel, using four-ball fatigue tests run at greatly elevated loads. Despite the fact that plastic deformation of the test ball occurs in this rig, the results appear to correlate with bearing data obtained at normal loads. Among the lubricant properties that seem to be controlling fatigue are viscosity, molecular shape, reactivity with steel and the nature of the reaction products formed. Longer life is observed with high-viscosity, nonpolar, bulky molecule lubricants such as

the polyphenyl ethers than with low-viscosity, polar, straight-chain molecule lubricants such as the fatty acids. Limited studies show that additives can alter life by amounts comparable to those observed for base oil changes. Precoating the balls can either raise or lower the fatigue life, depending on the coating. Precoating the balls by heating them in a diester oil is found to be the most beneficial, and lubricating is found to be the most detrimental. The data presented indicate that physical and chemical processes occurring at the contacting surfaces have a pronounced effect on fatigue.

A63-17600

WEAR AND FRICTION OF MECHANICAL CARBONS IN LIQUID OXYGEN AS INFLUENCED BY TRANSFER FILMS.
W. F. Hady, G. P. Allen, and R. L. Johnson (NASA, Lewis Research Center, Cleveland, Ohio).
American Society of Lubrication Engineers, Annual Meeting, 18th, New York, N. Y., May 1963, Paper 63AM 5B-3. 22 p. 10 refs.

Experimental investigation to determine the lubricating potential and compatibility of mechanical carbons (molded carbon-graphite bodies used as slider materials for seals and bearings) at conditions applicable to lox turbojet operation. Experiments are conducted using a hemispherically tipped rider sliding in a circumferential path on the flat of a rotating disk. Mechanical carbons (either amorphous, graphitic, or a combination of the two) with or without adjuncts, are run submerged in lox against various metal surfaces. The load applied is 1,000 gm, and sliding velocities from 1,000-6,500 ft/min are employed. The results show that dense, highly graphitic carbons have potential use as seal and bearing materials for lox applications. The graphitic carbons with a greater oxidation resistance and a greater capability of forming a transfer film give the lowest wear and friction. Metals that form the most stable oxide films promote greater adherence of the graphite to the mating surface. It is seen that impregnated carbons must be selected with caution because frictional heating generated during sliding can initiate hazardous reactions between oxygen and certain unstable organic compounds.

A63-17745

STUDIES IN SYNTHETIC ESTER TYPE LUBRICANTS. II - SYNTHETIC LUBRICANTS FROM ALIPHATIC MONOBASIC ACIDS.
K. D. Pathak and B. C. Subba Rao (National Chemical Laboratory, Poona, India).
Indian Journal of Technology, vol. 1, Feb. 1963, p. 83-86.

Experimental investigation of the effect of the number and position of branch units of branch chain monoesters on their low-temperature lubricant performance. The introduction of one branch chain is found to be inadequate to bring about sufficient reduction in pour point to the range specified for low-temperature lubricants. Compounds with satisfactory performance are obtained by introducing two branch chain units in such a manner that they are close to each other and situated near the center of the chain. The relative effects of the presence of ester, ether, and hydrocarbon linkages in the main chain upon the viscosity, viscosity index, pour point, and oxidation stability of the resulting compounds are investigated. Best results are obtained when ester linkage is present. It is shown that the only disadvantage in the compounds containing ester linkages - their low oxidation stability - can be overcome by adding suitable antioxidants.

A63-17758

FRICTION MEASUREMENTS ON A LOW EARTH SATELLITE. Appendix A - SAMPLE DATA TRACES FROM TELEMETERED RECORDS. Appendix B - ERROR ANALYSIS.
J. B. Rittenhouse (Lockheed Missiles and Space Co., Palo Alto, Calif.), L. D. Jaffe, R. G. Nagler and H. E. Martens (California Institute of Technology, Pasadena, Calif.)
American Society of Lubrication Engineers, Annual Meeting, 18th, New York, N. Y., May 1963, Paper 63AM 6A-1. 45 p. 17 refs.
Contract No. NAS 7-100.

Discussion of the coefficient of sliding friction for a variety of materials which was obtained during the flight of Ranger I. The coefficients observed for unlubricated metal pairs are not inconsistent with the hypothesis that high friction tends to correlate with high mutual solid solubility. In general, the coefficients in space and laboratory vacuum of 5×10^{-6} mm Hg are not systematically different. For unlubricated metallic materials, friction in vacuum is higher than in air at shorter running times.

A63-17775

NEW TEST PROCEDURES FOR AIRCRAFT PISTON ENGINE OILS.
C. A. Hall, J. B. Retzloff (Ethyl Corp., Research and Development Div., Detroit, Mich.), and S. M. Collegeman (U. S. Navy, Bureau of Naval Weapons, Power Plant Div., Fuels and Lubricants Br., Washington, D. C.)
Society of Automotive Engineers, Summer Meeting, Montreal, Canada, June 10-14, 1963, Paper 717A. 18 p.
Navy-sponsored research.

Description of the development of single-cylinder engine tests for evaluating the new additive-type oils for aircraft piston engines. These procedures utilize the CLR oil test engine. One procedure is designed to evaluate the high-temperature oxidation stability of these oils, while the ohter measures their low-temperature sludge dispersing qualities. The two procedures appear to be repeatable, and thus superior to any previous single-cylinder engine tests used for evaluating aircraft engine oils.

A63-17927

CORROSION PROCESSES IN SAMPLES OF VARYING COMPOSITION.
L. S. Palatnik and N. D. Gorban' (A. M. Gor'kii Khar'kov State University, Khar'kov, USSR).
(Akademiia Nauk SSSR, Doklady, vol. 147, Nov. 1962, p. 346-349.)
Soviet Physics - Doklady, vol. 7, May 1963, p. 1045-1047. Translation.

Experimental investigation of the effects in the Cu-Zn alloy system subjected to a corrosive atmosphere of ammonia. Preparation of the alloys is described, as is a new method for determining the required effects. Preliminary experiments show that noticeable corrosion of alloys containing 1-97% Zn occurs only when ammonia, oxygen, and water vapor are present in the atmosphere. The absence of any one of these components slows down the corrosion to such an extent that the surface of the sample remains brilliant even after one month of testing. An increase of the oxygen concentration, and particularly an increase in humidity, increases the corrosion rate considerably. The most effective corrosive atmosphere is found to be a mixture of equal amounts of air and ammonia with a relative humidity of 50%. Tests using this mixture are described. It is concluded that the method can be successfully used to study atmospheric corrosion of any physicochemical system.

A63-18260

A SURVEY OF VACUUM LUBRICATION DEVELOPMENTS.
J. E. Kingsbury and E. C. McKannan (NASA, George C. Marshall Space Flight Center, Huntsville, Ala.).
IN: Institute of Environmental Sciences, 1963 Annual Technical Meeting, Proceedings. Mt. Prospect, Ill., Institute of Environmental Sciences, 1963, p. 41-44. 10 refs.

Review of vacuum lubrication programs in eight laboratories. The purposes of the study are (1) to collect available information in one reference and to update a previous effort toward this end, (2) to determine the degree of coverage of probable applications and requirements by current development programs, and (3) to compare test methods and conclusions from different programs to increase the reliability in the selection of specific materials and components. Some generalized conclusions are also made where there is sufficient agreement among the programs reviewed.

A63-18278

A REVIEW OF USAF SERVICE PROBLEMS RELATED TO MATERIALS-PROCESSES-ENVIRONMENTS.
W. P. Conrardy (Aeronautical Systems Div., Applications Lab., Wright-Patterson AFB, Ohio).
IN: Institute of Environmental Sciences, 1963 Annual Technical Meeting, Proceedings. Mt. Prospect, Ill., Institute of Environmental Sciences, 1963, p. 153-155.

Review of materials problems being encountered by operational forces of the Air Force in order to identify the kind of an environmental information which must be emphasized to designers and users of Air Force equipment. On the basis of this discussion of primarily corrosion problems, it is shown that there is a need for closer cooperation involving the environmental specialist, designer, and materials engineer in order to build a maximum of environmental resistance into original equipment.

A63-18664
BEARINGS FOR VACUUM OPERATION — RETAINER MATERIAL AND DESIGN.
Harold E. Evans and Thomas W. Flatley (NASA, Mechanical Systems Branch, Goddard Space Flight Center, Greenbelt, Md.).
(American Society of Mechanical Engineers, Aviation Conference, Washington, D.C., June 26-28, 1962, Paper 62 - AV-11.)
ASME, Transactions, Series B, Journal of Engineering for Industry, vol. 85, May 1963, p. 129-134; Discussion and Authors' Closure, p. 134.

Description of the initial phase of an investigation of the high-speed operation of miniature ball bearings, with metallic film lubrication, in a vacuum environment. The study is conducted to determine the most promising retainer material and design for use in a general study of the effectiveness of various metallic coatings as lubricants. Fully machined retainers of five different materials, with all balls and races of gold-plated 440C stainless steel, are tested. Both pure gold plating and gold with additives are investigated. Size R2-5 bearings are run without external loading at a nominal motor speed of 10,000 rpm, and the goal is a bearing life of 1,000 hr in an ambient pressure of 10^{-7} torr. The results show that (1) thin metallic films as lubricants show promise when used in a vacuum environment; (2) pure gold plating is not as effective as the plating with additives; (3) fully machined retainers provide good performance, and the use of relatively hard retainer materials significantly extends the useful life of the bearings; and (4) the bearing failures tend to be catastrophic rather than gradual, making the prediction of the onset of failure difficult. A special multiport oil-free vacuum system designed and built for this program proves extremely effective in achieving a vacuum of 10^{-7} torr, and in permitting the operation of seven individual tests at one time.

A63-19073
NEW DEVELOPMENTS IN LIQUID LUBRICANTS.
E. E. Klaus (Pennsylvania State University, Petroleum Refining Laboratory Division, Dept. of Chemical Engineering, University Park, Pa.).
American Society of Mechanical Engineers, Design Engineering Conference and Show, New York, N.Y., May 20-23, 1963, Paper 63-MD-27. 8 p. 16 refs.
Members, $0.50; nonmembers, $1.00.

Examination of the properties of synthetic lubricants. A number of synthetics, including the chemical classes of esters, silicones, halocarbons, polyglycol ethers, aromatic structures, and hydrocarbons, are contrasted and compared with conventional lubricants. The critical properties of liquid range, volatility, viscosity, oxidative stability, lubricity, thermal stability, and corrosion are included in the comparison. The use of additives and blending techniques to improve specific property deficiencies of the various lubricant types is discussed. Some limitations of liquid lubricants are considered. The important lubricant properties are related to design problems.

A63-19076
ANTIFRICTION BEARING DESIGN CONSIDERATION FOR SOLID LUBRICATION.
M. J. Devine, E. R. Lamson, and J. H. Bowen, Jr. (Naval Air Engineering Center, Aeronautical Materials Laboratory, Philadelphia, Pa.).
American Society of Mechanical Engineers, Design Engineering Conference and Show, New York, N.Y., May 20-23, 1963, Paper 63-MD-43. 7 p.
Members, $0.50; nonmembers, $1.00.

Experimental examination of the mechanism by which metal surfaces are lubricated by solids. The reservoir concept derived in earlier experiments proves that the bearing and lubricant are functionally integral. Extension of the reservoir system to retainer surfaces having sliding contact in rotating assemblies gives a parameter that permits relating the effectiveness of the lubricant to the substrate. New approaches to antifriction bearing design are proposed, and methods for producing self-lubricating solid sections are described for an inorganic composition.

A63-19186
OUTGASSING CHARACTERISTICS OF DRY LUBRICANT MATERIALS IN A VACUUM.
P. H. Bowen and W. H. Hickam (Westinghouse Electric Corp., Research Laboratories, Pittsburgh, Pa.).
Machine Design, vol. 35, July 4, 1963, p. 119-124.
USAF-supported research.

Presentation of experimental data on outgassing properties of certain plastics, dry powders, and metallic composites suitable for lubricants in a hard-vacuum environment. Eleven plastic and carbon compositions, ten powders, and six composites are studied in a vacuum of 10^{-6} mm Hg to determine the amount and composition of gases evolved at various temperatures. These temperatures range from 160°F up to the point of thermal degradation for the plastic material, and from 760° to 1,160°F for the powders and composites. Outgassing data for all materials are recorded on a volume basis and are given as mol % of total gases evolved.

A63-19187
OILS AND GREASES.
Bruce M. Dunham (Dryden Oil Co., Inc., Baltimore, Md.).
Machine Design, vol. 35, June 13, 1963, p. 4-9.

Discussion of the use of oils and greases in the lubrication of rolling and sliding contact bearings. The respective assets of these substances are noted, and their basic characteristics briefly described. Various additives that can be used are also noted. Graphs and tables are given which can aid in the selection of oils or greases with desired characteristics.

A63-19188
SOLID AND BONDED-FILM LUBRICANTS.
Harry S. Gerstung (Alpha-Molykote Corp., Stamford, Conn.).
Machine Design, vol. 35, June 13, 1963, p. 10-14.

Description of materials which can be used for boundary lubrication. Requirements for this type of lubrication are presented. The principal solid lubricants of industrial importance are briefly described, and their basic characteristics are tabulated. Dry-film lubricants are also discussed, as are solid lubricants for bearings. Methods of applying lubricants are noted. The kinetic coefficients of friction for various materials are presented.

A63-19928
TEN YEAR WEATHERING DATA ON ALUMINUM ALLOYS.
William H. Ailor, Jr. (Reynolds Metals Co., Richmond, Va.) and Fred M. Reinhart (U.S. Naval Civil Engineering Laboratory, Port Hueneme, Calif.).
(National Association of Corrosion Engineers, Annual Conference, 18th, Kansas City, Mo., Mar. 19-23, 1962.)
Materials Protection, vol. 2, June 1963, p. 30, 31, 33, 36.

Description of a procedure for evaluating the resistance to corrosion of various aluminum alloys in urban and marine exposure environments. The corrosion effects upon the mechanical properties of these alloys are examined. A study of the pit depths indicates that atmospheric corrosion rates on aluminum tend to level off after an exposure of 2 years, and to remain relatively constant thereafter.

A63-20324
THE PERFORMANCE OF JET ENGINE CONTACT SEALS.
F. A. Schweiger (General Electric Co., Large Jet Engine Dept., Evendale, Ohio).
Lubrication Engineering, vol. 19, June 1963, p. 232-238; Discussion, p. 238.

Discussion of the application of circumferential seals to the main shaft positions of jet engines. It is concluded that the circumferential gas seal is reliable, of moderate cost, easy to assemble, and permits minimum gas leakage. A successful design can be accomplished by working within the developed capabilities of 90 psi pressure differential, 12,000 fpm rubbing velocity, and 750°F ambient temperature.

A63-20328
AIRCRAFT GREASES.
P. J. Douglas (Shell International Petroleum Co., Ltd., London, England).
Society of Licensed and Aircraft Engineers and Technologists, Journal, vol. 1, no. 1, 1963, p. 9-12.

Brief discussion of aircraft greases and additives. The physical mechanism of grease lubrication is briefly discussed, as are various additives, among them extreme pressure additives and rust preventives. Various tests are also described, including those for oil separation and water resistance.

A63-20717
FREE BOUNDARIES IN PARTIAL LUBRICATION.
Garrett Birkhoff and Donald F. Hays (Harvard University, Cambridge, Mass.).
Journal of Mathematics and Physics, vol. 42, June 1963, p. 126-138. 14 refs.

Determination of the free boundary condition for the problem of time-independent flow past an infinite cylindrical bearing. The results for this case are applied to the cases of plane and parabolic sliders, circular cylindrical and general convex sliders, and rotating cylinders, in the attempt to make these problems mathematically well-set boundary-value problems, with physically reasonable solutions.

A63-20921
CUTTING FLUIDS FOR MACHINING THE AEROSPACE ALLOYS.
Peter R. Arzt and Irving J. Stewart (Aerojet-General Corp., Sacramento, Calif.).
(American Society of Lubrication Engineers, Annual Meeting, New York, N.Y., Apr. 30-May 2, 1963.)
Lubrication Engineering, vol. 19, July 1963, p. 283-291. 36 refs.

Discussion of cutting fluids used in machining processes such as turning, face milling, end milling, drilling, tapping, and surface grinding. Several structural alloy groups, and the four refractory metal systems are considered. Empirical data are presented graphically. It is noted that, in general, appropriate fluid selection is more a function of the particular process than of the chemistry of the workpiece. The extreme chemical activity of the titanium alloy group is an outstanding exception to this rule in that machining these alloys by any process requires a highly chlorinated fluid. Fluid selection is also indirectly sensitive to the degree of tool-work impact and the "gumminess" of the workpiece. A new machinable form of tungsten is discussed as to the coolant-lubricant mechanisms upon which its improved machinability is based.

A63-20922
RUST PREVENTIVE ABILITIES OF GREASES AND THEIR IMPROVEMENT.
S. Fred Calhoun and R. L. Young (U.S. Army, Rock Island Arsenal, Rock Island, Ill.).
(American Society of Lubrication Engineers, Annual Meeting, New York, N.Y., Apr. 30-May 2, 1963.)
Lubrication Engineering, vol. 19, July 1963, p. 292-296.

Description of results obtained from tests made on the rust-preventive abilities of greases, using a method developed by the Coordinating Research Council. The tests reveal that a number of commercial and Specification MIL-G-10924A greases are deficient in rust-inhibiting properties. A search has been conducted and several additives have been found which enable the greases to pass the rust-inhibiting test. Other properties of the greases, however, are affected by additives.

A63-22271
PRINCIPLES OF HYDROMAGNETIC LUBRICATION.
J. B. Shukla (Indian Institute of Technology, Kanpur, India).
Physical Society of Japan, Journal, vol. 18, July 1963, p. 1086-1088

Derivation of a modified Reynolds equation governing the flow of an electrically-conducting, incompressible, viscous lubricant, in the presence of an applied magnetic field, by using hydromagnetic simplifications. Particular cases are deduced for infinitely long and very narrow bearings.

A63-22316
EFFECTS OF TWO-DIMENSIONAL, SINUSOIDAL ROUGHNESS ON THE LOAD SUPPORT CHARACTERISTICS OF A LUBRICANT FILM.
R. A. Burton (Southwest Research Institute, San Antonio, Tex.).
(American Society of Mechanical Engineers, Lubrication Symposium, Miami, Fla., June 4-6, 1962, Paper 62 - LubS-1.)
ASME, Transactions, Series D, Journal of Basic Engineering, vol. 85, June 1963, p. 258-262; Discussion, p. 263; Author's Closure, p. 263, 264. 11 refs.

Analysis of the effect of a simple type of boundary roughness on the load support and friction characteristics of a lubricant film. The analysis is restricted to relative sliding of parallel plates carrying a two-dimensional sinusoidal roughness, where the characteristic wavelength is the same on each plate. It is shown that for a fluid whose viscosity increases with pressure, there can be a net load-supporting effect in a parallel surface slider bearing with two-dimensional surface roughness. It is also shown that if fluid viscosity drops with increasing temperature, there is tendency toward cancellation of the net load support. If the temperature-viscosity effect predominates, the surfaces can actually be drawn together by film forces. The onset of this phenomenon may be thought of as an instability, and is different from the continuous relationship which may modify film thickness for different loads. Instead, in this case there is no film thickness which gives a stable solution. The results tend to suggest that asperity contact may occur only if the film between the asperities becomes locally unstable.

A63-22318
A STATISTICAL ANALYSIS IN SOLID FILM LUBRICATION.
Martin R. Adams and Mary D. Lum (USAF, Wright-Patterson AFB, Aeronautical Systems Division, Ohio).
(American Society of Mechanical Engineers, Lubrication Symposium, Miami, Fla., June 4-6, 1962, Paper 62 - LubS-6.)
ASME, Transactions, Series D, Journal of Basic Engineering, vol. 85, June 1963, p. 286-290.

Analysis of a factorially-designed experimental investigation of a ceramic-bonded solid lubricating film consisting of PbS/B_2O_3 in a 6:1 weight ratio. A p^r factorial design is one in which the responses to a set of r controlled factors or variables are determined at p selected levels of each factor. By analysis of a 2^3 factorially-designed experiment investigating the effects of bearing load, sliding speed, and rubbing block temperature on the endurance or wear life of a lubricating film, it is shown that this procedure often possesses distinct advantages over classical experimentation methods. The experimental procedure is described, and the results are presented and analyzed.

