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LIQUID METALS TECHNOLOGY ABSTRACT BULLETIN

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MSA RESEARCH CORPORATION

TECHNICAL INFORMATION DIVISION

LIQUID METALS TECHNOLOGY ABSTRACT BULLETIN

This is the twenty-first issue of a series of abstract bulletins covering current literature on liquid metals. These bulletins are prepared by the Technical Information Division as a service to industries engaged in related research and development programs.

The growing interest in liquid metals technology has led to an increased amount of literature published on the subject. MSA Research Corporation, as a pioneer in liquid metals technology, feels that other interested companies can benefit from a current and up-to-date abstract bibliography on liquid metals literature.

These bulletins will be issued at approximate quarterly intervals, depending upon the volume of literature to be covered. Existing abstracts will be used unless they are not adequate with respect to the subject scope.

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(APAE-112-Vol. III) 30 Megawatt Heat Exchanger and Steam Generator for Sodium Cooled Reactor System. Volume III. Material and Welding Specifications. 1

(Alco Products, Inc. Schenectady, N. Y.)
June 29, 1962. Contract AT(11-1)-666. 58 p.

Material inspection and welding specifications are presented for various parts of both the intermediate heat exchanger and steam generator. Tables are included that indicate the applicable parts and assemblies to which these specifications apply. For other parts, where the material requirements are not severe, the ASTM or other indicated specifications are applicable.

(APAE-112-Vol. IV) 30 Megawatt Heat Exchanger and Steam Generator for Sodium Cooled Reactor System. Volume IV. Operation and Maintenance Procedures. 2

(Alco Products, Inc. Schenectady, N. Y.)
May 15, 1962. Contract AT(11-1)-666. 65 p.

The design, characteristics, shipping and installation procedures, operation procedures, scram and casualty conditions, leak detection, maintenance, water chemistry recommendations, and sodium purity control recommendations for the intermediate heat exchanger and steam generator for 30-Mw sodium cooler reactor systems are described and discussed. (N.W.R.)

(ASD-TR-61-594) Literature Survey on Liquid Metal Boiling Final Report - Phase I. 3

Balzhiser, Richard E., Clark, John A., Colver, C. Phillip, Hucke, Edward E., Merte, Herman Jr., Smith, Lowell R., and Teller, Andrew S.
(Michigan University, Ann Arbor, College of Engineering) December 1961. Contract AF 33(616)-8277. 157 p. (AD-270481)

A survey was made of information pertaining to the current status of liquid-metal-boiling technology. Material pertaining to boiling and two-phase flow phenomena are also included, and existing correlations for predicting heat transfer coefficients in the nucleate- and film-boiling regimes are summarized. Correlations which predict the critical heat flux (or burnout flux) are presented and compared with experimental data available. The use of liquid metals as fluids in space-oriented Rankin cycles is considered, and interfacial considerations of possible importance are cited and discussed. Particular attention is called to the solid-liquid interfacial energy and its importance in limiting heat transfer across the interface. A summary of physical properties for various liquid metals and water is presented along with 1191 references to books, reports, journals, and theses published from approximately 1930 to 1961. (P.C.H.)

Heat Transfer in Sodium-Potassium Alloy 4

Baker, R. A. and Sesonske, Alexander
(Purdue University, Lafayette, Indiana.)
Nuclear Sci. and Eng., 13; 283-8 (July 1962)

To provide heat transfer data of high precision for NaK heat exchange systems, a NaK heat transfer loop was designed to minimize experimental errors and yield results with a high degree of reproducibility. Average heat transfer coefficients were determined for both tube and annulus in a horizontal, concentric-tube, NaK (56% K)-to-NaK exchanger. The results after correction for entrance effects were described by the following empirical relations: $N_{Nu} = 6.05 + 0.0074\ N_{Pe}^{0.95}$ (tube); and $N_{Nu} = 0.80\ (d_2/d_1)^{0.3}\ [5.12 + 0.0296\ N_{Pe}^{0.785}]$ (annulus), where N_{Pe} was the Peclet number and d_1 and d_2 were the inner and outer diameters of the annulus respectively. No distinction was found between the Nusselt moduli (N_{Nu}) measured at uniform heat flux and those measured at variable heat flux. No change in the experimental Nusselt moduli was observed when the oxide content was varied between 0.0025 and 0.006 wt % oxygen. (auth)

(DMIC-169) The Effect of Molten Alkali Metals on Containment Metals and Alloys at High Temperatures. 5

Amateau, M. F.
(Battelle Memorial Inst., Defense Metals Information Center, Columbus, Ohio). May 28, 1962. Contract AF 33(616)-7747. 54 p.