A63-22320
GAS LUBRICATED SPHERICAL BEARINGS.
C. H. T. Pan (Mechanical Technology, Inc., Latham, N.Y.).
(American Society of Mechanical Engineers, Lubrication Conference, Pittsburgh, Pa., Oct. 16-18, 1962, Paper 62 - Lub-5.)
ASME, Transactions, Series D, Journal of Basic Engineering, vol. 85, June 1963, p. 311-322; Discussion, p. 323; Author's Closure, p. 323. 17 refs.
DOD-AEC-NASA-supported research; Contract No. Nonr-3730(00).

Derivation of the equations for the gaseous fluid film in a spherical bearing. The steady-state load capacity is considered for a hemispherical bearing, and for a bearing differing from the former in having a small-feed orifice at the pole of the bearing surface. The isothermal Reynolds equation is generalized for any bearing geometry, and is used to derive expressions for the hemispherical bearings. The effect of external pressurization is considered, as is the case when the fluid film is nonuniform. For the latter case, a perturbation formulation is used, and the resulting solutions are presented graphically.

A63-22423
GREASE-TYPE LUBRICANTS COMPATIBLE WITH MISSILE FUELS AND OXIDIZERS.
Joseph Messina and Henry Gisser (U.S. Army Munitions Command, Pitman-Dunn Institute for Research, Frankford Arsenal, Philadelphia, Pa.).
(American Chemical Society, Division of Petroleum Chemistry, Meeting, 144th, Los Angeles, Calif., Mar. 1963.)
I & EC - Product Research and Development, vol. 2, Sept. 1963, p. 209-212. 14 refs.

Study of the thickening of mixed perfluorotrialkylamines (alkyl = C_4 to C_6) with tetrafluoroethylene polymers (molecular weights 2,000-30,000) in connection with the development of grease-type lubricants for liquid-fuel-powered missiles. Grease-type mixtures were stable to shear stresses, and showed no separation on standing (up to one year) and little separation in the cone tests at 100°C. The greases were unreactive with, and insoluble in, ethyl alcohol, JP-4, unsym-dimethylhydrazine, diethylenetriamine, a 60:40 mixture of the last two, a 50:50 mixture of unsym-dimethylhydrazine and hydrazine, 90% hydrogen peroxide, and inhibited red fuming nitric acid. There was no explosive reactivity in impact tests with liquid oxygen or nitrogen tetroxide. A typical grease exhibited antiwear and extreme pressure properties comparable to conventional petroleum greases, and did not attack most conventional elastomers. Average particle size of the polymers was 5 μ.

A63-22447
STRESS CORROSION CRACKING IN HIGH STRENGTH STEEL - OR HYDROGEN EMBRITTLEMENT?
Ivar Weibull (Saab Aircraft Co., Materials Laboratory, Linköping, Sweden).
IN: ADVANCES IN AERONAUTICAL SCIENCES. VOL. 3. 2nd International Congress in the Aeronautical Sciences, Proceedings, Zurich, Switzerland, Sept. 12-16, 1960.
New York, Pergamon Press, Inc., 1962, p. 335-356.

Description of corrosion tests carried out under stress in a humidity cabinet with steels of different compositions and hardness levels. The results are analyzed in terms of the practical experience with these steels. Also described are experiments to determine if the failures were due to true stress corrosion cracking, or to hydrogen embrittlement induced by corrosion. Brittle failures are observed in nonplated threaded bolts of high strength, which are probably caused by hydrogen generated by atmospheric moisture corrosion. It is found that the sensitivity to such failures, and to hydrogen embrittlement in general, is very different for steels of different compositions and hardness levels.

A63-22816
AIRCRAFT GREASES. III.
P. J. Douglas (Shell International Petroleum Co., Ltd., London, England).
Society of Licensed Aircraft Engineers and Technologists, Journal, vol. 1, no. 2, 1963, p. 9, 10, 12, 13.

Brief review of some of the major greases used in aircraft. The major applications and limitations of six greases are briefly described, and the uses of seven other greases are noted. Different factors governing the choice of greases are discussed, among them operating temperature range, and bearing size and speed.

A63-23037
APPLICATION OF MICROPHOTOGRAPHY IN THE STUDY OF SOLID-PHASE STRUCTURE OF LUBRICANTS AT LOW TEMPERATURES [PRIMENENIE MIKROS'EMKI DLIA ISSLEDOVANIIA STRUKTURY TVERDOI FAZY SMAZOCHNYKH MASEL PRI NIZKIKH TEMPERATURAKH].
V. F. Dudin and L. F. Mazharov (Groznyi Petroleum Institute, Groznyi, USSR).
Zhurnal Nauchnoi i Prikladnoi Fotografii i Kinematografii, vol. 8, May-June 1963, p. 201, 202. In Russian.

Description of a microphotographic investigation of the MS-20 lubricant at freezing temperatures. An analysis of microphotographs shows that at the freezing temperature, the lubricant represents a system in which the dispersion-phase particles form a reticular structure. The MS-20 lubricant is therefore related to the class of "freezing" lubricants, in which the mean size of the dispersion-phase particles constitutes 0.004 mm at the freezing temperature, and is not dependent on the time of cooling. It is found that the size of dispersion-phase particles increases as the temperature decreases. The application of microphotography to the thermal analysis of structural systems at low temperatures is recommended for other analog studies.

A63-23195
THE IMPORTANCE OF ENVIRONMENT IN FATIGUE FAILURE OF METALS.
J. A. Bennett, W. L. Holshouser, and H. P. Utech.
IN: FATIGUE OF AIRCRAFT STRUCTURES. Direction Technique et Industrielle de l'Aéronautique and International Committee on Aeronautical Fatigue, French Center, Fatigue of Aircraft Structures, Symposium, Paris, France, May 16-18, 1961, Proceedings. Edited by W. Barrois and E. L. Ripley. New York, Pergamon Press, 1963, p. 1-17; Discussion, p. 17, 18. 33 refs.

Review of experiments during the past 30 years on fatigue strength of metals. It is indicated that the fatigue strengths of many metals are reduced by the surface reactions occurring even in a normal indoor atmosphere. For most iron-, aluminum-, or copper-base alloys the reduction is 5 to 10 percent as compared with the fatigue strength in vacuum or inert atmosphere. Recent investigations show that these effects often can be eliminated by application of certain polar organic liquids which form protective films on the metal. The presence of these compounds on the surface of fatigue specimens may increase both the number of cycles required to initiate a crack and the number required to propagate the crack to fracture.

A63-23271
STANDARD HARDWARE AND CORROSION: PERSHING PROBLEMS AND ACTION. Appendix - PERSHING INTERIM PURCHASE DESCRIPTION.
W. L. Chandler and D. E. Davis (Martin Marietta Corp., Martin Co., Orlando, Fla.).
(Institute of Electrical and Electronics Engineers, International Conference and Exhibit on Aerospace Support, Washington, D.C., Aug. 4-9, 1963.)
IEEE Transaction on Aerospace, vol. AS-1, Aug. 1963, p. 580-588.

Discussion of the hardware corrosion problems, in terms of the reliability requirements of the Pershing Weapon System. Outlined is the test plan for which 28 different parts and 69 combinations representative of types I and II cadmium plated hardware, stainless steel, and nickel plated hardware were selected for testing. Typical problems encountered during the procurement of the necessary parts are considered, as are their solutions.

A63-23729
INVESTIGATION OF THE LUBRICATION PROCESS UNDER HEAVY FRICTION CONDITIONS.
G. V. Vinogradov, N. T. Pavlovskaia, and Iu. Ia. Podolskii (Academy of Sciences, Institute of Petrochemical Synthesis, Moscow, USSR).
Wear, vol. 6, May-June 1963, p. 202-225. 41 refs.

Demonstration that the most important factor at boundary conditions of friction of low-alloy and tungsten steels with organic lubricating media is the presence of molecular oxygen and lubricant oxidation products. The action of molecular oxygen as a natural additive component of lubricants must be taken into account even when they contain synthetic additives designed to cause chemical modification of the steel surface and prevent or mollify seizure. Oxygen and lubricant oxidation products, on the one hand, and thio-, chloro- and phospho-organic compounds, on the other, may manifest both synergism and antagonism in their effect on steel friction. If the occurrence of oxidative processes is facilitated, as in the case of low-viscosity hydrocarbon lubricants, the dominating effect on friction may be that of the formation of oxide layers on the steel.

A63-24091
GRAPHITE, MOLYBDENUM DISULFIDE AND PTFE - A COMPARISON.
Arthur J. Stock (Acheson Colloids Co., Port Huron, Mich.).
(American Society of Lubrication Engineers, Annual Meeting, 18th, New York, N.Y., Apr. 30-May 2, 1963.)
Lubrication Engineering, vol. 19, Aug. 1963, p. 333-338; Discussion, p. 338; Author's Closure, p. 338. 45 refs.

Comparison of the properties of graphite, molybdenum disulfide, and PTFE solid lubricants. Complete data presented on load, speed, temperature, and friction show that PTFE has serious limitations; both graphite and molybdenum disulfide can withstand higher loads and greater speeds, and graphite can also withstand higher temperatures.

A63-24108
TITANIUM IN STRUCTURAL DESIGN.
I. L. G. Baillie and T. W. Coombe (Bristol Aircraft, Ltd., Filton, Bristol, England).
Aircraft Engineering, vol. 35, Aug. 1963, p. 226, 227, 241.

Comparison of the suitability of titanium alloys and other conventional alloys for airframe structures. Factors considered include static strength, fatigue and cracking, low- and high-temperature applications, and corrosion and stress corrosion.

A63-24359
SURFACE ROUGHNESS IN WEAR.
Eugene Finkin (Rensselaer Polytechnic Institute, Dept. of Mechanics, Troy, N.Y.).
Wear, vol. 6, July-Aug. 1963, p. 293-302.

Experimental determination of the role played by surface roughness in wear. Rotational experiments were carried out with sliders on plates for lightly loaded systems of copper on copper and steel on steel. The average maximum surface roughness was measured for lubricated and unlubricated sliding conditions and compared with the mean wear particle size. The roughness was found to approach a value independent of initial conditions and determined by dynamic equilibrium. The equilibrium peak-to-peak roughness values were found to have a good rank correlation with the mean wear particle size in systems of the same material. Wear particles were found to have a characteristic shape which varies with the material, being roughly an ellipsoid for copper and a strip or extended plate for 102(steel.

A63-24506
THE CONTAMINATION OF TUNGSTEN BY DIFFUSION OF CARBON FROM GRAPHITE LUBRICANTS.
L. N. Aleksandrov (Mordovian State University, Saransk, USSR).
(Inzhenerno-Fizicheskii Zhurnal, no. 9, 1962, p. 53.)
International Chemical Engineering, vol. 3, Jan. 1963, p. 108-111. 14 refs. Translation.

Experimental investigation, using a radioactive tracer method, to study the diffusion of carbon in polycrystalline tungsten at temperatures below 1,000°C. The investigation was conducted on samples of type VA-3 tungsten wire (of 0.25-mm diam.), from which the industrial graphite lubricant had previously been cleaned. The samples were covered with a specially prepared graphite lubricant containing radioactive carbon C-14, and annealing was carried out in vacuo. The experimental results are discussed in terms of the possible diffusion-contamination of tungsten by carbon from graphite lubricants during the wire manufacturing process, and also during the thermal treatment of the spirals.

A63-25426
TRENDS IN LIQUID LUBRICANTS.
E. E. Klaus (Pennsylvania State University, Dept. of Chemical Engineering, Refining Laboratory Div., University Park, Pa.).
Mechanical Engineering, vol. 85, Oct. 1963, p. 42-45. 12 refs.

General discussion of the thermal, mechanical, and chemical stability of liquid lubricants from mineral oils, additives, and synthetics, for applications to aerospace hardware. The discussion is in terms of viscosity-volatility characteristics of lubricants, viscosity properties, and the use of polymeric materials, boundary lubrication, lubricant compounding, and super-refined mineral oils.

A63-25481
PROPERTIES OF MATERIALS TO AID LUBRICATION.
M. B. Peterson and S. F. Murray (Mechanical Technology, Inc., Latham, N.Y.).
(American Society of Mechanical Engineers, Design Engineering Conference, New York, N.Y., May 1963, Paper 63 - MD-44.)
Machine Design, vol. 35, Sept. 12, 1963, p. 200, 202, 205, 208-211, 214, 215.

Discussion of techniques for selecting materials and lubricants for sliding contacts, for equipment which must operate at temperatures from -400° to 4,000°F, and at speeds of up to Mach 10. Emphasized in the discussion are friction, wear, and surface damage. Difficulties discussed are those which arise when materials are inadequate from a surface-damage standpoint, or when lubricant fails or does not reach the sliding interface. The discussion applies only to unlubricated or boundary-lubricated surfaces.

A63-25801
LUBRICATION.
Francis J. Clauss (Lockheed Aircraft Corp., Lockheed Missiles and Space Co., Palo Alto, Calif.).
IN: MATERIALS FOR MISSILES AND SPACECRAFT.
Edited by Earl R. Parker.
New York, McGraw-Hill Book Co., Inc., 1963, p. 277-324. 44 refs.

Discussion of lubrication problems in the orbital environment. Silicone oils and greases are among the most successful lubricants tested to date. The tests indicate that they should be suitable for six months of continuous operation in space on small, double-shielded ball bearings in many spacecraft applications, provided that operating temperatures do not exceed 79°C and that speeds do not exceed 8,000 rpm. Thin films of laminar solids, such as MoS_2, can provide low running torques, long-wear lives, low evaporation rates, relative insensitivity to temperature, and excellent radiation stability. Plastics, such as Teflon and nylon, offer many advantages as self-lubricating parts for spacecraft mechanisms, among which is a minimum tendency to cold-weld to metals under vacuum conditions. Ceramics and cermets are essentially hard, brittle materials such as sapphire, glass, cemented carbides, fully dense oxides, and Pyroceram. As in the case of plastics, the ceramics and cermets have little tendency to cold-weld to metals under vacuum conditions.

A63-26050
MOLYBDENUM-DISULPHIDE - ITS USE IN AIRCRAFT MANUFACTURE AND MAINTENANCE.
H. Peter Jost and W. Bye.
HAL Technical Society Digest, vol. 3, July 1963, p. 28-35.

Discussion of the various applications of molybdenum-disulphide as a lubricant in the field of production engineering. Shown are the advantages of the use of molybdenum-disulphide as a method of overcoming difficult conditions of lubrication in the service life of an aircraft. The application of the correct grade of molybdenum-disulphide, either in the form of a dry or semi-dry film, or in a suitable carrier, will improve lubrication in virtually every case. However, except for running-in, it may be uneconomical to use this material where normal lubricants are already proving quite satisfactory.

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A64-10067
THE QUANTITY OF HYDROGEN PEROXIDE EVOLVED IN ATMOSPHERIC CORROSION OF ALUMINIUM, AS A FUNCTION OF AIR PRESSURE.
I. L. Roikh and E. T. Kononchik (Odessa Lomonosov Technological Institute, Odessa, Ukrainian SSR).
(Zhurnal Fizicheskoi Khimii, July 1959, p. 433.)
Russian Journal of Physical Chemistry, vol. 37, Feb. 1963, p. 222-224. Translation.

Description of a technique for investigating the processes of evolution of H_2O_2 in the corrosion of metals during the early stages, as a function of the pressure of the gaseous medium. The H_2O_2 evolution in the corrosion of aluminum is studied as a function of air pressure over the range 5-760 mm Hg. In the range 5-100 mm, the quantity of H_2O_2 evolved increases rapidly with increase in pressure; a maximum is observed at about 100 mm, with further increases in pressure up to 760 mm decreasing the quantity of H_2O_2 evolved.

A64-10585
THE MAGNETOHYDRODYNAMIC JOURNAL BEARING.

Dennis C. Kuzma (General Motors Corp., Research Laboratories, Warren, Mich.).
(American Society of Mechanical Engineers, Lubrication Conference, Pittsburgh, Pa., Oct. 16-18, 1962, Paper 62 - Lub-16.)
ASME, Transactions, Series D, Journal of Basic Engineering, vol. 85, Sept. 1963, p. 424-427; Discussion, p. 427, 428; Author's Closure, p. 428.

Analysis of an infinite journal bearing, for the case of an electrically conducting fluid in the presence of a magnetic field. The magnetohydrodynamic form of Reynolds' bearing equation is derived and solved for the pressure distribution, from which the load carrying capacity is determined. Numerical data are presented for nonconducting bearing surfaces, and are compared with the data from the ordinary journal bearing. It is shown that the load carrying capacity is increased by the application of a magnetic field.

A64-10586
THE NONLINEAR HYDRODYNAMIC SLIDER BEARING.
William T. Snyder (New York, State University, Oyster Bay, N. Y.).
(American Society of Mechanical Engineers, Lubrication Conference, Pittsburgh, Pa., Oct. 16-18, 1962, Paper 62 - Lub-1.)
ASME, Transactions, Series D, Journal of Basic Engineering, vol. 85, Sept. 1963, p. 429-433; Discussion, p. 433, 434; Author's Closure, p. 434. 10 refs.

Analysis of the influence of nonlinear inertia terms in the equations describing the slider bearing. A series solution is obtained which considers the local variation of the inertia terms across the film, as well as in the direction of motion of the slider.

A64-10587
HALF SOMMERFELD APPROXIMATION FOR FINITE JOURNAL BEARINGS.
J. V. Fedor (NASA, Goddard Space Flight Center, Greenbelt, Md.).
(American Society of Mechanical Engineers, Lubrication Conference, Pittsburgh, Pa., Oct. 16-18, 1962, Paper 62 - Lub-3.)
ASME, Transactions, Series D, Journal of Basic Engineering, vol. 85, Sept. 1963, p. 435-438; Discussion, p. 438; Author's Closure, p. 438.

Presentation of an approximate analytical solution for full journal bearings, which includes the effects of bearing finiteness and an incomplete oil film. The approximate solution is obtained by modifying the complete oil film solution to Reynolds equation. The developed equations are in finite form and are simple to evaluate. Calculated values agree well with published computer solutions.

A64-10588
THE ROLE OF ELASTOHYDRODYNAMIC LUBRICATION IN ROLLING-CONTACT FATIGUE.
E. V. Zaretsky, W. J. Anderson (NASA, Lewis Research Center, Cleveland, Ohio), and L. B. Sibley (Battelle Memorial Institute, Columbus, Ohio).
(American Society of Mechanical Engineers, Lubrication Conference, Pittsburgh, Pa., Oct. 16-18, 1962, Paper 62 - Lub-4.)
ASME, Transactions, Series D, Journal of Basic Engineering, vol. 85, Sept. 1963, p. 439-447; Discussion, p. 447-449; Authors' Closure, p. 449, 450. 18 refs.

The five-ball fatigue tester is used to determine the rolling-contact fatigue life of 1/2-in.-diam. M-1 steel balls with four lubricants at 300°F. Film thickness measurements are made with the rolling-contact disk machine under simulated five-ball test conditions. Under certain conditions, elastohydrodynamic lubrication is found to exist at initial maximum Hertz stress levels up to 800,000 psi. There appears to be a correlation among the following variables: plastically deformed profile radius of the ball specimen at ambient temperature, lubricant type, and rolling-contact fatigue. No correlation was found between contact temperature obtained with different lubricants and fatigue life.

A64-10589
EXPERIMENTAL INVESTIGATION OF THE MINIMUM OIL-FILM THICKNESS IN SPUR GEARS.
D. W. Dareing and E. I. Radzimovsky (Illinois, University, Dept. of Mechanical Engineering, Urbana, Ill.).
(American Society of Mechanical Engineers, Lubrication Conference, Pittsburgh, Pa., Oct. 16-18, 1962, Paper 62 - Lub-9.)
ASME, Transactions, Series D, Journal of Basic Engineering, vol. 85, Sept. 1963, p. 451-455, Discussion, p. 455; Authors' Closure, p. 455, 456. 21 refs.

As a pair of gears is loaded, the minimum oil-film thickness between the gear teeth decreases and can approach a magnitude equal to the magnitude of the surface roughness. Metal-to-metal contact then occurs between the microscopic peaks on both mating teeth surfaces. Therefore, the minimum thickness of the film separating the mating teeth surfaces may be considered as one of the criteria of capacity for a gear drive. A testing technique that was developed for measuring oil-film thickness between loaded gear teeth while running is presented. The voltage drop across a thin oil film that is required to cause an electrical discharge is used to determine the oil-film thickness. A specially designed machine containing a planetary gear train is employed in these experiments. The relationships between the minimum oil-film thickness and the load transmitted by the gearing under certain conditions are determined using this method.

A64-10590
LUBRICATION REVIEW: DEVELOPMENTS IN BEARINGS AND LUBRICANTS - A DIGEST OF THE LITERATURE FOR 1960-1961.
R. L. Wehe (Cornell University, Ithaca, N.Y.), J. C. Lawrence (SKF Industries, Inc., Research Laboratory, Philadelphia, Pa.), W. J. Derner, H. Ryffel (Curtiss-Wright Corp., Wright Aeronautical Div., Wood-Ridge, N.J.), E. W. Hitchcock (Rust-Lick, Inc., Boston, Mass.), W. J. Wojtowicz (H. A. Montgomery Oil Co., Inc., Detroit, Mich.), R. A. Burton (Southwest Research Institute, Lubrication Research Sect., San Antonio, Tex.), and H. A. Hartung.
(American Society of Mechanical Engineers, Winter General Meeting, New York, N.Y., Nov. 26-Dec. 1, 1961.)
ASME, Transactions, Series D, Journal of Basic Engineering, vol. 85, Sept. 1963, p. 457-473.

Survey of 369 papers and books covering various aspects of work on bearings and lubricants. Considered are fluid-film and rolling-element bearings, gear and metalworking lubrication, automotive lubricants, and friction and wear, the latter including extreme environment studies.

A64-10705
INVESTIGATION OF BINDERS FOR SOLID LUBRICANTS AT ELEVATED TEMPERATURES.
Bernard C. Stupp and John W. Wright (Hohman Plating and Manufacturing Co., Dayton, Ohio).
(American Society of Lubrication Engineers, Annual Meeting, 18th, New York, N.Y., Apr. 30-May 2, 1963.)
Lubrication Engineering, vol. 19, Nov. 1963, p. 463-468; Discussion, p. 469; Author's Closure, p. 469.

Investigation of several materials as binders for solid lubricant materials having molybdenum disulfide and graphite as lubricating pigments. Binders investigated were silicates, borates, phosphates, and combinations of these materials with metal oxides. This investigation shows the results of wear life tests made on these binders to temperatures of 350C. Effect of temperature on wear life, coefficient of friction, film weight loss, film density, and chemical composition are shown for one composition having sodium phosphate as a binder.

A64-10762
ANALYSIS AND NUMERICAL CALCULATIONS OF THE DYNAMIC BEHAVIOR OF PLANE PIVOTED SLIDER BEARINGS.
W. Stuiver and R. S. McDuffie (International Business Machines Corp., San Jose Research Laboratory, San Jose, Calif.).
IBM Journal of Research and Development, vol. 7, Oct. 1963, p. 303-316.
Contract No. Nonr 3448(00), Task No. 061-120.

Investigation of the behavior of plane, self-acting, pivoted slider bearings of infinite length, for the case of an incompressible lubricating film. The equations of motion for the slider are

derived, with the lubricant force expressed in terms of the motion-coordinates and their derivatives and of the parameters that characterize the system. Equilibrium positions of the system are determined numerically, and the stability of small motions in the neighborhood of these positions is examined. The nature of large motions is investigated by numerical integration of the equations of motion, and the transient behavior of the system is shown and discussed for some specific cases.

A64-10887
WEAR CONSIDERATIONS IN DESIGN. I.
Charles Lipson (Michigan, University, School of Mechanical Engineering, Ann Arbor, Mich.).
Machine Design, vol. 35, Oct. 24, 1963, p. 156-164.

Discussion of the phenomenon of mechanical wear. The wear theories considered are the adhesion, the interlocking, the abrasion, and the quanta theories. The relation between friction and wear is analyzed. Factors influencing wear are discussed, among them hardness, load, temperature, sliding velocity, contaminants, and environmental effects. Principles of wear measurement and of wear control are indicated. The mechanisms of score and seizure are examined, and among the data considered are the score and seizure resistance of various metals in sliding contact. The effects of impurities on wear are noted.

A64-10970
THE PROBLEM OF MATERIAL SELECTION FOR PARTS EXPOSED TO WEAR [DAS PROBLEM DER WERKSTOFFWAHL BEI VERSCHLEISSTEILEN].
Paul Esslinger (Batelle-Institut e.V., Frankfurt/Main, Germany).
VDI Zeitschrift, vol. 105, Sept. 1963, p. 1209-1218. 39 refs. In German.

Discussion of the problem of wear resistance, showing that it does not represent a defined material property but rather constitute a complex integral function which is dependent on the wear conditions. This situation is attributed to the interaction of a variety of basic wear mechanisms whose relative contribution to the overall wear depends on the wear conditions. For each of these basic processes there is a different relationship with the material properties. Hence, it is only in the case of "basic wear conditions" that a simple relationship can be derived between wear resistance and material properties. This is illustrated by an example of "scratching" in the region of severe wear.

A64-11352
WEAR CONSIDERATIONS IN DESIGN. II.
Charles Lipson (Michigan, University, Ann Arbor, Mich.).
Machine Design, vol. 35, Nov. 7, 1963, p. 177-185. 10 refs.

Consideration of surface film prevention of friction between two sliding surfaces. The coefficient of friction is seen to depend directly on the degree to which the surface film prevents asperity contact and on the strength of the junctures formed by the welding that does occur. Oxide and graphite carbon films are discussed, and the properties of extreme pressure, liquid, and solid lubricants are delineated. The nature of abrasion is briefly considered, and methods of abrasion control using rubber are outlined.

A64-11353
FRICTION AND WEAR CHARACTERISTICS OF DRY LUBRICANTS.
P. H. Bowen (Westinghouse Electric Corp., Research Laboratories, Insulation and Chemical Technology Dept., Pittsburgh, Pa.).
Machine Design, vol. 35, Nov. 7, 1963, p. 195-199.
USAF-sponsored research.

Review of tests in a search for lubricants which would function at high temperature and low pressure, made in a dry inert atmosphere. Test results are discussed for plastics, dry powders, and composites and alloys. The tests yielded promising materials and a fundamental principle for the use of a dry lubricant in a vacuum. This principle states that a dry-lubricant composite must contain a matrix or reservoir to hold the lubricating component of the composite. One component must be a film former that can flow and coat both rubbing surfaces; the other component must be a material which provides load carrying ability.

A64-11379
CONCERNING THE MECHANISM OF FATIGUE IN WEAR FOR ELASTIC CONTACT [OB USTALOSTNOM MEKHANIZME IZNOSA PRI UPRUGOM KONTAKTE].
I. V. Kragel'skii and E. F. Nepomniashchii.
Akademiia Nauk SSSR, Izvestiia, Mekhanika i Mashinostroenie, Sept.-Oct. 1963, p. 190-195. 12 refs. In Russian.

Discussion of wear in elastic contact, resulting from failure by fatigue due to repeated interaction of rough surfaces in friction. Derived are expressions relating the degree of wear with the conditions of friction, and the mechanical properties of the material subject to wear with the roughness of the body with which it is in friction.

A64-11394
NATURAL OSCILLATIONS OF AN ELASTIC SHAFT AT NEAR EQUILIBRIUM OF SLIDE BEARING [AVTOKOLEBANIIA GIBKOGO VALA OKOLO RAVNOVESNOGO SOSTOIANIIA V PODSHIPNIKAKH SKOL'ZHENIIA].
S. P. Maksimov.
Akademiia Nauk SSSR, Izvestiia, Mekhanika i Mashinostroenie, July-Aug. 1963, p. 10-17. In Russian.

Discussion of the periodic self-induced oscillations of a symmetric elastic shaft with a disk, caused by the effect of the lubrication film in slide bearings. Specifically examined are the oscillations that arise at near equilibrium of the system shaft-bearings. The results of the calculations are presented in graphs and tables. Some conclusions drawn from the results are included.

A64-11405
LUBRICATION OF THRUST BEARINGS WITH CONICAL BEARING SURFACE, TAKING HEAT TRANSFER INTO ACCOUNT [O SMAZKE UPORNYKH PODSHIPNIKOV, IMEIUSHCHIKH KONICHESKUIU NESUSHCHUIU POVERKHNOST', S UCHETOM TEPLOPEREDACHI].
I. Ia. Tokar' and P. S. Cherniakov.
Akademiia Nauk SSSR, Izvestiia, Mekhanika i Mashinostroenie, July-Aug. 1963, p. 123-126. In Russian.

Presentation of a solution to the problem of the steady motion of a viscous incompressible fluid between a plane rotating disk and a fixed truncated cone with a plane strip at the end. The solution is an extension of previous results obtained on the assumption of an isothermic lubrication process to include a varying viscosity of the lubricant on the assumption of the absence of wall heat transfer.

A64-11474
ELASTO-HYDRODYNAMIC LUBRICATION.
Jerrold W. Kannel (Battelle Memorial Institute, Columbus, Ohio).
Battelle Technical Review, vol. 12, Nov. 1963, p. 11-16.
USAF-supported research.

Discussion of current approaches to the study of the lubrication of rolling-contact heavily loaded machine elements. Following a survey of the essential features of lubrication, the theoretical aspects of elasto-hydrodynamic lubrication are outlined. Methods of verifying qualitatively and quantitatively the existence of a hydrodynamic lubricating film between heavily loaded rolling elements are noted. Graphs showing the theoretical prediction of (1) pressure distribution between rollers as related to speed, and (2) roller deformation as related to speed are presented, as are the effects of speed and of loading on roller deformation. Theoretical and actual measurements of lubricant thicknesses are compared.

A64-11664
FATIGUE WEAR AS A RATE PROCESS.
L. Rozeanu (Technion-Israel Institute of Technology, Dept. of Metallurgy, Haifa, Israel).
Wear, vol. 6, Sept.-Oct. 1963, p. 337-340.

Presentation of the main steps of the quantitative treatment of a wear process in conditions in which adhesion, ploughing, and chemical wear mechanisms have relatively unimportant contributions. In agreement with the concepts modifying Griffith's theory of brittle fracture when applied to metals, the fatigue wear prevailing in these conditions should involve two distinct processes: work hardening of the asperity, and removal of the work-hardened asperity top by shearing due to impact during the sliding process itself.

A64-11666
CONICAL STEP BEARING USING A POWER LAW LUBRICANT.
J. B. Shukla (Institute of Higher Technology, Khanpur, India).
Wear, vol. 6, Sept.-Oct. 1963, p. 371-374.

Consideration of the use of a power law fluid as lubricant in a conical step bearing. The effect of the flow behavior index on the load capacity is studied, and it is shown that the load capacity can be increased by using a pseudo-plastic fluid as a lubricant rather than a Newtonian lubricant.

A64-11668
THE INFLUENCE OF WEAR ON THE COEFFICIENT OF STATIC FRICTION IN THE CASE OF HEMISPHERICAL SLIDERS.
D. H. Wiid and W. F. Beezhold (Pretoria, University, Dept. of Applied Mathematics, Pretoria, South Africa).
Wear, vol. 6, Sept.-Oct. 1963, p. 383-390.

Experimental investigation which demonstrates that the value of the coefficient of static friction decreases as the number of successive small relative displacements of a spherical slider on a flat metal base increases. It is shown that the results can be attributed to wear of the slider. The effect seems to become distinctly noticeable only in the case of sliders which are nearly perfectly spherical.

A64-12051
WHAT CAN BE GAINED WITH ADDITIVE OILS IN UTILITY AIRCRAFT ENGINES.
C. K. Bransford and H. A. Poitz (Shell Oil Co., Products Application Dept., Houston, Tex.).
Society of Automotive Engineers, Automotive Engineering Congress, Detroit, Mich., Jan. 13-17, 1964, Paper 781C. 12 p. 12 refs.
Members, $0.75; nonmembers, $1.00.

Discussion of three types of additive aircraft oils introduced in the past several years and approved by the manufacturers of engines for which they are suitable. The functions of the additives are described, and the advantages provided in terms of engine condition and performance are discussed and illustrated by examples, as a result of extensive experience with oils incorporating the additives. The approach to the subject matter is oriented toward the interests of private and corporate operators of aircraft, but some use is also made of information from airline and military sources.

A64-13127
ION ENGINE RELIABILITY AS AFFECTED BY CORROSION OF MATERIALS.
P. M. Winslow (Hughes Aircraft Co., Materials Technology Dept., Metallurgy Group, Culver City, Calif.).
(American Institute of Aeronautics and Astronautics, Electric Propulsion Conference, Colorado Springs, Colo., Mar. 11-13, 1963, Paper 63-032.)
AIAA Journal, vol. 2, Jan. 1964, p. 42-45.

Presentation of detailed corrosion information on 50- and 500-hr exposure tests of a number of ion engine structural metals in both cesium vapor and liquid. The structural metals tested for corrosion included the 300 series stainless steels, Sicromo, and Inconel, as well as a titanium-vanadium alloy. Tests on tantalum, tungsten, and a possible oxygen getter alloy are also run. Important aspects of the impurity studies are the effects of oxygen in cesium on corrosion as well as on potential degradation of the ionizer. The most formidable problems associated with oxygen relate to the measurement of the oxygen level in cesium. It is shown that analytical methods used for oxygen in other alkali metals have not proved entirely satisfactory for cesium.

A64-13447
FUELS AND LUBRICANTS.
R. C. Sheard (USAF, Systems Command, Aeronautical Systems Div., Aero Propulsion Laboratory, Wright-Patterson AFB, Ohio).
Materials Research and Standards, vol. 3, Oct. 1963, p. 820-824.

Review of a lubricant and fuel testing program to develop materials for the SST. A large test rig for fuel testing is diagrammed and briefly described. Periodically throughout each test examinations will be made of system components to observed evidence of fuel and component performance degradation. The fuel selected for the first test is one of the better quality commercial jet fuels and is in the ASTM Type A category. Its properties are tabulated. Factors influencing fuel degradation are briefly discussed, as are fuel deposits and deterioration. The lubricant program is primarily directed toward finding base stocks and additives. The oil consumption of an SST is tabularly compared to that of current aircraft. Fuel and lubricant costs are discussed, and the properties of hydraulic fluids are considered and tabulated.

A64-13640
ADVANCED LUBRICANTS AND LUBRICATION TECHNIQUES.
Robert L. Adamczak, Robert J. Benzing, and Herbert Schwenker (USAF, Systems Command, Washington, D. C.).
I & EC - Industrial and Engineering Chemistry, vol. 56, Jan. 1964, p. 41-47. 36 refs.

Discussion of lubricants and lubrication techniques able to meet the requirements of the space age. Considered are specially processed mineral oils and synthetic hydrocarbons, esters, silicon-containing fluids, polynuclear aromatics, advanced fluids, liquid metals and salts as lubricants, gas lubricated bearings, solid films, dry lubrication, in situ films, and miscellaneous techniques. It is shown that there is a wide variety of lubrication techniques for potential use at elevated temperatures. It then becomes a major problem to select the correct system for use in an advanced vehicle. It is noted that it is an even greater problem to select those systems which offer promise for future use and which should receive the major research effort.

A64-13989
INFLUENCE OF SLIDING SPEED ON BOUNDARY LUBRICATION.
Yukio Miyakawa (National Aerospace Laboratory, Tokyo, Japan).
JSME, Bulletin, vol. 6, Nov. 1963, p. 833-839.

Study of the effect of sliding speed on the boundary friction under various conditions by measuring the friction and electrical contact resistance between the sliding metal surfaces. It is found that the friction speed characteristic is affected by the oil-content of the lubricant. The addition of varying amounts of oleic acid to a spindle oil not only reduces the friction, but also greatly affects the friction-speed characteristic. A thick film of lubricant is formed even at low speeds, if a small percentage of oleic acid is added to a spindle oil. On the other hand, a 100% oleic acid provides good boundary lubrication and reduces friction, but causes a considerable increase in the amount of wear.

A64-13990
WEAR OF MONO- AND MULTI-MOLECULAR LAYERS.
Yukio Miyakawa (National Aerospace Laboratory, Tokyo, Japan).
JSME, Bulletin, vol. 6, Nov. 1963, p. 840-845.

Study of the wear properties of mono- and multi-molecular layers of barium stearate under various conditions of loads and speeds. The wear properties of molecular layers are compared by measuring the increase of friction coefficient and the critical number of runs with the abrupt rise of friction coefficient during repetition of sliding over the same track. It is found that the critical number of runs is increased with the increase of film thickness or speed and the decrease of load. However, there is a marked decrease in the durability of the film where the number of layers is more than 10 molecular layers.

A64-14027
DESIGN CRITERIA FOR ROLLING ELEMENT AIRFRAME BEARINGS FOR HIGH TEMPERATURE AND HIGH ALTITUDE USE.
J. B. Havewala and J. H. Johnson (Marlin-Rockwell Corp., Jamestown, N.Y.).
(American Society of Lubrication Engineers, Annual Meeting, 18th, New York, N.Y., Apr. 30-May 2, 1963.)
Lubrication Engineering, vol. 20, Jan. 1964, p. 25-33; Discussion, R. E. Murteza and W. A. Glaeser, p. 33-35; Authors' Closure, p. 35.
Contract No. AF 33(616)-6650.

Experimental investigation for the evaluation of bearing materials and lubricants for operation in the temperature range of 1,200°F at simulated altitude of 250,000 ft. Four different roll

designs, together with twelve different material combinations, were investigated. The resulting best design and two best material combinations were subjected to stresses up to 325,000 psi average Hertz Stresses at the temperature and vacuum. One inch diameter bore self-aligning double row roller bearings fabricated from Wrought alloy carried loads to 5,000 lb (280,000 psi average Hertz Stresses) for 40,000 cycles at 1,200°F and vacuum. All contact surfaces were treated with DF-700 dry film (MoS_2 + Graphite + Sodium Silicate). Friction coefficients with dry lubricants were in the range of 0.08 to 0.25. It is noted that successful bearing operation required considerable deviation from design criteria for fluid lubricated bearings.

A64-14371

CONDITIONS FOR THE ONSET OF PITTING DUE TO FRICTION [USLOVIIA VOZNIKNOVENIIA PITTINGA PRI TRENII].

B. P. Mitrofanov.

Akademiia Nauk SSSR, Doklady, vol. 153, Dec. 11, 1963, p. 1065, 1066. 12 refs. In Russian.

Experimental investigation of the conditions for the onset of cracks which lead to material failure due to fatigue by pitting corrosion. Steel conical models are used in the tests to study qualitatively the nature of the plastic deformation of the individual microcusps of a rough surface. The results indicate that the localization zone of the plastic deformation of the material's contact layers creates the conditions for, and determines the nature of, the development of fatigue cracks in the surface layers.

A64-14906

THE HYDROMAGNETIC THEORY OF BEARINGS [HYDROMAGNETISCHE LAGERTHEORIE].

W. Fucks and J. Uhlenbusch (Aachen, Technische Hochschule, Physikalisches Institut, Aachen, Germany).

Zeitschrift für angewandte Mathematik und Mechanik, vol. 43, Dec. 1963, p. 553-560. 7 refs. In German.

Investigation of the hydromagnetic flow between two slightly inclined infinite plates for the case in which, when one of the plates is moved, an increased pressure in the fluid between the two plates arises. It consists of two components, hydrodynamic and hydromagnetic. In addition, the cylindrical case (journal and bearing) is calculated. The magnetic field is assumed to be constant and perpendicular to the surface of the journal. The calculation shows that a similarity law exists for large Hartmann numbers. This similarity corresponds to the hydrodynamic theory, if the velocity U is replaced by the product of the velocity U and the Hartmann number $\mathcal{H}$.

A64-14980

HIGH TEMPERATURE OIL EVALUATION IN FULL-SCALE BEARING FATIGUE TESTS.

J. H. Gustafson (Marlin Rockwell Corp., Jamestown, N. Y.).

(American Society of Lubrication Engineers, Annual Meeting, 18th, New York, N. Y., Apr. 30-May 2, 1963.)

Lubrication Engineering, vol. 20, Feb. 1964, p. 65-68.

Description of full-scale bearing fatigue tests conducted on a typical jet engine bearing under operating conditions foreseen for advance design engines. Four MIL-L-9236 class, high-temperature fluid lubricants were evaluated on the basis of their effect on bearing fatigue life. Polyphenyl ether fluid gave the best results with the B-10 life of seven times the catalog rated life. Ball retainer failures that resulted indicate that additional research is needed in the design of retainers and selection of the best retainer material and lubricant combination.

A64-15531

THE DIFFERENT BEHAVIOUR OF HEXAGONAL AND CUBIC METALS IN THEIR FRICTION, WEAR AND WORK HARDENING DURING ABRASION.

P. J. Alison and H. Wilman (London, University, Imperial College of Science and Technology, Dept. of Chemical Engineering and Chemical Technology, Applied Physics and Chemistry of Surfaces Laboratory, London, England).

British Journal of Applied Physics, vol. 15, Mar. 1964, p. 281-289. 16 refs.

The mass wear per centimeter M and the friction coefficient μ of metals during abrasion on a relatively rigid hard rough surface are studied experimentally at 1 kg load and a speed of a few centimeters per second. "Smooth-cut" steel files were used as the abrasive surface, cleaned carefully by scratch-brushing rather than by etching, between consecutive experiments. In the mean, linear relations were observed, as expected theoretically, between the reciprocal of the volume-wear rate and the microhardness H_D of the filed surface (thus work-hardened to the maximum extent), but the loci were widely different for the cubic metals (Pb, Ca, Al, Ag, Cu, Pt, Fe, Ni, Mo, Cr) and the hexagonal metals (Cd, Mg, Zn, Zr, Ti). For a given surface hardness, the volume-wear rate for the hexagonal metals was about half that for the cubic metals; hence for the hexagonal metals a larger proportion of the metal is displaced by plastic flow (slip) from the groove volume instead of being removed as wear; and this is evidently because of easier slip, mainly on a single slip plane (0001), instead of multiple slip and the associated heavy work hardening as occurs in cubic metals. A single linear locus was obtained when the reciprocal of the volume-wear rate was plotted against the hardness of the annealed metals. For the cubic metals μ decreased mainly linearly with increasing H_D of the (work-hardened) filed surface, but for the hexagonal metals μ was practically constant, independent of H_D. The relatively rapid surface oxidation of Mg and Ca caused a decrease in μ relative to that of the other metals of similar structure and hardness. These results establish clearly that there is a fundamental difference in wear and friction behavior of hexagonal and cubic metals.

A64-15635

CORROSION OF HIGH-TEMPERATURE MATERIALS IN ALKALI METALS.

Kenneth J. Kelly (United Aircraft Corp., Pratt and Whitney Aircraft Div., CANEL Project, Middletown, Conn.), Carl J. Klamut (Brookhaven National Laboratory, Upton, N. Y.), Louis Rosenblum (NASA, Lewis Research Center, Cleveland, Ohio), J. W. Semmel, Jr. (General Electric Co., Space Power and Propulsion Section, Cincinnati, Ohio), and William C. Thurber (Oak Ridge National Laboratory, Metals and Ceramics Div., Oak Ridge, Tenn.).

Nucleonics, vol. 22, Mar. 1964, p. 37-42. 9 refs.

Panel discussion for the advanced space reactor program of the status of the alkali-metal systems, and particularly of the corrosion of refractory containment materials by the liquid alkali metals. Among the topics discussed are: (1) evidence that the lithium-niobium system will last to 10,000 hr at temperatures of 2000°F or higher; (2) the development of turbine and bearing materials; (3) stress alloying or stress-corrosion effects in refractory metal-alkali-metal systems; (4) the effects of significant amounts of oxygen ("oxygen disease") in an alloy; (5) status of working fluids for the secondary system including cesium, rubidium, and potassium; and (6) capsule tests of the more advanced materials.

A64-15648

ADAPTATION OF A MoS_2 "IN SITU" PROCESS FOR LUBRICATING SPACECRAFT MECHANICAL COMPONENTS.

Charles E. Vest (NASA, Goddard Space Flight Center, Greenbelt, Md.).

IN: AIAA ANNUAL STRUCTURES AND MATERIALS CONFERENCE, FIFTH, PALM SPRINGS, CALIF., APRIL 1-3, 1964 (AIAA Publication CP-8).

New York, American Institute of Aeronautics and Astronautics, 1964, p. 120-125. 6 refs.

Evaluation of a MoS_2 "in situ" process for lubrication of spacecraft mechanical components. It is concluded that (1) the film thickness can be controlled within ± 35 micro inches; (2) the average coefficient of friction of this film is 0.05 or less and is comparable to or the same as MoS_2 powder and lower than bonded MoS_2 films; (3) the film can be easily and safely deposited onto a number of common spacecraft materials, including 2024 Al, 6061 Al, 7075 Al, 303SS, 316SS, 416SS, 440C SS, mild steel, M10 tool steel, and Circle "C" tool steel; (4) the film has a better wear life than sodium silicate bonded MoS_2, slightly better wear life than a burnished MoS_2 powder, and a somewhat poorer wear life than epoxy bonded MoS_2; and (5) the film follows the surface contour and fills up the smallest crack, lap, seam or indentation and therefore makes it possible to place a controlled amount of MoS_2 on hard to reach surfaces, such as outer races of miniature ball bearings.

A64-16032
GAS BEARINGS - A SURVEY.
W. A. Gross (Ampex Corp., Research Laboratory, Redwood City, Calif.).
Wear, vol. 6, Nov.-Dec. 1963, p. 423-443. 12 refs.

General consideration of the techniques of gas lubrication. Liquid and gas lubrication are briefly compared, and the history of gas bearings is outlined. The types, operation, and applications of gas bearings are described, including squeeze-film, externally-pressurized, and self-acting bearings. The types of fluid lubricant flow associated with these bearings are considered, as are the time effects, and the limiting and special conditions. The physical principles involved in gas film lubrication are presented, emphasizing the density and viscosity. Recently investigated gas bearing problems are briefly discussed.

A64-16033
BOUNDARY LUBRICATION OF TITANIUM-TITANIUM AND TITANIUM-STEEL.
Richard W. Roberts and Robert S. Owens (General Electric Co., Research Laboratory, Schenectady, N. Y.).
Wear, vol. 6, Nov.-Dec. 1963, p. 444-456. 19 refs.

Experimental investigation of the boundary lubrication of titanium with charge-transfer complexes of iodine and aromatic compounds. Friction experiments were performed in a thrust-washer test apparatus, which rotates a titanium cup having an annular rubbing area of 0.396 inch, against a titanium washer at 0.23 ft/min under a 10-kg load. It is found that the charge-transfer complexes and aromatic compounds greatly reduce the coefficient of friction and wear when used as a boundary lubricant for titanium or steel sliding on titanium. Similar results were obtained when a mixture of these complexes and a straight chain hydrocarbon oil was used. The mechanism of lubrication appears to involve the formation of titanium diiodide, a low shear strength laminar solid, at the wearing interface. The hydrophobic nature of the lubricant prevents the titanium diiodide from reacting with water in the air.

A64-16968
A RAPID METHOD FOR DETERMINING THE TENDENCY OF DURALUMIN TYPE ALLOYS TO CORROSION CRACKING.
E. M. Zaretskii and A. F. Kireeva.
(Zavodskaia Laboratoriia, vol. 29, Sept. 1963, p. 1098-1101.)
Industrial Laboratory, vol. 29, Mar. 1964, p. 1193-1196. Translation.

Recommendation of solutions for speeding up the corrosion-cracking testing of duralumin-type alloys. The solutions contain NaCl, HNO_3, KNO_3. The duration of the tests is approximately 1 hour. Shown in a table are the principal features of the solutions which were used for testing corrosion cracking of duralumin-type aluminum alloys. The solution 4 M NaCl + 0.1 M HNO_3 + 0.5 M KNO_3 caused cracking much earlier than other solutions. It is noted that the rate of general corrosion is not high, and that the corrosion products show good solubility, while the tendency to corrosion cracking changes according to the structural condition of the D16 alloy. With slight tendency to corrosion cracking (naturally aged D16 duralumin), the time to cracking is stated to be about 30 hours.

A64-17354
CONTRIBUTION TO THE SYNTHESIS AND STUDY OF DISPERSION ADDITIVES FOR LUBRICANTS - PREPARATION AND PROPERTIES OF SOME DIALKYLTETRAHYDRONAPHTHALENES AND THEIR SULFONATES [CONTRIBUTION A LA SYNTHESE ET A L'ETUDE DE DISPERSANTS POUR LES LUBRIFIANTS - PREPARATION ET PROPRIETES DE QUELQUES DIALCOYLTETRAHYDRONAPHTALENES ET DE LEURS SULFONATES].
H. Djavanmard-Haghi (Institut Français du Pétrole, Paris, France).
Institut Français du Pétrole, Revue, vol. 19, Jan. 1964, p. 53-93. 96 refs. In French.

Study of the relationships between the properties of dispersion additives for lubricants and their chemical structure. Ten new hydrocarbons were synthesized. Three of them, of different chain lengths, were sulfonated, then transformed into sulfonates of sodium, calcium and barium. Motor bench tests on lubricants containing the synthetic sulfonates were made and results obtained indicating that, for the same cation, the dispersive properties increase with molecular weight (or length of the alkyl chain). Aniline point and viscosity index increase rapidly with increase in the length of the alkyl chain.

A64-17505
DRY FILM LUBRICATION OF HIGHLY LOADED BEARINGS IN VACUUM.
E. C. McKannan and K. E. Demorest (NASA, Marshall Space Flight Center, Huntsville, Ala.).
(American Society of Lubrication Engineers, Annual Meeting, 18th, New York, N. Y., Apr. 30-May 2, 1963.)
Lubrication Engineering, vol. 20, Apr. 1964, p. 134-141.

Results of tests of thirteen dry film lubricants in a gimbal simulation device. The problem was posed by the necessity of lubricating gimbal bearings for the upper stages of boost vehicles operating in vacuum and under high loading. The lubricant was required to be nonvolatile and resistant to temperature variations, vibration, and nuclear radiation. It had to perform satisfactorily under slow oscillating motion, resist cold welding during quiescent periods, and permit restarting. The test apparatus duplicated flight conditions for bearing contact load, bearing materials, type of motion, and environment. Of the lubricants tested, the following two provided the necessary properties: (a) a mixture of molybdenum disulphide, graphite and gold powders with a binder of sodium silicate, capable of being sprayed with an air gun, and (b) a flame-sprayable coating of zirconium silicate as a binder for burnished molybdenum disulphide powder. Tables and graphs of test results are presented.

A64-19124
LUBRICANT BEHAVIOR IN HIGH VACUUM.
George S. Reichenbach, Robert Shaw, Jr., and Robert G. Foster (Massachusetts Institute of Technology, Surface Laboratory, Dept. of Mechanical Engineering, Cambridge, Mass.).
(American Society of Lubrication Engineers, Lubrication Conference, Rochester, N.Y., Oct. 15-17, 1963.)
ASLE Transactions, vol. 7, Jan. 1964, p. 82-87; Discussion, D. H. Buckley (NASA, Lewis Research Center, Cleveland, Ohio), R. A. Burton, R. D. Brown (Southwest Research Institute, San Antonio, Tex.), and Douglas Godfrey (California Research Corp., Richmond, Calif.), p. 88, 89; Authors' Closure, p. 89, 90. 16 refs.

Description of pin-on-disk friction tests and crossed-cylinder load-carrying tests run in air and in vacuum. Dry friction behavior was found to be very sensitive to pressure level and previous history of the specimens. It is stated that lubricated friction behavior for the lubricants tested was essentially independent of pressure unless there was selective evaporation of friction-reducing additives in the lubricant. Most of the fluids tested evaporated very slowly in these room-temperature tests. Load-carrying ability was reduced in vacuum by more than 50% for several lubricants tested. This reduction was attributed to the absence of oxygen needed to form EP load-carrying films.

A64-19125
MECHANISM OF LUBRICATION FOR SOLID CARBON MATERIALS IN VACUUM TO 10^{-9} MILLIMETER OF MERCURY.
Donald H. Buckley and Robert L. Johnson (NASA, Lewis Research Center, Cleveland, Ohio).
(American Society of Lubrication Engineers, Lubrication Conference, Rochester, N.Y., Oct. 15-17, 1963.)
ASLE Transactions, vol. 7, Jan. 1964, p. 91-100. 29 refs.

Determination in vacuum, at ambient pressures from 760 to 10^{-9} mm Hg, of the friction and wear characteristics of various carbon materials sliding on metals and aluminum oxide. The friction and wear experiments were conducted with a hemispherically tipped carbon rider, under a load of 1 kg, sliding on various disks rotating at a speed of 390 ft/min. The results of this investigation are stated to show that additional research on carbon in vacuum is warranted. Adsorbed surface films present on both carbons and metal, as well as the presence of oxide on metals, appreciably influenced the friction and wear obtained with carbons in vacuum. Some impregnants were beneficial in reducing friction and wear of carbon in vacuum, while others were not.

A64-19126
THE EFFECT OF INTERFACE COMPOSITION ON THE WEAR RATE OF SAPPHIRE.

E. J. Duwell and H. C. Butzke (Minnesota Mining and Manufacturing Co., Central Research Laboratories, St. Paul, Minn.).
(American Society of Lubrication Engineers, Lubrication Conference, Rochester, N.Y., Oct. 15-17, 1963.)
ASLE Transactions, vol. 7, Jan. 1964, p. 101-105; Discussion, N. S. Eiss, Jr. (Cornell Aeronautical Laboratory, Inc., Buffalo, N.Y.), L. D. Dyer (General Motors Corp., Research Laboratories, Warren, Mich.), D. G. Flom (General Electric Co., Missile and Space Div., Space Sciences Laboratory, Philadelphia, Penn.), and A. G. King (Norton Co., Research and Development Dept., Worcester, Mass.), p. 106, 107; Authors' Closure, p. 107, 108. 14 refs.

Discussion of the rate of wear of a single crystal sapphire sphere, which depends on crystal orientation and slide direction. It is stated that this effect can be correlated with the shear mechanism of the crystal structure at elevated temperatures. On oxidized metal surfaces or on glass, sapphire appears to wear more rapidly than on freshly generated metal surfaces as a result of chemical degradation. The effect of crystal orientation, which is associated with the shear strength of the crystal, is therefore decreased. Lubrication is stated to appear to decrease wear, but the effect of crystal orientation on wear rate persists.

A64-20088
DEVELOPMENTS IN BEARINGS AND LUBRICANTS - A DIGEST OF THE LITERATURE FROM 1961-1962.
R. P. Shevchenko (United Aircraft Corp., Pratt and Whitney Aircraft Div., East Hartford, Conn.) and G. S. Reichenbach (Massachusetts Institute of Technology, Cambridge, Mass.).
(American Society of Mechanical Engineers, Winter Annual Meeting, New York, N.Y., Nov. 25-30, 1962.)
ASME, Transactions, Series D - Journal of Basic Engineering, vol. 86, June 1964, p. 367-386.

Reviews of papers presented during the period. They have been arranged to fit into eight categories: friction and wear, boundary lubrication, metalworking lubricants, automotive lubricants, gear lubrication, rolling-element bearings, fluid-film bearings, and lubricant properties. Comment is made that readers should check related as well as specific areas in the literature because of much overlapping of applicability when the fundamentals of lubrication are considered. A total of 331 papers has been reviewed and cited.

A64-20151
FUEL AND ENGINE LUBRICANT REQUIREMENTS FOR THE CONCORD.
G. Morris (Bristol Siddeley Engines, Ltd., London, England).
Society of Automotive Engineers and American Society of Mechanical Engineers, Air Transport and Space Meeting, New York, N.Y., Apr. 27-30, 1964, Paper 863A. 9 p.
Members, $0.75; nonmembers, $1.00.
Research supported by the Ministry of Aviation.

Discussion of the ability of the engines in the Concord supersonic airliner to use existing aviation kerosene fuels for flight at a speed of Mach 2.2. It is stated that it may not even be necessary to introduce a thermal stability requirement into the existing fuel specifications. It is noted that, however, since existing turbine engine lubricants are not entirely satisfactory for SST use, some improvement in this area is required, particularly in connection with thermal stability at high operating temperatures. Detailed descriptions of three test rigs designed by Bristol Siddeley, for the purpose of evaluating gas-turbine engine lubricants, are also provided.

A64-20287
HEAT TRANSFER BETWEEN OIL FILM AND METAL SURFACE IN A FRICTION BEARING, TAKING THE VARIABLE OIL VISCOSITY INTO ACCOUNT [DER WÄRMEAUSTAUSCH ZWISCHEN ÖLSCHICHT UND METALLFLÄCHEN IN EINEM GLEITLAGER UNTER BERÜCKSICHTIGUNG DER VERÄNDERLICHKEIT DER ÖLVISKOSITÄT].
N. Motosh (Karlsruhe, Technische Hochschule, Institut für Maschinenkonstruktionslehre und Kraftfahrzeugbau, Karlsruhe, West Germany).
Ingenieur-Archiv, vol. 33, no. 3, 1964, p. 149-161. 21 refs. In German.

Investigation of the local heat transfer upon the pressure and temperature distribution in the lubricant film of a friction bearing. To account for the variability of the lubricant's viscosity, the pressure and energy equations are solved simultaneously. The effect of local heat transfer is demonstrated in several examples. The results are used to verify the theory of ball bearings, based on the assumption of constant viscosity.

A64-20632
THE DEVELOPMENT OF LONG LIFE, LIQUID MERCURY LUBRICATED BEARINGS FOR THE SUNFLOWER RANKINE CYCLE POWER SYSTEM.
O. Decker and H. L. Reed (Thompson Ramo Wooldridge, Inc., Cleveland, Ohio).
Society of Automotive Engineers and American Society of Mechanical Engineers, Air Transport and Space Meeting, New York, N.Y., Apr. 27-30, 1964, Paper 871D. 20 p. 5 refs.
Members, $0.75; nonmembers, $1.00.
Thompson Ramo Wooldridge-sponsored research; Contracts No. NAS 5-462; No. AT (11-1)GEN-8; No. AF 33(616)-6623; No. AF 33(616)-7979; No. AT (30-3)-217.

Outline of the development of the journal and thrust bearings used in the Sunflower turboalternator. The topics discussed include the general operation of the typical Rankine-cycle space system; the types of bearings considered for this application, and their desirable characteristics; and the factors which influence life capability. Details of the bearings finally selected are given. The procedures and results of four turboalternator tests which incorporated the bearings are discussed. The major conclusion reached is stated to be that experience and technology exist today which permit the accomplishment of space-power life requirements with a Mercury Rankine system.

A64-20633
LONG-LIVED LUBRICATION FOR SPACECRAFT EQUIPMENT.
Francis J. Clauss (Lockheed Aircraft Corp., Lockheed Missiles and Space Co., Sunnyvale, Calif.).
Society of Automotive Engineers and American Society of Mechanical Engineers, Air Transport and Space Meeting, New York, N.Y., Apr. 27-30, 1964, Paper 871C. 14 p.
Members, $0.75; nonmembers, $1.00.
Research supported by USAF and Lockheed Missiles and Space Co.

Discussion of vacuum and radiation conditions in space and their influence on lubrication for spacecraft equipment. It is stated that, while many lubricants suffer a drastic loss in lifetime, as a result of these environments, experimental studies have demonstrated that certain oils and greases can lubricate lightly loaded ball bearings without replenishment for periods of 18 months to 2 years under the following conditions of operation: speeds of 8000 rpm, temperatures of 160 to 200°F, and vacuum of 10^{-8} torr. Selected oils and greases are also said to have lubricated satisfactorily at radiation doses of 10^7 r in vacuum, which is more than twice the internal dose that would be accumulated in a period of 1 year in space. Experimental evaluations of molybdenum disulfide and special retainer materials are also discussed.

A64-21242
PRACTICAL USES OF THE SURFACE ENERGY CRITERION.
E. Rabinowicz (Massachusetts Institute of Technology, Dept. of Mechanical Engineering, Cambridge, Mass.).
(Conference on Fundamental Mechanisms of Solid Friction, Midwest Research Institute, Kansas City, Mo., Sept. 16-18, 1963.)
Wear, vol. 7, Jan.-Feb. 1964, p. 9-22. 15 refs.
Research supported by DuPont de Nemours and Co.; Contract No. DA-19-020-ORD-4706.

Study of eight distance effects which arise during sliding, including a discussion of experimental data and theoretical treatments. The ratio of surface energy to hardness (the W/p ratio) of sliding

surfaces has the dimensions of length and many length parameters of sliding systems, including the diameters of loose and of adherent wear particles, the equilibrium peak-to-trough surface roughness, the diameter of junctions, and the size of the smallest abrasive particles which give full abrasive action are shown to be proportional to W/p. At very low loads, when the real area of contact has a diameter smaller than that of the wear particles for that system, new effects are encountered, leading to low wear rates and the production of smooth surfaces.

A64-21244

FRICTION AND WEAR OF SINGLE CRYSTALS.

R. P. Steijn (DuPont de Nemours and Co., Mechanical Research Laboratory, Wilmington, Del.).

(Conference on Fundamental Mechanisms of Solid Friction, Midwest Research Institute, Kansas City, Mo., Sept. 16-18, 1963.)
Wear, vol. 7, Jan.-Feb. 1964, p. 48-66. 25 refs.

Discussion of sliding tests carried out on single crystals of F. C. C. and B. C. C. metals and on crystals of the NaCl-type structure by dragging a fine diamond stylus or a hard sapphire sphere across the surface. The forces of friction and the width of the track are measured and found to be dependent on orientation. For B. C. C., F. C. C., and NaCl-type crystals, the anisotropy on the cube face is found to be the same despite their different slip systems. Quantitative expressions are presented for the forces of ploughing and adhesion, and their relevance with respect to the experimental findings is discussed. Some of the aspects of surface cracks in LiF leading to wear and slip bands in copper are described.

A64-21246

AN EVALUATION OF THE ROLE OF VAPOR LUBRICATION MECHANISMS IN MoS_2.

A. J. Haltner (General Electric Co., Research Laboratory, Schenectady, N. Y.).

(Conference on Fundamental Mechanisms of Solid Friction, Midwest Research Institute, Kansas City, Mo., Sept. 16-18, 1963.)
Wear, vol. 7, Jan.-Feb. 1964, p. 102-117. 16 refs.

Study of the sliding behavior of MoS_2 in room air, in controlled atmospheres, and in vacuum at pressures as low as 10^{-9} torr. The results confirm the occurrence of friction transients under a number of experimental conditions. However, evidence indicates that these transient effects are not involved in the sliding mechanism. It is concluded that, unlike graphite, MoS_2 does not depend on a vapor lubrication mechanism.

A64-21398

SURFACE TEMPERATURES IN SLIDING CONTACT.

M. J. Furey (Esso Research and Engineering Co., Products Research Div., Linden, N. J.).

(American Society of Lubrication Engineers, Lubrication Conference, Rochester, N. Y., Oct. 15-17, 1963.)
ASLE Transactions, vol. 7, Apr. 1964, p. 133-146; Discussion, B. W. Kelley and L. Lichtenstein (Caterpillar Tractor Co., Research Dept., Peoria, Ill.), p. 146. 16 refs.

Study of the surface temperatures generated by friction in a sliding system - a fixed constantan ball riding on a rotating steel cylinder. Using the principle of the Herbert-Gottwein dynamic thermocouple, time-average as well as instantaneous surface temperatures are determined. Some measurements are also made with imbedded thermocouples, and advantages and limitations of both methods are discussed. It is found that the average surface temperature is quite independent of running time and gross wear but increases markedly with increasing speed or load. The experimental results are considerably lower than those predicted theoretically from the work of Block, Jaeger, and Archard. Possible reasons for this difference are discussed.

A64-21399

ENGINE FRICTION AND BEARING WEAR. III - THE ROLE OF ELASTICITY IN BEARING PERFORMANCE.

E. H. Okrent (Esso Research and Engineering Co., Process Research Div., Linden, N. J.).

(American Society of Lubrication Engineers, Lubrication Conference, Rochester, N. Y., Oct. 15-17, 1963.)
ASLE Transactions, vol. 7, Apr. 1964, p. 147-152; Discussion, Edward Saibel (Rensselaer Polytechnic Institute, Troy, N. Y.), p. 152. 17 refs.

Presentation of data showing that the performance of a dynamically loaded journal bearing depends on the viscoelasticity of the polymer modifying the lubricant oil. This unexpected behavior is investigated in the presented studies on solutions of different polymer types, using a range of molecular weights and concentrations for each type and blending all solutions to the same low shear viscosity. The viscosity and elasticity of these solutions are measured at different rates of shear in an ultrasonic crystal viscometer. The governing parameter controlling bearing performance appears to be the recoverable shear, which is related to the elastic modulus of the system. The polymer type also appears to be important in determining the critical value of recoverable shear required for good bearing performance.

A64-21404

THE FRICTIONAL BEHAVIOR OF MATERIALS AND SYNTHETIC LUBRICANTS IN SLIDING SYSTEMS.

W. F. Rush and R. H. Krueger (Borg-Warner Corp., Roy C. Ingersoll Research Center, Des Plaines, Ill.).

(American Society of Lubrication Engineers, Lubrication Conference, Rochester, N. Y., Oct. 15-17, 1963.)
ASLE Transactions, vol. 7, Apr. 1964, p. 197-208; Discussion, Gordon Cervo (American Brake Shoe Co., Mahwah, N. J.), F. K. Orcutt (Mechanical Technology, Inc., Latham, N. Y.), W. A. Marshall, and R. J. Benzing (Air Force Materials Laboratory, Nonmetallic Materials Div., Fluid and Lubricant Materials Branch, Wright-Patterson AFB, Ohio), p. 208, 209; Authors' Closure, p. 209, 210. 9 refs.

Evaluation of the frictional behavior of various material combinations in several synthetic lubricants, and a comparison with actual pump performance. A laboratory apparatus designed for the evaluation of materials and lubricants in sliding friction and for the prediction of performance of a particular type of hydraulic pump is discussed. A metahydrodynamic correlation for the region just below the hydrodynamic region is found to be applicable in all systems evaluated on the apparatus. It is shown that both hydrodynamic and metahydrodynamic behavior are dependent on the materials and lubricant comprising the system. Solid-to-solid contact in the metahydrodynamic region appears to be a consequence of both film thickness and surface finish. Film collapse resulting from degassification of the supporting film is also shown to contribute to high friction development. When the solid-to-solid contact occurs, hydrodynamic or metahydrodynamic laws are obeyed; this condition depends principally on the material combination and hardness of materials.

A64-21637

WEAR PROBLEMS ASSOCIATED WITH LUBRICATION IN INERT ATMOSPHERES.

R. Irving and N. A. Scarlett (Shell Research, Ltd., Thornton Research Centre, Chester, England).

(Institution of Mechanical Engineers, Lubrication and Wear Convention, Bournemouth, England, May 23-25, 1963.)
Wear, vol. 7, May-June 1964, p. 244-252; Discussion, p. 253, 254.

Investigation of the operation of grease-lubricated ball bearings in hydrogen and helium atmospheres - i.e., environments containing extremely small amounts of oxygen and water. The experimental setup is described, and the test results are given. Using a 20-mm bore, grease-lubricated, ball bearing at 200°C and 1450 rpm, it is found that bearing metal distress occurs during operation in pure hydrogen or helium, whereas no distress is observed during similar tests with oxidizing atmospheres such as air or unpurified carbon dioxide. In hydrogen, the surface damage is mainly in the form of extensive pitting and flaking of the balls of the bearing, each pit or cavity having an appearance indicative of hydrogen embrittlement. With helium, on the other hand, the damage is in the form of fine surface pitting which metallurgical examination indicates to occur by a mechanism different from that operative in hydrogen.

A64-21639
THE TRANSITIONS BETWEEN BOUNDARY, MIXED AND HYDRODYNAMIC LUBRICATION.
A. Dobry (American Oil Co., Research and Development Dept., Whiting, Ind.).
Wear, vol. 7, May-June 1964, p. 290-297. 7 refs.

Presentation of a model for plane parallel sliding surfaces in which the velocity at the transition from boundary to mixed lubrication is proportional to an expression involving the external pressure, surface roughness, lubricant viscosity, unit load, and a constant of proportionality. The proportionality relationship between the velocity at the transition from mixed to hydrodynamic lubrication and surface roughness, unit load, and lubricant viscosity is presented. The experimental results obtained are compared with results obtained by Lenning. Reasons for the observed discrepancy are discussed, and improved measurements to resolve it are suggested.

A64-21761
LUBRICATING PROPERTIES OF LEAD FILMS ON COPPER.
Yuko Tsuya and Riitsu Takagi (Government Mechanical Laboratory, Tokyo, Japan).
Wear, vol. 7, Mar.-Apr. 1964, p. 131-143; Discussion, p. 175-177. 11 refs.

Study of the frictional behavior between a lead film, 0.1-130μ thick, deposited on an annealed copper surface and an electropolished similar copper surface at a sliding speed of 0.005 cm/sec under a pressure of 0.4-100 kg/cm^2. The friction coefficient μ, which is generally higher for a thicker film, decreases at a given film thickness under increasing pressure, at first steeply and then gradually beyond 5 kg/cm^2. The smallest friction-coefficient (0.4) obtained at the highest pressure is, however, about ten times the value (shear strength of lead)/(hardness of substrate copper) predicted by the Bowden-Tabor theory. The area of real contact is actually determined by the hardness of copper substrate, at least for thinner films, and the shearing occurs within the lead film: however, the increase of the area actually sheared off through the growth of adhesive masses that occurs on application of the frictional force makes μ considerably larger than that predicted by the theory.

A64-21764
PROCESSES OF METAL TRANSFER AND WEAR.
Morton Antler (Burndy Corp., Research Div., Norwalk, Conn.).
Wear, vol. 7, Mar.-Apr. 1964, p. 181-203; Discussion, p. 217-219. 19 refs.

Study of the direction of metal transfer in unlubricated sliding and its effect on wear and friction with a variety of metals, using a "rider-flat" apparatus. The apparatus consists of a hemispherically-ended "rider" which is dead-weight loaded against the "flat" specimen which is secured to a turntable. Four sliding processes were identified. (1) "Prow (or wedge) formation" is characterized by build-up of work-hardened transfer solid on the rider, which grows against the direction of sliding by continuous plastic shearing of the flat. Sliding is at the junction between prow and flat. (2) In "wedge flow formation", transfer is also from flat to rider, but growth of transfer solid is now in the direction of sliding, and is accompanied by softening of transfer metal. (3) "Rider wear" occurs with progressive loss of metal from both rider and flat. (4) "Sliding seizure found with In, is characterized by displacement of rider metal in the direction of sliding without prow formation, and subsequent gross seizure of the specimens after brief sliding. The necessary conditions for the various sliding mechanisms are described, together with their relationship to symmetry of wear, mechanisms of debris generation, debris size and shape, surface roughening, friction, and contact electrical resistance.

A64-21902
CONDITIONS UNDER WHICH PITTING OCCURS DURING FRICTION.
B. P. Mitrofanov.
(Akademiia Nauk SSSR, Doklady, vol. 153, Dec. 1963, p. 1065, 1066. Soviet Physics - Doklady, vol. 8, June 1964, p. 1246, 1247. 11 refs. Translation.
[For abstract see Accession no. A64-14371 07-18]

A64-22417
CORROSION RESISTANCE OF METALS AND ALLOYS (2nd Edition).
Edited by F. L. LaQue and H. R. Copson (International Nickel Co., Inc., New York, N.Y.).
ACS Monograph No. 158.
New York, Reinhold Publishing Corp.; London, Chapman and Hall, Ltd., 1963. 712 p.
$21.

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NICKEL. W. Z. Friend (International Nickel Co., Inc., New York, N.Y.), p. 467-513.
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OTHER METALS. J. S. Pettibone (International Nickel Co., Inc., New York, N.Y.), p. 623-687.

A64-22748
GREASE LUBRICANTS AND THEIR POTENTIAL IN AEROSPACE APPLICATIONS.
Herbert Schwenker (USAF, Systems Command, Research and Technology Div., AF Materials Laboratory, Fluid and Lubricant Materials Branch, Wright-Patterson AFB, Ohio).

(American Society of Lubrication Engineers, Annual Meeting, Chicago, Ill., May 26-28, 1964.)
Lubrication Engineering, vol. 20, July 1964, p. 260-264. 9 refs.

Discussion of various greases used in aerospace vehicles and their supporting equipment. The requirements for these greases are reviewed for applications in aircraft, missiles, spacecraft, satellites, and ground equipment. Currently available greases are discussed, including mineral oil and synthetic hydrocarbon greases, ester-base greases, and silicone greases. Some experimental greases are noted, and possible future research and development programs for new greases are indicated.

A64-22851
ON THE SLIDING FRICTION OF A LIGHT ALLOY ON POLYTETRAFLUOROETHYLENE (PTFE) PURE OR CHARGED AT RAPIDLY VARIABLE SPEEDS (0 TO 100/KM/HR) [SUR LE FROTTEMENT DE GLISSEMENT D'UN ALLIAGE LEGER SUR DU POLYTETRAFLUOROETHYLENE (PTFE) PUR OU CHARGE A DES VITESSES RAPIDEMENT VARIABLES (0 A 100 KM/H)].
Pierre Nadal, Michel Lavault, Jean Blouet, and Robert Courtel (Laboratoire de l'I.S.M.C.M., Saint-Ouen; Laboratoire de Sud-Aviation, Courbevoie; Centre National de la Recherche Scientifique, Centre Technique d'Analyse des Surfaces de Frottement, Bellevue, Seine-et-Oise, France).
Académie des Sciences (Paris), Comptes Rendus, vol. 258, no. 12, Mar. 23, 1964, p. 3182-3184. In French.

Experimental determination of the friction coefficient of a light alloy (AG 5) sliding at different pressures against PTFE charged with graphite, used in the state of bondable thin sheets. A tribometer of modern design has enabled investigation of a wide range of linear speeds and the corresponding development of the friction. It is concluded that the addition of charges, such as micronized graphite, to PTFE, enables expansion of the limits of its lubricating power at high speeds.

A64-22899
THE MAGNETOHYDRODYNAMIC SQUEEZE FILM.
Dennis C. Kuzma, E. Roland Maki (General Motors Corp., Research Laboratories, Warren, Mich.), and Russell J. Donnelly (Chicago, University, Chicago, Ill.).
Journal of Fluid Mechanics, vol. 19, July 1964, p. 395-400. 7 refs.
NSF Grant No. G-23068.

Theoretical and experimental investigation of magnetohydrodynamic squeeze films. The theory of magnetohydrodynamic lubrication as applied to squeeze films is extended to include fluid-inertia effects and buoyant forces. It is stated that the use of only one iteration seems to give excellent results. Furthermore, the presence of a magnetic field increases the accuracy of the iteration procedure since the inertia terms then become small compared to the combined viscous and inertia terms. At large values of the Hartmann number, the magnetic effects completely overshadow both the viscous and inertia effects. The results of the experiment are said to be in excellent agreement with the theory.

A64-23166
CORROSION PROTECTION OF ROTATING ASSEMBLIES OF THE TURBOMECA MARBORE II BOOSTER JET ENGINES ON THE NORD 2500 [PROTECTION CONTRE LA CORROSION DES ENSEMBLES TOURNANTS DES GROUPES REACTEURS D'APPOINT TURBOMECA MARBORE II SUR NORD 2500].
M. Vialatte (Services Techniques de l'Armée, Paris, France), J. Szydlowski (Turboméca, S.A., Bordes, Basses-Pyrénées, France), and A. Mihail (Génie Maritime, Paris, France).
Association Technique Maritime et Aéronautique, Bulletin, no. 63, 1963, p. 635-661; Discussion, p. 662-664. 8 refs. In French.

Discussion of corrosion problems affecting internal parts of the booster engines mounted on the aircraft wing tips for the purpose of increasing payload and decreasing take-off run. The Turbomeca engine installation on the Nord 2500 twin piston-engined transport is described. Corrosion problems have arisen which are considered to be related to the fact that the booster jets are only in operation for 2 to 3% of the total flight time, and also to the fact that the aircraft operate from a base where the humidity is generally above 90%. Because the main engines and the booster jets both use aviation gasoline as fuel, deposits have been found on rotating elements of the jet engines which, analysis showed, consisted of several lead compounds. Various methods of protection such as enameling, chrome-plating, electrolytic treatment, and metal-spraying are described and evaluated.

A64-23649
CONFIDENCE LIMITS AND THEIR SIGNIFICANCE IN RELIABILITY STUDIES.
Edward C. Longhurst (RCA Victor Co., Ltd., Product Design Assurance, Montreal, Canada).
IN: AMERICAN SOCIETY FOR QUALITY CONTROL, ANNUAL CONVENTION, 18TH, BUFFALO, N.Y., MAY 4-6, 1964, TRANSACTIONS.
Edited by Irving W. Burr.
Milwaukee, American Society for Quality Control, Inc., 1964, p. 81-90. 7 refs.

Presentation, for prompt evaluation and decision by practitioners in reliability engineering and contracts administration and design, of facts which may be overlooked in the assignment of responsibilities and the exchange of information among various departments. The areas treated are the evaluation of field failure reports in terms of their impact on a priori reliability assessments, and the prediction of electronic, electro-mechanical, and mechanical spares requirements for purposes of quotation or logistics. It is stated that the "wear" or degradation effect in operating equipment makes its appearance quite early in the useful life period and must be controlled by the judicious replacement of unfailed early-wearout parts to ensure acceptable equipment longevity. It is noted that reasonable statements of confidence must be confined to those failure effects which are distributed in a random fashion, where failure effects are additive, and where quantities of units may be multiplied by the appropriate values of operating time to furnish the operative number of unit-hours. Statistical investigations and theoretical treatments of the most advanced nature must be used in fields in which failure rates increase with time.

A64-23758
FRICTION AND WEAR OF AIRFRAME BEARING MATERIALS AT -100 TO 2500°F.
R. J. Matt, C. B. Muratore, and J. J. Zupkus (General Motors Corp., New Departure Div., Bristol, Conn.).
American Society of Mechanical Engineers, Lubrication Symposium, Cleveland, Ohio, Apr. 28-30, 1964, Paper 64-LubS-3. 9 p. 11 refs.
Members, $0.50; nonmembers, $1.00.

Study of the possibility of designing airframe bearings suitable for future space re-entry vehicles. The friction, wear, and limiting load of eight-candidate superalloy, cermet, and ceramic specimen materials were studied at temperatures of -100, 1500, 2000 and 2500°F. Tests were run under rolling and sliding contact conditions in test rigs designed to closely simulate projected bearing requirements. Results are said to have established the need for two separate methods for determining the limiting loads of the different types of material. Two materials, tantalum beryllide and aluminum exide, are stated to have demonstrated promise of fulfilling satisfactorily projected airframe bearing requirements. Theoretical ball and spherical rod-end bearing models using one of these materials are described.

A64-23759
FRICTION AND WEAR OF BEARING MATERIALS FOR RE-ENTRY VEHICLE CONTROL SURFACES.
R. J. Matt, J. B. Muratore, and C. J. Zupkus (General Motors Corp., New Departure Div., Bristol, Conn.).
American Society of Mechanical Engineers, Lubrication Symposium, Cleveland, Ohio, Apr. 28-30, 1964, Paper 64-LubS-13. 13 p. 6 refs.
Members, $0.50; nonmembers, $1.00.
USAF-supported research.

Study of the material performance characteristics necessary to design control-surface bearings for future space re-entry vehicles. The friction, wear, and limiting load capacity of candidate superalloy, cermet, and ceramics with six lubricants were studied at temperatures from -100 to 2500°F in air. The most promising materials or lubricant combinations were run at temperatures from -100 to 1500°F in a vacuum ranging from 10^{-6} to 10^{-9} torr. The results are said to indicate significant differences in material performance, and that none of the lubricants tested provided any major improvement. The effect of hard vacuum substantially increased the coefficient of sliding friction and did not appear to increase the coefficient of rolling friction. It is noted that high-temperature, re-entry, vehicle, control-surface bearing materials appear feasible. The determination of the effects of thermal and mechanical shock and of variable duty cycle requires additional work.

A64-24113

PROTECTION AGAINST CORROSION OF THE ROTATING ASSEMBLIES OF THE TURBOMECA MARBORE II BOOSTER JET ENGINES ON THE NORD 2500 AIRCRAFT [PROTECTION CONTRE LA CORROSION DES ENSEMBLES TOURNANTS DES GROUPES REACTEURS D'APPOINT TURBOMECA MARBORE II SUR NORD 2500].

M. Vialatte (Ministère de l'Armée de l'Air, Service Technique Aéronautique, Paris, France), J. Szydlowski (Turboméca, S.A., Bordes, Basses-Pyrénées, France), and A. Mihail (Bureau Véritas, Paris, France).

(Association Technique Maritime et Aéronautique, Paris, France, May 30, 1963.)

Technique et Science Aéronautiques et Spatiales, Mar.-Apr. 1964, p. 131-138. In French.

Report of corrosion problems encountered. The Nord 2500 aircraft, powered with two 2119 hp Hercules piston engines also utilizes two Turbomeca Marbore II jet engines, of 400 kg thrust each, mounted on the wing tips, as boosters to reduce take-off distance, improve climb, and permit carrying a larger payload. The boosters operate only on take-off and landing, and are shut down for 97% to 98% of the total flight time. Corrosion problems have arisen due to condensation, and the effects of rain, salt air, and lead deposits, aggravated by the humid, tropical conditions under which the aircraft operate. The corrosion has mostly affected the rotating parts, and details are given, with photographs and drawings. Methods developed to counteract the corrosion are to be presented in a continuation of the paper.

A64-24164

GEAR AND TRANSMISSION LUBRICANTS.

C. J. Boner (Battenfeld Grease and Oil Corp., Inc., Kansas City, Mo.).

New York, Reinhold Publishing Corp.; London, Chapman and Hall, Ltd., 1964. 493 p. 378 refs.
$18.

A detailed discussion of gear lubrication is offered, with emphasis placed on lubricants for metal gears. Intended for practical use, the book stresses the application of lubricants and problems arising in connection with their use. Since most gear sets are lubricated with fluid products or gear oils, such compounds are given major consideration, but plastic or semifluid products such as lubricating greases, and also solids, which are semifluid products such as lubricating greases, and also solids, which are sometimes used as gear lubricants, also receive attention. Fluids employed in certain drives are described. Here, the oils in question must not only lubricate different mechanisms, but must also act as torque converters and hydraulic agents. Explanation is made of how lubricants for gears function, and their composition, methods of compounding, and limitations are described. Aircraft gear lubrication is discussed with reference to airframe gears, helicopter gear problems, propeller drive gearing, and turbojet and turboprop engine-gear lubricants. The latter-type lubricants are described with reference to deposit tendencies, formulation, problems, and requirements. Specifications are presented. In addition to an index of authors cited, a subject index is provided which is considered to be sufficiently detailed to permit a reader to locate specific information quickly.

A64-24390

LUBRICATION OF SMALL MOTOR BEARINGS FOR UNATTENDED SERVICE IN AUTOMATIC EQUIPMENT.

George H. Kitchen (Bell Telephone Laboratories, Inc., Murray Hill, N.J.).

(American Society of Lubrication Engineers, Annual Meeting, 19th, Chicago, Ill., May 26-28, 1964.)

Lubrication Engineering, vol. 20, Aug. 1964, p. 311-315; Discussion, Charles E. Vest (NASA, Goddard Space Flight Center, Greenbelt, Md.), p. 315; Author's Closure, p. 315.

Experimental study to determine the most effective lubricant for the lubrication of the bearings of small electric motors found in automatic, unattended, electromechanical equipment. The objects of the study are to attain maximum wear life and minimization of sliding friction between balls and races. It is found that a high-concentration of molybdenum disulfide in a mineral oil-lithium grease provides both maximum life and minimum sliding friction.

A64-24484

CORROSION MECHANISMS IN REFRACTORY METAL-ALKALI METAL SYSTEMS.

J. R. DiStefano and E. E. Hoffman (Oak Ridge National Laboratory, Metals and Ceramics Div., Oak Ridge, Tenn.).

IN: THE SCIENCE AND TECHNOLOGY OF TUNGSTEN, TANTALUM, MOLYBDENUM, NIOBIUM AND THEIR ALLOYS; PROCEEDINGS OF THE NATO AGARD CONFERENCE ON REFRACTORY METALS, OSLO UNIVERSITY CENTRE, OSLO, NORWAY, JUNE 23-26, 1963.
Edited by N. E. Promisel.
AGARDograph 82.
Oxford, Pergamon Press, 1964, p. 257-288. 102 refs.

Description of the corrosion mechanisms which appear to be operative in solid metal-alkali metal systems, emphasizing the mechanisms with niobium, tantalum, molybdenum, and tungsten. Dissolutive corrosion mechanisms considered are dissolution of solid metal in liquid metal, alloying of liquid metal with solid metal, dissimilar-metal mass transfer, and temperature-gradient mass transfer. Liquid metal and solid metal impurity reactions are delineated, as is the partitioning of impurities between solid metal and liquid metal. Experimental results obtained on refractory metal-alkali metal systems are summarized. These results include the solubility of the refractory metals in alkali metals, corrosion experiment results, dissimilar-metal corrosion results of the metals in iron-lithium and nickel-sodium systems after 400 hours at 1000°C, and the effect of mass transfer of carbon and nitrogen on room-temperature tensile properties of niobium tested in sodium.

A64-24771

AN EXPERIMENTAL METHOD FOR EVALUATION OF RESISTANCE TO CAVITATION EROSION.

Milton S. Plesset (California Institute of Technology, Pasadena, Calif.).

IN: CAVITATION AND HYDRAULIC MACHINERY; INTERNATIONAL ASSOCIATION FOR HYDRAULIC RESEARCH, SYMPOSIUM, SENDAI, JAPAN, SEPTEMBER 3-5, 1962, PROCEEDINGS.
Edited by F. Numachi.
Sendai, Tohoku University, Institute of High Speed Mechanics, 1963, p. 87-99; Discussion, p. 99-107; Author's Closure, p. 107-111.

Description of a technique for exposing materials to cavitation in an intermittent, periodic manner. Pulsed cavitation is proposed as a method which is believed to overcome the accelerated nature of the usual laboratory procedure for the study of the cavitation damage properties of materials. The experimental procedure uses pulsed excitation of a magnetostrictive transducer. Specimens under study are subjected to oscillating accelerations in the cavitating liquid, and the oscillation amplitude is modulated so that the cavitating interval can be made any desired fraction of the total period. In the test of the pulsing procedure the behavior of materials was compared with steady and pulsed cavitation in distilled water, in a 3% salt solution, and in distilled water buffered to pH 8. The materials used were mild steel, 4340 steel, 17-7 PH stainless steel, and Inconel 718. The expectation was confirmed that the first two of

these materials would be much more sensitive to corrosive environmental effects and to cavitation damage. When the pulsed and steady cavitation are compared in a chemically inert liquid (toluene) with an inert gas environment (helium), no significant difference in cavitation damage rate is reportedly observed. It is concluded that the pulsed cavitation technique provides a significant method for studying cavitation damage when proper consideration of the chemical nature of the environment is desired.

A64-25289

USE OF THE POLAROGRAPH FOR THE RECORDING OF POTENTIODYNAMIC CURVES [POUŽITÍ POLAROGRAFU PRO ZÁZNAM POTENCIODYNAMICKÝCH KŘIVEK].

Ferdinand Franz, Rudolf Štefec (Vysoká Škola Chemicko-Technologická, Katedra Chemické Technologie Kovů, Prague, Czechoslovakia), and Milan Pražák (Státní Výzkumný Ústav Ochrany Materiálu, Prague, Czechoslovakia).

Hutnické Listy, vol. 19, Aug. 1964, p. 562-566. 17 refs. In Czech.

Adaptation of the Heyrovsky polarograph to the investigation of the corrosion behavior of metals by its transformation into a classical potentiostat. Such a potentiostat is inherently simpler than its electronic counterpart and is thus readily available to fairly modest laboratories. Comparison of the potentiodynamic curves obtained for stainless ferritic-pearlitic and austenitic steels shows good agreement with published data.

A64-25519

THE INFLUENCE OF FINITE-WALL CONDUCTANCE ON LOAD CAPACITY OF THE MAGNETOHYDRODYNAMIC SLIDER BEARING.

W. T. Snyder (New York, State University, Dept. of Thermal Sciences and Fluid Mechanics, Stony Brook, N.Y.).

(American Society of Lubrication Engineers and American Society of Mechanical Engineers, Lubrication Conference, Rochester, N.Y., Oct. 15-17, 1963, Paper 63 - Lub-4.)
ASME, Transactions, Series D - Journal of Basic Engineering, vol. 86, Sept. 1964, p. 436-440. 9 refs.

Analysis of the influence of finite wall conductance on the pressure distribution and load capacity of the magnetohydrodynamic slider bearing. The analysis is based on general external loading conditions with the open-circuit condition being a special case. The load capacity is a linear function of the quantity $\phi = E_2/VB_y$ and the dependence of ϕ on the conductivity and thickness of the walls is shown in explicit form. Curves showing the variation of ϕ with wall conductance are presented. A numerical example is included which indicates a substantial reduction of load capacity from the case of insulating walls to the case where the wall conductivity is 1% of the fluid conductivity.

A64-25520

MAGNETOHYDRODYNAMIC SQUEEZE FILMS.

D. C. Kuzma (General Motors Corp., Research Laboratories, Warren, Mich.).

(American Society of Lubrication Engineers and American Society of Mechanical Engineers, Lubrication Conference, Rochester, N.Y., Oct. 15-17, 1963, Paper 63 - Lub-3.)
ASME, Transactions, Series D - Journal of Basic Engineering, vol. 86, Sept. 1964, p. 441-444. 9 refs.

Analysis of hydrodynamic squeeze films for the case of an electrically conducting fluid, in the presence of a magnetic field. Circular plates and infinitely long rectangular plates are considered with a uniformly applied magnetic field. The relationships between fluid-film thickness and time are determined analytically and compared with the ordinary hydrostatic squeeze films. It is shown that the application of a magnetic field improves the squeeze-film action.

A64-25521

THE FINITE MAGNETOHYDRODYNAMIC JOURNAL BEARING.

D. C. Kuzma (General Motors Corp., Research Laboratories, Warren, Mich.).

(American Society of Lubrication Engineers and American Society of Mechanical Engineers, Lubrication Conference, Rochester, N.Y., Oct. 15-17, 1963, Paper 63 - Lub-9.)
ASME, Transactions, Series D - Journal of Basic Engineering, vol. 86, Sept. 1964, p. 445-448; Discussion, W. F. Hughes (Carnegie Institute of Technology, Pittsburgh, Pa.), p. 448; Author's Closure, p. 448. 8 refs.

Analysis of a finite journal bearing for the case of an electrically conducting fluid in the presence of a radial magnetic field. The magnetohydrodynamic form of the two-dimensional Reynolds equation is derived and solved numerically for the pressure distribution. The load-carrying capacity and torque are determined from the pressure distribution. Numerical data for nonconducting bearing surfaces are compared with the data from the ordinary journal bearing. It is shown that the load-carrying capacity and torque are increased by application of the magnetic field.

A64-25524

PRECISE MEASUREMENT AND PREDICTION OF BULK-MODULUS VALUES FOR FLUIDS AND LUBRICANTS.

E. E. Klaus (Pennsylvania State University, Dept. of Chemical Engineering, Petroleum Refining Laboratory Div., University Park, Pa.) and J. A. O'Brien (Socony Mobil Oil Co., Inc., Applied Research Dept., Paulsboro, N.J.).

(American Society of Mechanical Engineers, Winter Annual Meeting, Philadelphia, Pa., Nov. 17-22, 1963, Paper 63 - WA-112.)
ASME, Transactions, Series D - Journal of Basic Engineering, vol. 86, Sept. 1964, p. 469-473; Discussion, H. A. Hartung, p. 473, 474; Authors' Closure, p. 474. 5 refs.
Contracts No. AF 33(616)-7590; No. AF 33(657)-10374.

Presentation of a series of precise determinations conducted with the PRL bulk modulus apparatus designed to measure isothermal secant bulk modulus over the range of 0 to 10,000 psig and 32 to 350°F. The measurements have been used as the basis for the development of a series of correlations between isothermal secant, isothermal tangent, and adiabatic tangent bulk-modulus values. It is stated that the validity of these correlations has been demonstrated by the use of measured and calculated bulk-modulus values obtained from several literature references.

A64-26002

ELOXAL METHOD FOR THE NONPLATED Al-ALLOY Al, Zn, Mg, Cu 1.5 [ELOXALVERFAHREN FÜR DIE Al-LEGIERUNG Al Zn Mg Cu 1,5 UNPLATTIERT].

Jürgen Weigel (Hamburger Flugzeugbau GmbH, Hamburg, West Germany).

Luftfahrttechnik Raumfahrttechnik, vol. 10, Aug. 1964, p. 210-215. 5 refs. In German.

Discussion of two methods for preventing corrosion of aluminum alloys containing heavy metals, when pressed to shapes that do not lend themselves to corrosion-proof plating. It is shown that efficient protection can be obtained by electrolytic surface oxidation in (1) a sulfuric-acid electrolyte with subsequent strengthening in a potassium-bichromate solution, and (2) in a chromic-acid electrolyte with subsequent strengthening in boiling water.

A64-26037

SUBMICRON SIZE BORON NITRIDE AS A GREASE THICKENER.

Robert D. Allen, Jerome F. Ditter, Melvin Gerstein (Dynamic Science Corp., South Pasadena, Calif.), and John B. Christian (USAF, Systems Command, Aeronautical Systems Div., Nonmetallic Materials Laboratory, Wright-Patterson AFB, Ohio).

Lubrication Engineering, vol. 20, Sept. 1964, p. 339-344. 5 refs.
Contract No. AF 33(657)-9155.

Report of development of an oxidation- and temperature-resistant grease by thickening silicone fluid with boron nitride. The rheological properties of greases prepared with such a thickener are considerably improved if it consists of particles of submicron dimensions rather than the usual coarser-grained material of commercial boron nitride. ASTM penetration of 260-300 was achieved with less than 20% thickener with the submicron additive, as opposed to more than 40% for the commercial compound. Preliminary capillary rheometer tests indicated shearing out and approach to Newtonian flow at about 10,000 sec^{-1} for greases made with the commercial thickener, whereas those with submicron additive still retained considerable structure at that point. Submicron-size boron nitride was prepared as a smoke at 900°C by gas phase reduction of ammonia and boron trichloride under high nitrogen dilution, then purified by vacuum sublimation of by-product ammonium chloride. Particle size distribution was modulated by varying the amount of nitrogen diluent during synthesis.

A64-26905
PREDICTING THE WEAR OF SLIDING PLASTIC SURFACES.
Robert Bee Lewis (Du Pont de Nemours and Co., Inc., Engineering Dept., Wilmington, Del.).
Mechanical Engineering, vol. 86, Oct. 1964, p. 32-35.

Presentation of a method of using relatively simple, economical tests to form a basis for wear prediction. The two most important criteria in the design of unlubricated plastic bearings, piston rings, and seals are pressure-velocity (PV) limits and wear. The PV limit of a plastic in a given environment tells the designer if the material will operate, but in addition, he must have a basis of predicting wear or life. Any unlubricated plastic sliding against another surface at a given ambient temperature has a PV limit, caused by the plastic's surface temperature reaching or exceeding a critical value, and the subject is discussed in some detail. Test equipment to determine PV limits and wear factor, utilizing the thrust-washer principle, and which can measure wear with an accuracy of better than ±10%, was designed. It consists of a standard table-mounted drill press, a variable-speed drive with control, and machined parts to accommodate washer-shaped test samples. The samples can be loaded and friction can be measured. Factors affecting PV limits and wear include changes in mating surface material, finish and hardness, and the composition of the plastic itself. F. R. L.

A64-26936
GAS LUBRICATION IN SPECIALIZED MACHINES.
G. W. K. Ford (United Kingdom Atomic Energy Authority, Reactor Development Div., London, England).
Engineering, vol. 198, Sept. 18, 1964, p. 369-371. 14 refs.
Research supported by the United Kingdom Atomic Energy Authority.

Consideration of the principal areas of application of gas lubrication. The applications are illustrated with examples. It is stated that, in some applications, the gas bearings have simply improved on the job other types of bearings do; in others, achievements impracticable with conventional bearings have been feasible. The first category includes applications ranging from dental drills to nuclear powerplants, and includes digital computers; the second extends from space guidance gyroscopes to high-speed motors and turbines for duties at the hot or cold extremes of operating temperatures. A table summarizes and analyzes the various applications of different types of gas bearings. M. M.

A64-27205
SOME PRINCIPLES FOR DEVELOPING A GENERAL SAFETY THEORY OF MACHINE PARTS AND INSTRUMENTS [NEKOTORYE PRINTSIPY POSTROENIIA OBSHCHEI TEORII NADEZHNOSTI ELEMENTOV MASHIN I PRIBOROV].
V. N. Treier (Institut Mashinovedeniia i Avtomatizatsii, Moscow, USSR).
Akademiia Nauk BSSR, Doklady, vol. 8, July 1964, p. 465-467. In Russian.

Discussion of the principal safety parameters for instrument and machine components subject to wear. The safety parameters that are essential for the development of a general safety theory are illustrated in graphic form. Three expressions are proposed using which it is possible to establish a direct relation between the safety calculations and durability calculations of components. V. P.

A64-27430
MECHANISM OF THE VAPOR LUBRICATION OF GRAPHITE.
Peter Cannon (General Electric Co., Research Laboratory, Schenectady, N. Y.).
Journal of Applied Physics, vol. 35, Oct. 1964, p. 2928, 2929. 9 refs.

Transformation of the minimum pressure vs molecular size at which the vapor lubrication of graphite is effective (Savage's operating curve) into a linear law. The linearity of the resulting semilogarithmic plot is seen to demand the nucleation of a liquidlike adsorbed film, and this is reconciled with recent studies of physical adsorption on graphite. A physical model, consistent with the law, is sketched. (Author) W. M. R.

A64-27586
LOAD-CARRYING CAPACITY OF A LUBRICANT LAYER [O NESUSHCHEI SPOSOBNOSTI SMAZOCHNOGO SLOIA].
S. B. Ainbinder and A. M. Grinshtein (Akademiia Nauk Latviiskoi SSR, Institut Mekhaniki Polimerov, Riga, Latvian SSR).
Akademiia Nauk SSSR, Doklady, vol. 155, Mar. 11, 1964, p. 320-322. 6 refs. In Russian.

Discussion of the compression of a plastic interlayer between two rigid rough plates whose width is much larger than the thickness of the interlayer. The condition is considered as a mechanical model to explain the relatively high compression-resistance of thin boundary layers of lubricants, by simple mechanical considerations rather than by anisotropic effects. Expressions, derived for the cases of plane and axially symmetrical compression, are verified by comparing calculated maximum normal stresses at contact surfaces in the center of compression with experimental results. V. Z.

A64-27875
FRICTION AND WEAR IN MACHINERY. VOLUME 16.
Edited by M. M. Khrushchov.
(Translation of Trenie i Iznos v Mashinakh. Volume 16, 1962.)
New York, American Society of Mechanical Engineers, 1964.
305 p.
Members, $6.00; nonmembers, $7.50.

CONTENTS:

A64-27876
INVESTIGATION OF PITTING BY MEANS OF A FOUR-BALL MACHINE.
M. D. Bezborod'ko and G. S. Krivoshein.
IN: FRICTION AND WEAR IN MACHINERY. VOLUME 16.
Edited by M. M. Khrushchov.
(Translation of Trenie i Iznos v Mashinakh. Volume 16, 1962.)
New York, American Society of Mechanical Engineers, 1964, p. 1-17. 18 refs.

Study of the effect of lubricating oils on the pitting of gear teeth and rolling contact bearings. To perform the measurements, a four-ball friction machine was used in conjunction with an acoustic probe. A change in the amplitude and frequency of oscillations displayed on an oscilloscope screen signalled the onset of pitting. The scatter of the results followed the normal distribution law. For the investigated low-viscosity, petroleum-based lubricants (not containing activating additives), the log-log graph of the time elapsed before onset of pitting vs applied load (200-500 kg) proved to be linear. It was found that, in the case of spur-wheel reduction gears, a suitable concentration of properly dispersed molybdenum disulfide in the lubricant effectively reduces pitting. W. M. R.

A64-27879
THEORY OF HYDRODYNAMIC LUBRICATION OF POROUS BEARINGS.
M. V. Korovchinskii.
IN: FRICTION AND WEAR IN MACHINERY.
Edited by M. M. Khrushchov.
(Translation of Trenie i Iznos v Mashinakh. VOLUME 16, 1962.)
New York, American Society of Mechanical Engineers, 1964.
p. 131-191. 22 refs.

Development of a rigorous theory of hydrodynamic friction in a porous bearing for the case when there is no loss of lubricant by leakage and the permeability of the porous liner or porous bearing is constant. The basic integrodifferential singular equations are obtained. These equations determine the pressure distribution in the lubricating layer of a porous bearing when the cross section of the liner is an annulus. The dimensionless criterion β, which takes into account the penetration (infiltration) of lubricant into the body of the porous liner, is established as an essential parameter. This criterion is proportional to the square of the ratio $\sqrt{c}/\Delta$ - i.e., the ratio of the square root of the transmissibility c (a quantity proportional to the linear dimension characterizing the pore size) to the radial clearance (a linear dimension characterizing the layer thickness). A simple method is given for solving the basic integrodifferential equation for a bearing having the shape of an annulus. On the basis of a numerical example and certain general considerations, it is established that this method is sufficiently accurate for equally spaced interpolation nodes when the degree of the interpolation polynomial is not greater than 3 ($s \approx 4$) and $\beta \geq 0.1$. At lower values of β, the small-parameter method in which β is taken as the parameter proves adequate. It is found that the accuracy of the interpolation approximation can be improved if interpolation nodes at unequal distances coinciding with zeros of Chebyshev polynomials are taken, and if normalized Chebyshev polynomials are used as approximating functions. This technique is seen to be analogous to Multhoppe's method for the solution of Prandtl's equation. On the basis of an example calculated for the case of an annular bearing of large OD, the general pattern of pressure distribution change in the lubricating layer is determined as a function of the change in the characteristic parameter β as the relative eccentricity χ is held constant. W.M.R.

A64-28280
DETERMINATION OF THE AXIAL CONSUMPTION OF THE LIQUID DURING THE ROTATION OF A SHAFT [OPREDELENIE OSEVOGO RASKHODA ZHIDKOSTI PRI VRASHCHENII VALA].
A. I. Belousov.
Aviatsionnaia Tekhnika, vol. 7, no. 3, 1964, p. 106-109. In Russian

Determination of the consumption of a lubricant along the bearing's axis in a turbulent flow, considering the shaft's rotation. Expressions for lubricant losses in the cylindrical annular groove of hydrostatic bearings are derived on the assumptions that (1) the flow rate in the groove is stable; (2) the flow rate in a cavity, perpendicular to the flow motion, is constant and equal to a flow rate at which there is average lubricant consumption; (3) the groove is entirely filled with the liquid; (4) the coefficient of friction is independent of the rotation rate; (5) the coefficients of losses at the inlet and outlet are independent of the rotation rate, and (6) rotation does not affect the degree of low turbulence. V. Z.

A64-28520
FUNDAMENTALS OF HYDRODYNAMIC LUBRICATION AND THEIR CONSEQUENCES IN DESIGN ENGINEERING. I.
F. H. Theyse (Delft, Technological University, Machine Elements Laboratory, Delft, Netherlands).
Wear, vol. 7, Sept.-Oct. 1964, p. 419-434. 76 refs.

Discussion of the need to make better use, in design engineering, of available knowledge about full film lubricated bearings. Low friction, low wear, and the absence of metallic contact are the advantages inherent in full film lubrication. The ways in which full film lubrication, and hence complete separation of the bearing surfaces in machinery, can be achieved are discussed. Static lubrication is shown to be the simplest method in which the lubricant is fed to the bearing after being pressurized by an external source of energy. Here, the absolute viscosity of the lubricant governing the flow in the bearing, is shown to be important. This is especially true in the case of dynamic lubrication in which the energy for bearing operation is derived from the velocities of the bearing surfaces. Study of the mechanism of this type of pressure generation proves that all possible modes of surface velocities, provided that the bearing clearance has the correct geometry and can be used to generate pressures and thus load carrying capacity. Pressure generation may involve: (1) a squeeze effect through the buffer velocities of the surfaces, (2) a stretch effect through velocity gradients within the bearing surfaces, and (3) a wedge effect through the tangential velocities of the surfaces. The last is particularly suitable for use in design. These concepts are used to show how a full film lubricated radial sleeve bearing can be designed. This type of bearing is taken as an example because it is so often encountered in practice. (Author) J. R.

1965
IAA ENTRIES

A65-10031 #
SOME PECULIARITIES OF THE IRRADIATION OF LUBRICANTS IN THE STUDY OF THEIR RADIATION RESISTANCE [O NEKOTORYKH OSOBENNOSTIAKH OBLUCHENIIA SMAZOCHNYKH MATERIALOV PRI ISSLEDOVANII IKH RADIATSIONNOI STOIKOSTI].
Iu. S. Zaslavskii, A. D. Stukin, and G. I. Shor.
Khimiia i Tekhnologiia Topliv i Masel, vol. 9, Oct. 1964, p. 44-48. 5 refs. In Russian.

Discussion of the energy transfer from nuclear particles into atoms and molecules of lubricants during irradiation, causing breaks of chemical bonds and formation of ions, ion-radicals, and free radicals, and affecting the useful properties of lubricants. The principle and procedure for advanced studies of these effects are described in detail. V. Z.

A65-10094
HIGH TEMPERATURE BEARINGS.
William J. Anderson (NASA, Lewis Research Center, Cleveland, Ohio).
Machine Design, vol. 36, Nov. 5, 1964, p. 164-181. 16 refs.

Discussion of the need created by high-speed flight and the space age for rolling-element bearings that must operate reliably at high temperatures. It is stated that estimates of future high-temperature bearing requirements for conventional, as well as exotic applications, range from 600°F to well above 1000°F. These temperatures are beyond the useful limits of conventional organic oils usually employed as liquids in recirculating systems, as the

liquid constituents in greases, or as an oil-air mist in throw-away systems. It is noted that the development of successful high-temperature bearings depends on the development of new lubrication techniques, new bearing materials, and new designs.

(Author) M. M.

A65-10095

NASA CHECKS OUT CERAMIC COATINGS.

Harold E. Sliney (NASA, Lewis Research Center, Cleveland, Ohio).

Machine Design, vol. 36, Nov. 5, 1964, p. 170, 171.

Discussion of the use of inorganic binders for coatings exposed to high temperatures which cause thermal or oxidative degradation of an organic-resin binder. The following coatings are considered in detail: (1) a ceramic coating that effectively lubricates 440 C and 304 stainless steels to 1250°F and which is prepared from a water slurry of yellow lead monoxide and finely powdered silica; (2) a ceramic coating that provides protection against wear of nickel-base superalloys and which is prepared from a slurry with a solids content of 60% cobaltous oxide, 20% barium oxide, and 20% boric oxide; it is stated that this composition has been effective as a binder for another high-temperature solid lubricant, calcium fluoride, which has too high a melting point to be fused directly on superalloys.

M. M.

A65-10405

THE SUPPORTING CAPACITY OF A LAYER OF LUBRICANT.

S. B. Ainbinder and A. M. Grinshtein (Akademiia Nauk Latviiskoi SSR, Institut Mekhaniki Polimerov, Riga, Latvian SSR).

(Akademiia Nauk SSSR, Doklady, vol. 155, Mar. 11, 1964, p. 320-322.)

Soviet Physics - Doklady, vol. 9, Sept. 1964, p. 230-232. 6 refs. Translation.

[For abstract see Accession no. A64-27586 24-17]

A65-10581

BOUNDARY LUBRICATION BEHAVIOR OF ORGANIC FILMS AT LOW TEMPERATURES.

J. A. Russell, R. A. Burton, P. M. Ku (Southwest Research Institute, San Antonio, Tex.), and W. E. Campbell (Rensselaer Polytechnic Institute, Troy, N. Y.).

American Society of Lubrication Engineers and American Society of Mechanical Engineers, Lubrication Conference, Washington, D. C., Oct. 13-16, 1964, Paper 64 LC - 6. 11 p. 12 refs.

Members, $0.50; nonmembers, $1.00.

Contract No. AF 33(657)-11088.

Discussion of sliding experiments on metals lubricated with thin films of hydrocarbons, fatty acids, and synthetic lubricants in helium and air. The temperature range -195 to +200°C is investigated. For copper and iron pairs lubricated with pure organic compounds, a marked rise in friction and wear is found to occur at the melting point of the film material. From just below the melting point down to -195°C, there is an increase in friction but negligible wear, indicating increased shear strength of the solid film. This is substantiated by contact-resistance measurements. The behavior of fatty acids in dry air indicates that oxygen promotes the formation of higher-melting soap and defers the friction rise to the melting point of the soap. Humidity is found to displace the friction rise to an even higher temperature. (Author) M. L.

A65-10582

SOME ILLUSTRATIVE PROBLEMS IN THE FLOW OF VISCO-ELASTIC NON-NEWTONIAN LUBRICANTS.

R. I. Tanner (Sydney, University, Dept. of Mechanical Engineering, Sydney, Australia).

American Society of Lubrication Engineers and American Society of Mechanical Engineers, Lubrication Conference, Washington, D. C., Oct. 13-16, 1964, Paper 64 LC - 10. 5 p. 9 refs.

Members, $0.50; nonmembers, $1.00.

Discussion of the factors affecting the choice of an equation of state for the description of non-Newtonian viscoelastic lubricants. Simple solutions for squeeze films with and without superimposed steady shears are given. These illustrate the complexity of the action of these fluids, including the variation of the effective relaxation time and the "softening" of the film under dynamic loading. (Author) M. L.

A65-10583

NEW METHODS OF INVESTIGATIONS OF LUBRICANT PROPERTIES.

Ju. S. Zaslavsky, G. I. Shor, I. A. Morozova, F. B. Lebedeva, E. V. Evstigneev, and R. N. Shneerova (All-Union Scientific Research Institute of Oil Refining, Moscow, USSR).

American Society of Lubrication Engineers and American Society of Mechanical Engineers, Lubrication Conference, Washington, D. C., Oct. 13-16, 1964, Paper 64 LC - 9. 8 p. 6 refs.

Members, $0.50; nonmembers, $1.00.

Investigation of the mechanism of the true detergent action of motor-oil additives. The sorption of the charged additive particles on the surface of the carbonaceous products of fuel combustion and oil oxidation, as well as on the surface of engine metal parts, is studied. The data confirm the impression that the charged additive particles characterized by low E_0 values should have a greater relative sorption ability as compared to the particles with higher E_0 values. The conclusion is reached that oil solutions of the tested additives possessing true detergent and deflocculating properties are anhydrous electrolytes, as their dissociation degree sharply increases with the decrease in the additive concentration. They obey Ohm's law, and they are electrolyzed, practically all of the additive depositing on the electrodes as decomposition products. A greater mobility of the cation particles as compared with the anion particles has been found. A radiotracer method for the simultaneous evaluation of antiwear and detergent properties of motor oils and a radiotracer method for the evaluation of the chemical activity of EP additives are discussed. M. L.

A65-10585

EFFECTS OF LUBRICANTS ON TRANSITION TEMPERATURES.

R. S. Fein (Texaco, Inc., Research Center, Beacon, N. Y.).

American Society of Lubrication Engineers and American Society of Mechanical Engineers, Lubrication Conference, Washington, D. C., Oct. 13-16, 1964, Paper 64 LC - 7. 9 p. 22 refs.

Members, $0.50; nonmembers, $1.00.

Confirmation and extension of studies of transitions between low and high friction and wear in the four-ball machine, using lubricants consisting of noncyclic hydrocarbons and dilute solutions of stearic acid and cetane and squalane. These materials show transition temperatures which are the same for AISI 4140 and 52100 steels and which increase with increasing ratio of speed to load. Hydrocarbons with cyclic structures are found to show similar performance with 4140 steel and, at high speed-load ratios, with 52100 steel. However, with the 52100 steel at low speed-load ratios, there is a speed-load ratio independent transition temperature. Neat stearic acid with 52100 steel is found to show similar performance to the cyclic hydrocarbons with the speed-load ratio independent transition temperature agreeing with pin-on-disk machine results on other steels in the literature. These results and results obtained from the literature are discussed using a mechanism involving viscous trapping of lubricant between interacting load-supporting asperities. (Author) M. L.

A65-10586

CHEMISTRY OF BOUNDARY LUBRICATION OF STEEL BY HYDROCARBONS.

R. S. Fein and K. L. Kreuz (Texaco, Inc., Research Center, Beacon, N. Y.).

American Society of Lubrication Engineers and American Society of Mechanical Engineers, Lubrication Conference, Washington, D. C., Oct. 13-16, 1964, Paper 64 LC - 4. 10 p. 21 refs.

Members, $0.50; nonmembers, $1.00.

Investigation of boundary lubrication by hydrocarbons using a four-ball machine with 52100 steel specimens at 0.35 cm per second sliding velocity. The chemical type of the hydrocarbon and the amount of oxygen dissolved in it are found to be important. Low molecular weight liquid-aromatic hydrocarbons exposed to ambient air are found as effective as straight mineral oils in controlling wear, while saturated hydrocarbons are found to be generally poorer. Benzene and cyclohexane are used as model lubricants in the study of oxygen concentration in vapor and liquid phase. Both high and low oxygen-to-hydrocarbon ratios favor high wear and inorganic wear products. Certain intermediate ratios are seen to result in low wear

and the formation of an oxygenated organic "friction polymer" which prevents metallic contact. The results are discussed in the light of available information concerning catalytic reactions at clean metal surfaces. (Author) M. L.

A65-10587
THE LUBRICATION MECHANISM OF TRICRESYL PHOSPHATE ON STEEL.
Douglas Godfrey (California Research Corp., Richmond, Calif.).
American Society of Lubrication Engineers and American Society of Mechanical Engineers, Lubrication Conference, Washington, D.C., Oct. 13-16, 1964, Paper 64 LC - 1. 11 p. 45 refs.
Members, $0.50; nonmembers, $1.00.

Discussion of the results of a literature survey showing that the lubricating mechanism of tricresyl phosphate (TCP) is not clear. The theory of polishing by formation of an iron-iron phosphide eutectic is not supported. Wear reduction by the formation of iron phosphate is seen to be a more likely explanation. Experimental work is discussed which shows that, when steel sliding on steel is lubricated with TCP, a film consisting of a mixture of $FePO_4$ and $FePO_4 \cdot 2H_2O$ is formed. Other friction and wear experiments, as well as film analyses, are shown to support the phosphate mechanism. (Author) M. L.

A65-10589
ON THE MECHANISMS OF MoS_2-FILM FAILURE IN SLIDING FRICTION.
A. W. J. De Gee (Central Organization TNO, Metal Research Institute, Physico-Mechanical Dept., Delft, Netherlands), G. Salomon (Central Organization TNO, Central Laboratory, Delft, Netherlands), and J. H. Zaat (Eindhoven, Technical University, Dept. of Mechanical Engineering, Eindhoven, Netherlands).
American Society of Lubrication Engineers and American Society of Mechanical Engineers, Lubrication Conference, Washington, D.C., Oct. 13-16, 1964, Paper 64 LC - 30. 8 p. 7 refs.
Members, $0.50; nonmembers, $1.00.
Research sponsored by the Alpha Molykote Corp., the Molykote Produktions-gesellschaft mbH, and the Molykote S.A.R.L.

Study of the effect of oxygen on the life expectancy of a run-in molybdenum disulfide film under heavy load. Tested in argon, with only small quantities of oxygen present, the smooth running period is found to be increased by at least two decades as compared to a test in oxygen. Blister formation is seen to be an important factor in the gradual destruction of the lubricant film. Blisters of submicroscopic size can be traced with the electron microscope. In the presence of oxygen, macroscopic blisters are seen to be formed rapidly. Oxygen promotes sintering of the individual particles to a continuous, smooth, and therefore highly reflective lubricant layer. No wear occurs during the smooth running period of MoS_2 lubrication. Graphite differs from MoS_2 in this respect and in its much lower load-carrying capacity. A cine-film on graphite-lubricated surfaces shows a rougher surface and the formation of smaller blisters. On addition of graphite to MoS_2, a sudden change in surface features is seen to occur within narrow limits of graphite concentration. It is concluded that the addition of 15% by weight of graphite increases the total life expectancy of the MoS_2 film, but reduces the length of the smooth running period. (Author) M. L.

A65-10597
TEMPERATURE - THE KEY TO LUBRICANT CAPACITY.
E. F. Leach and B. W. Kelley (Caterpillar Tractor Co., Peoria, Ill.).
American Society of Lubrication Engineers and American Society of Mechanical Engineers, Lubrication Conference, Washington, D.C., Oct. 13-16, 1964, Paper 64 LC - 13. 10 p. 9 refs.
Members, $0.50; nonmembers, $1.00.

Results of an investigation showing that the failure of a non-reactive mineral oil can be predicted by Blok's formula for determining the maximum temperature between two bodies in rolling and sliding contact. The evaluation of many lubricants on a geared roller test machine is discussed, and it is shown that the lubricant failure for any particular lubricant-material combination occurs at a constant, critical contact temperature, film thickness, and viscosity grade. The coefficient of friction can be predicted by a parameter involving the unit load, inlet viscosity, sum velocity, and sliding velocity. The load capacity of a lubricant is shown to vary inversely with specimen temperature for a constant set of test conditions. Electrical-resistance measurements across the contact zone are shown to aid in identifying the lubricant failure point and in revealing the action of two deposit-forming additives. (Author) M. L.

A65-10599
SLIDER BEARING PERFORMANCE WITH A NON-NEWTONIAN LUBRICANT.
Y. C. Hsu and Edward Saibel (Rensselaer Polytechnic Institute, Dept. of Mechanics, Troy, N.Y.).
American Society of Lubrication Engineers and American Society of Mechanical Engineers, Lubrication Conference, Washington, D.C., Oct. 13-16, 1964, Paper 64 LC - 17. 5 p.
Members, $0.50; nonmembers, $1.00.

Analysis of a method capable of approximating the behavior of a slider bearing without side leakage, using a non-Newtonian fluid. An example of this method is given, and it is found to be relatively easy to apply and valid for a large range of strain rates. The difference between this treatment and earlier ones is found to be in the type of constitutive equations used. This treatment satisfies the invariant condition and is considered applicable to both pseudo-plastic and dilatant fluids. The pressure distribution, oil flow, and friction force are calculated, and the results are compared with the corresponding ones for a Newtonian fluid. M. L.

A65-10604
THE EFFECTS OF LOAD ON THE FRICTIONAL PROPERTIES OF MOLYBDENUM DISULFIDE.
S. A. Karpe (U.S. Navy, Marine Engineering Laboratory, Friction and Wear Div., Annapolis, Md.).
American Society of Lubrication Engineers and American Society of Mechanical Engineers, Lubrication Conference, Washington, D.C., Oct. 13-16, 1964, Paper 64 LC - 21. 12 p. 20 refs.
Members, $0.50; nonmembers, $1.00.
Navy-supported research.

Determination of the kinetic coefficient of friction for several grades of commercially available molybdenum disulfide powder. The powders are individually applied to separate steel-supporting substrates to form a thin lubricant film. Friction measurements are made at loads of 0.1 to 10 kg and at a slow speed of sliding. It is shown that the coefficient of friction decreased with increasing load, contrary to Amontons' second law. A theory is postulated to explain the observed variation in the friction coefficient with load. It is concluded that this variation could be explained solely on the basis of the macroelastic and/or macroelastic and plastic deformation characteristics of the supporting substrates. (Author) M. L.

A65-10605
METHODS FOR DETERMINING PRESSURE DISTRIBUTIONS IN LUBRICATED ROLLING CONTACT.
J. W. Kannel, J. C. Bell, and C. M. Allen (Battelle Memorial Institute, Columbus, Ohio).
American Society of Lubrication Engineers and American Society of Mechanical Engineers, Lubrication Conference, Washington, D.C., Oct. 13-16, 1964, Paper 64 LC - 23. 15 p. 16 refs.
Members, $0.50; nonmembers, $1.00.
Contract No. AF 33(657)-10494.

Analysis of two methods of pressure-distribution determinations. In the first method, the circumferential profile of the gap between rolling disks is found by using an X-ray technique, and the pressures are inferred from the observed deformations of the disks. The pressure distribution is derived from the deformed shape by the use of an exact series solution for pressure in terms of the coefficients of a Fourier series for the shape. By using polyphenyl ether as the lubricant, profiles are obtained for a range of loadings, temperatures, and plausible (but not detailed) pressure distributions. The second method uses a strip of manganin coating on a glass disk which is loaded into lubricated contact with a second glass disk. The change in electrical resistance of the manganin due to film pressures is measured. It is found that the resistance traces are consistent in predicting the right total loads. It is concluded that both

methods yield pressure patterns which are qualitatively quite similar to each other and which have much in common with published theoretical pressures. M. L.

A65-10607

THE ISOTHERMAL LUBRICATION OF CYLINDERS.

D. Dowson and A. V. Whitaker (Leeds, University, Dept. of Mechanical Engineering, Leeds, England).

American Society of Lubrication Engineers and American Society of Mechanical Engineers, Lubrication Conference, Washington, D.C., Oct. 13-16, 1964, Paper 64 LC - 22. 11 p. 9 refs.
Members, $0.50; nonmembers, $1.00.
Research supported by the Department of Scientific and Industrial Research.

Consideration of the hydrodynamic problem of cylinder lubrication. Rigid solids lubricated by a constant-property fluid, rigid solids lubricated by a variable-property fluid, and elastic solids lubricated by a variable-property fluid are considered. The cylinder is selected for analysis since many real contacts in machinery can be represented. It is found that for light loads, the cylinders retain their unloaded geometry, but, when the contact forces are large, significant elastic deformation may occur. Computing methods appropriate to the "rigid" and "elastic" situations are summarized. The valid application range of the "rigid" and "elastic" film thickness relationships is discussed, and an intermediate range is defined. A chart to enable a particular problem to be located in the "rigid," "intermediate," or "elastic" zone is presented. M. L.

A65-10608

THE FRICTION AND WEAR BEHAVIOR OF MOLYBDENUM-TUNGSTEN-CHROMIUM ALLOYS IN HIGH-TEMPERATURE SODIUM ENVIRONMENTS.

W. H. Roberts (United Kingdom Atomic Energy Authority, Rector Group, Reactor Engineering Laboratory, Risley, Lancs., England).

American Society of Lubrication Engineers and American Society of Mechanical Engineers, Lubrication Conference, Washington, D.C., Oct. 13-16, 1964, Paper 64 LC - 25. 14 p. 22 refs.
Members, $0.50; nonmembers, $1.00.

Study of wear data and friction coefficients of molybdenum-tungsten-chromium alloys in the presence of liquid sodium and sodium vapor and argon. Data are obtained with a crossed-cylinders apparatus over a range of 200-500°C. Comparisons are made with results obtained in gaseous environments of pure argon, helium, and carbon dioxide. The effect of increasing the oxygen content of liquid sodium from 5 to 80 ppm on friction and wear behavior is indicated. It is shown that chemisorbed double-oxide films, formed by the reaction of the molybdenum, tungsten, and chromium alloys with the sodium environment, play a significant role in providing boundary lubrication in high-temperature sodium. It is found that the availability of oxygen is an essential feature of the reactions for producing the double oxides in sodium. It is concluded that the molybdenum and tungsten double oxides are not thermodynamically stable in high-purity sodium at high temperatures (above 400°C), but that sodium-chromium complexes can be effective to quite high temperatures. The effectiveness of the lubrication provided by such films is found to be a function of the specific nature of the sodium environment and temperature, as well as time at temperature. M. L.

A65-10610

MICROTOPOGRAPHY OF FINELY GROUND STEEL SURFACES IN RELATION TO CONTACT AND WEAR.

A. Dorinson (Sinclair Research, Inc., Fundamentals of Lubrication Section, Harvey, Ill.).

American Society of Lubrication Engineers and American Society of Mechanical Engineers, Lubrication Conference, Washington, D.C., Oct. 13-16, 1964, Paper 64 LC - 15. 9 p. 14 refs.
Members, $0.50; nonmembers, $1.00.
Research supported by Sinclair Research, Inc.

Results of interferometric examination and taper sectioning to elucidate the microtopography of the contacting surfaces of a finely ground disk and a conically ended rider. The question of the real area of contact when these surfaces are put together under high pressure is considered. It is found that after a short period of rubbing, with either a white or compounded oil, the visible evidence of true metal-to-metal contact is quite sparse in comparison to the potential real area of contact deduced from microtopograhical considerations. The scar on the end of the rider, on the other hand, is found to show evidence of extensive rubbing, as a consequence of the high ratio of the area of the disk track to the area on the end of the rider. It is found that, when an indifferent lubricant is used in high-pressure wear experiments, the first worn-off material detected with any certainty consists of obviously secondary agglomerates of primary wear material. The adhesion of these agglomerates to the rubbing surface of the disk is shown to radically alter the nature of the surface, so that any analysis of contact based on the initial topography of the disk and the rider is no longer valid. It is concluded that an effective extreme-pressure lubricant, on the other hand, tends to preserve the initial topography of the contacting surfaces. Thus, the action of extreme-pressure lubricants is found to be intimately connected with changes in surface topography due to wear and the influence of these changes on further wear. M. L.

A65-10752

FLUID DYNAMIC FOUNDATION OF TURBULENT LUBRICATION THEORY.

Chung-wah Ng (Mechanical Technology, Inc., Latham, N. Y.).

(American Society of Lubrication Engineers, Annual Meeting, Chicago, Ill., May 1964.)
ASLE Transactions, vol. 7, Oct. 1964, p. 311-321. 20 refs.
AEC-supported research.

Critical examination of Constantinescu's theory of turbulent fluid film lubrication. By applying the "law of wall" with Reichardt's formula for the entire channel width, a new method for analyzing the one-dimensional turbulent fluid film has been developed, which can be used to analyze an infinitely long bearing lubricated by a turbulent film. The method permits a smooth transition in contrast with the abrupt change from laminar flow to turbulence (Constantinescu). Also, the thickness of the laminar sublayer is maintained constant in the region $0 \leqslant y^+ \leqslant 5.0$, where the relation $u^+ = y^+$ holds. Using the new method to construct a B vs $\bar{u}_m$ plot, anomalies appear in the region where the two wall shears are of greatly different magnitudes. This can be attributed to the fact that transverse shear gradient effect is neglected. The friction factor calculated by the new method for the Couette flow agrees very well with experimental data obtained by Smith and Fuller, and recently by Robertson. For the Poiseuille flow, correlation with Nikuradse's data for pipe flow is less satisfactory, but within 20% for $Re > 10^4$. This is due to overlooking the law of defect, which should dominate in the core region. The analysis yields values of film pressures and load capacities that are smaller than Constantinescu's. The attitude angles predicted by the two theories are practically identical (within 1%). F.R.L.

A65-10758

FLUOROALKYLPHOSPHONITRILATES - A NEW CLASS OF POTENTIAL FIRE-RESISTANT HYDRAULIC FLUIDS AND LUBRICANTS. I.

Ehrenfried Kober, Henry Lederle, and Gerhard Ottmann (Olin Mathieson Chemical Corp., New Haven, Conn.).

(American Society of Lubrication Engineers, Annual Meeting, Chicago, Ill., May 1964.)
ASLE Transactions, vol. 7, Oct. 1964, p. 389-397. 13 refs.
Contract No. NObs 86482.

Description of the preparation and preliminary evaluation of a number of trimeric and tetrameric bis (α, α, ω-tri H-polyfluoroalkyl) phosphonitrilates, mixed substituted trimeric and tetrameric (phenyl-α, α, ω-tri H-polyfluoroalkyl) phosphonitrilates, and mixed substituted trimeric and tetrameric (substituted phenyl-α, α, ω-tri H-polyfluoroalkyl) phosphonitrilates. Many products have wide liquid ranges with pour points ranging down to -55°F. They also have high compression-ignition ratios and relatively high spontaneous-ignition temperatures. Good wear and compatibility with

rubber are other favorable properties. In order to obtain hydrolytically stable products, new synthesis and purification methods were developed. The compounds are considered to have potential applicability for use as fire-resistant hydraulic fluids and lubricants. (Author) F.R.L.

A65-10888 #
RESISTANCE TO ABRASIVE WEAR AND PHYSICAL PROPERTIES OF MATERIALS.
M. M. Khruschov and M. A. Babichev (Institute for Study of Machines, Laboratory of Wear Resistance, Moscow, USSR).
American Society of Mechanical Engineers and American Society of Lubrication Engineers, International Lubrication Conference, Washington, D.C., Oct. 13-16, 1964, Paper 64 - Lub-31. 7 p. 8 refs.
Members, $0.50; nonmembers, $1.00.

Experimental investigations of the relationship between the abrasion resistance of certain materials (commercially pure metals, steels, alloys, and minerals) and their physical properties. The relations are obtained as functions of material history (annealing, heat treatment, cold working) and initial hardness. With the exception of heat-treated steels, general laws are developed connecting the moduli of elasticity of all the tested materials with the relative wear resistance. The presence of residual stresses of the first kind is shown to have no effect on the resistance of metals to abrasive wear. W.M.R.

A65-11523
CORROSIVE ENVIRONMENT CERAMIC TO METAL SEALS FOR SPACE POWER APPLICATIONS.
L. Reed and R. C. McRae (Eitel-McCullough, Inc., Process and Materials Laboratory, Ceramics Section, San Carlos, Calif.).
IN: SOCIETY OF AEROSPACE MATERIAL AND PROCESS ENGINEERS, NATIONAL SYMPOSIUM ON MATERIALS FOR SPACE VEHICLE USE, 6TH, SEATTLE, WASH., NOVEMBER 18-20, 1963. VOLUME 3.
Seattle, Society of Aerospace Material and Process Engineers, 1963. 38 p. 24 refs.
Research supported by the Westinghouse Electric Corp.

Description of development of seals for high-temperature operation (300-1000°C) in atmospheres of Li, Na, K, Cs, or Hg for alternator bore seals. It is stated that alumina ceramics brazed to a metal member using the conventional techniques practiced in the electron-tube industry are unsatisfactory in all cases mentioned. Alkali-metal vapors leach out silica, which is present in the secondary phases of most ceramic bodies. With a mercury-vapor environment, the main avenue of attack is through the braze when using alloys containing copper, silver, and gold. In all cases, the final working assembly presents both metallurgical and mechanical problems. The rigid dimensional tolerances on the thin ceramic membrane in the electromagnetic flux gap of alternators requires special considerations in design, metalizing, and brazing. Special silica-free ceramic bodies have been fabricated to the authors' specifications and are being investigated for the alkali-metal vapor applications. (Author) M.M.

A65-11524
CORROSION BEHAVIOR OF STRUCTURAL MATERIALS WITH FLUORINE-CONTAINING LIQUID OXIDIZERS.
W. D. English, S. W. Pohl, and N. A. Tiner (Astropower, Inc., Newport Beach, Calif.).
IN: SOCIETY OF AEROSPACE MATERIAL AND PROCESS ENGINEERS, NATIONAL SYMPOSIUM ON MATERIALS FOR SPACE VEHICLE USE, 6TH, SEATTLE, WASH., NOVEMBER 18-20, 1963. VOLUME 3.
Seattle, Society of Aerospace Material and Process Engineers, 1963. 30 p. 8 refs.
Contract No. AF 33(657)-9162.

Description of experimental procedures used and results obtained on the corrosion of structural materials with oxygen difluoride and a mixture of dinitrogen tetrafluoride-perchloryl fluoride. The results are shown in tabular form. It is stated that the susceptibility of metals to corrosion with fluorine-containing oxidizers depends largely on the oxidizer's chemical attack on metal surfaces to yield fluorides. The compounds F_2, OF_2, O_3F_2, and N_2F_4 do not show much tendency to ionize in the liquid state. Certain metals and alloys do not form protective fluoride films on the surface by the corrosive attack of OF_2 or of the N_2F_4-$FClO_3$ blend. In general, teflon is not chemically attacked by fluorine oxidizers, but the pores in this material filled with oxidizer, and weight change usually is not indicative of corrosion rate. The oxidizers used in the corrosion tests described were relatively pure. Careless handling of the test bombs, specimens, and racks, or inadvertent addition of impurities such as HF and H_2O in the oxidizer, has a considerable effect on corrosion rates. M.M.

A65-11644
THE NEW LUBRICANTS.
R. L. Adamczak, R. J. Benzing, and H. S. Schwenker (USAF, Systems Command, Research and Technology Div., Materials Laboratory, Fluid and Lubricants Materials Branch, Wright-Patterson AFB, Ohio).
Space/Aeronautics, vol. 41, June 1964, p. 104-108.

General description of the characteristics, advantages, and disadvantages of unconventional lubricants -i.e., materials other than greases and oils. These include dry, solid-film, electromagnetic and static, vapor-phase, gas, and cryogenic lubricants, and gas-entrained powders, liquid metals, and salts. Although the conventional materials are reliable (a good petroleum oil can lubricate for tens of thousands of hours) and have secondary capabilities such as sealant, scavenging, heat-transfer, power-transfer, power-transmission, and anticorrosive action, their development is seen to have been outpaced by expanding temperature requirements (a 1000°F conventional lubricant is believed to be 15 years away). The liquid metals and cryogenics may never completely replace these oils and greases, but they are expected to have increasing application in high-vacuum (beyond 10^{-10} torr), high-temperature (above 2500°F), and strong-radiation environments. W.M.R.

A65-11813
LUBRICANTS AND LIQUIDS FOR MOTORS AND JET ENGINES [MOTORNYE I REAKTIVNYE MASLA I ZHIDKOSTI]. 4TH EDITION.
Edited by K. K. Papok and E. G. Semenido.
Moscow, Izdatel'stvo Khimiia, 1964. 704 p. In Russian.

This book discusses the fundamentals of friction and lubrication, and reviews methods of evaluating the physical and chemical properas functions of hydrocarbon structure. Experience obtained in the and similar liquids. The properties of the lubricants are examined as function of hydrocarbon structure. Experience obtained in the production of hydrocarbon lubricants and of synthetic lubricants without hydrocarbon content is noted. Particular attention is given throughout to the effects of various additives. The stability, fractional composition, and thermal properties of lubricants are examined, as are the mechanisms of formation of carbon-black and other sediments in engines, including the method of removing the latter. Several chapters are devoted to the quality and selection of lubricants and liquids (including some foreign brands) for use in aircraft piston and jet engines, aircraft and conventional gas turbines, as well as engines of automobiles and ships. Some aspects of the recovery of used lubricants are noted. The book is designed for engineers and technicians working in the lubrication field. V.P.

A65-11975 #
GREASES FOR THE SST.
P. J. Douglas (Shell International Petroleum Co., Ltd., London, England).
Shell Aviation News, no. 316, 1964, p. 22-24.

Discussion of the problem of lubrication of flying control system bearings. For the SST, the problem is complicated by the need for high-temperature properties in the grease, in addition to the usual low-temperature properties. Although self-lubricated bearings will be used wherever possible, grease lubrication will be necessary at some points: trouble-free operation for 6,000 hr is a basic requirement, and the grease must be capable of operation at very high altitude, of withstanding deterioration, and of preventing fretting

damage. Because of the importance of the latter, an extensive testing program has been carried out on the Fafnir "Friction Oxidation Rig." On this apparatus, a 600-lb thrust load is applied to the bearing, and the rotating bush is oscillated through an arc of 6° by suitable driving arms. F. R. L.

A65-11979 #
SECOND GENERATION SYNTHETIC AIRCRAFT GAS TURBINE LUBRICANTS.
H. M. Brewster (Esso International, Inc., New York, N.Y.).
Esso Air World, vol. 17, Sept.-Oct. 1964, p. 36-39.

Discussion of the requirements of a second-generation turbo oil. It is thought that advantages such as (1) reduced engine deposits; (2) improved accessory performance; (3) lower in-flight oil consumption; (4) extended oil drain intervals (where applicable); and (5) the ability to withstand high thermal and oxidative stresses - make the use of a second-generation turbo oil (such as Esso Turbo Oil 5251) desirable in all jet-engine and accessory equipment, regardless of operational severity. It is said that, for these reasons, many airlines have selected and are currently operating with Esso Turbo Oil 5251; over 750,000 hours of use in commercial operations were reportedly accumulated by Sept. 1964. D. H.

A65-12067
MECHANISMS OF SOLID FRICTION; CONFERENCE, MIDWEST RESEARCH INSTITUTE, KANSAS CITY, MO., SEPTEMBER 16-18, 1963, PAPERS.
Edited by P. J. Bryant, M. Lavik (Midwest Research Institute, Kansas City, Mo.), and G. Salomon (Central Organization T.N.O., Central Laboratory, Delft, Netherlands).
Amsterdam, Elsevier Publishing Co., 1964. 224 p.
$9.00.

CONTENTS:

A65-13040 #
ROLLING-FRICTION AND WEAR OF CYLINDRICAL BODIES [TRENIE I IZNOS PRI KACHENII TSILINDRICHESKIKH TEL].
N. I. Glagolev.
Inzhenernyi Zhurnal, vol. 4, no. 4, 1964, p. 659-672. 32 refs.
In Russian.

Discussion of the problem of rolling-friction and wear of an elastic wheel moving along an elastic surface, on the basis of Reynolds' scheme. The principal assumptions of this scheme are: (1) resistance to rolling is due to sliding friction at the contact surface of the rolling body and the base, and (2) the contact surface is composed of sliding and cohesion elements. A solution is obtained within the framework of the theory of elasticity, using Muskhelishvili's method and results. V. P.

A65-13674 #
A NEW VISCOSITY-TEMPERATURE CRITERION FOR LUBRICATION OILS.
C. J. A. Roelands, J. C. Vlugter (Delft, Technological University, Laboratory for Chemical Technology, Delft, Netherlands), and H. Blok (Delft, Technological University, Dept. of Mechanical Engineering, Laboratory for Machine Elements, Delft, Netherlands).
American Society of Mechanical Engineers and American Society of Lubrication Engineers, International Lubrication Conference, Washington, D.C., Oct. 13-16, 1964, Paper 64-LUB-3. 16 p. 43 refs.
Members, $0.50; nonmembers, $1.00.

Presentation of a new two-parameter equation which reportedly has proved successful in describing - over a substantial temperature range - the viscosity-temperature relationships of the various kinds of lubricating oils, including synthetic ones, normally encountered in present lubrication practice. The equation is described as having the unique feature of permitting the viscosity-temperature relationships of the members of a "naturally" homologous group of mineral oils to be plotted as a family of lines that are both straight and parallel within normal viscometric accuracy. This "homologous parallelism" is used to obtain the new viscosity-temperature criterion proposed: the "Slope Index." This index is defined as the slope common to the parallel lines representing the various members of the group concerned. Major advantages claimed for the Slope Index are: its assessment is extremely simple, particularly when the relevant viscosity-temperature chart is used; it needs no standard reference temperatures or reference oils; and it is not subject to the ambiguities and irregularities of the conventional Viscosity Index. D. H.

A65-13847 #
CALCULATION OF WEAR RATE.

A65-13853

I. V. Kraghelsky (Academy of Sciences, Research Institute of Mechanical Engineering, Moscow, USSR).
American Society of Mechanical Engineers, Winter Annual Meeting, New York, N. Y., Nov. 29-Dec. 4, 1964, Paper 64 - WA/LUB-5.
6 p. 16 refs.
Members, $0.50; nonmembers, $1.00.

Presentation of exhaustive analytical data on factors contributing to the wear of a deformed body interacting with an absolutely rigid rough solid. It is believed that wear results from the deformation of a body due to geometrical and mechanical factors and due to its adhesion bonds. Three types of wear are considered: by elastic deformation, by plastic deformation, and by microcutting. The suggested criteria allow the determination of conditions which cause these types of wear to appear. It is shown that the rate of wear - i.e., the ratio of height of the worn layer to the distance of sliding at elastic contact - depends on the elasticity modulus, roughness, friction coefficient, nominal pressure, rupture stress of material, and on the power exponent of the fatigue curve. In plastic contact it depends on the roughness, nominal pressure, hardness, destroying deformation, and the friction coefficient. In microcutting, it depends on roughness, nominal pressure, and hardness. Wear in microcutting is found to be independent of the friction coefficient. The formulas derived are borne out by experiments. These formulas may be readily modified for the case of two rough surfaces.
(Author) M. L.

A65-13853 #
LUBRICATION REVIEW.
American Society of Mechanical Engineers, Winter Annual Meeting, New York, N. Y., Nov. 29-Dec. 4, 1964, Paper 64 - WA/LUB-1.
24 p. 450 refs.
Members, $0.50; nonmembers, $1.00.

Presentation of information on publications relating to several aspects of the field of lubrication. Many of the results of current theoretical and experimental investigations are summarized. The areas reviewed include fluid-film lubrication, developments in lubricants, metalworking lubricants, automotive lubricants, gear lubrication, boundary lubrication, rolling element bearings, and friction and wear.
(Author) M. L.

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