A review is given on the corrosive effects of molten alkali metals on high temperature materials, and conclusions are drawn from existing data. Most of the high-temperature engineering metals such as refractory metals, nickel-base and cobalt-base superalloys, and the austenitic and ferritic stainless steels are sufficiently resistant to liquid sodium and NaK to be useful up to about 1600°F. The refractory metals and alloys are particularly susceptible to attack by sodium containing excessive amounts of oxygen. No material is truly corrosion resistant to Li, although the refractory metals Ta, Nb, and Mo do have some potential for high-temperature service in engineering applications. The nitrogen content of the Li is a particularly important factor in its corrosive effects. K, Rb, and Cs are somewhat less corrosive than the other alkali metals. The refractory metals and alloys are little affected by these liquid metals. Na and K can cause degradation of mechanical properties of containment materials, depending on the amount of oxygen and nitrogen found in the respective liquid metals. Also, the sliding and bearing properties of metals are generally affected adversely by the presence of pure molten metals. (P.C.H.)

(AGN-8051) Rubidium Corrosion Capsule Program. Quarterly Technical Report, November 1, 1961 - January 1962. Report No. 4 6

Arabian, Robert B.
(Aerojet-General Nucleonics, San Ramon, Calif.) Contract AT(04-3)-368. 9 p.

Tests are being carried out to obtain corrosion and sooubility data on various containment materials for rubidium at temperatures from 1000 to 2000 F. Progress is reported on corrosion and solubility test runs, test analysis, and analytical procedures. (M.C.G.)

(NP-11952) An Investigation of the Corrosion Resistance of Metallic Materials to Molten Lithium Hydride at Cyclic Elevated Temperatures. 7

Vargo, E. J. and Cooper, D. B.
(TAPCO, Div. of Thompson Ramo Wooldridge Inc., Cleveland.) Feb. 14, 1962. Contract NAS 5-462. 158 p. (ER 4774)

The corrosive effects of LiH, Li, and mixtures of LiH and Li on various structural metals were investigated. The materials included Fe, Ni, Co, and refractory base alloys as well as unalloyed Mo and Ti in the form of tubing. The tests were conducted in air, argon, and hydrogen atmospheres for periods up to 3008 hr and were either conducted at static temperatures of 1500 to 1600°F or were cycled between 1165 and 1600°F. Based on single metal capsule results, the materials were classified into three groups dependent on the depth of corrosive attack as indicated by metallographic examination. AISI 1010 and Mo (containing no more than 0.005% C) were indicated to be superior to the other materials. It was indicated that the other materials would suffer a corrosive attack which would penetrate to a depth of more than 5 mils in 10,000 hr. The presence of two or more dissimilar metals in a capsule in some cases caused increased corrosion activity. It was revealed that the problem of containing hydrogen and thus halting the dissociation of LiH, $2\ LiH \rightarrow 2\ Li + H_2$ would be formidable. Various hydrogen barrier coatings were tested, but only glass and aluminum oxide proved to have any merit. (P.C.H.)

(FTD-TR-61-31, p. 41-59) Strength of Alloys in Contact with Sodium 8

Kishkin, S. T. and Benediktova, G. P. (Translation)

The mechanical strength of a number of alloys operating in contact with sodium at high temperatures was investigated. Short-term and long-term tests were carried out with hollow, sodium-filled steel specimens. Results of short term tests at 1000°C showed that sodium-filled samples yield a negligible increase in ultimate strength and a decrease in the plasticity of the alloys. According to long-term test data the limit of long-time strength of the alloys remained the same or increased. (M.C.G.)

(NP-11671) Engineering Properties of Potassium. Quarterly Report No. 6, January 1 through March, 1962. 9

Lemmon, Alexis W., Jr.
(Battelle Memorial Inst., Columbus, Ohio)
April 30, 1962. Contract NAS 5-584. 18 p.

The thermodynamic and transport properties of potassium are being determined at 900 to 2100°F. Measurements are being made on the viscosity of the liquid and the vapor pressure. Modifications of the apparatus for purification of potassium by distillation, gettering of the charge, and performing the fifth distillation at pressures as low as 5×10^{-4} mm Hg resulted in oxygen contaminations as low as 35 ppm. Vapor pressure data were found to compare closely with those previously reported. The Nb-1 Zr alloy capsules for the specific heat measurements were completed, filled with potassium, sealed and radiographed. Assembly of the vapor viscometer was continued. Fabrication and assembly of the P-V-T apparatus was also continued. (M.C.G.)

(BNL-728) Proceedings of the Eleventh Annual AEC Corrosion Symposium, May 23-25, 1962. 10

Weeks, John R., ed.
(Brookhaven National Lab., Upton, N. Y.)
Contract AT(30-2)-Gen-16. 69 p.

Thirty-two papers were presented at the Eleventh Annual AEC Corrosion Symposium. Abstracts are given of the unclassified papers. Classified papers are listed by title only, or, when possible, by an unclassified summary. Three abstracts of papers received but not presented are included. Topics covered include: liquid metals, zirconium and radiation effects, general corrosion, stress corrosion cracking, steel corrosion, and high-temperature corrosion. (M.C.G.)

Improvements in or Relating to Electromagnetic Flowmeters 11

Thorpe, Percy Eric
(To United Kingdom Atomic Energy Authority)
British Patent 899,095. June 20, 1962.

An electromagnetic flowmeter is designed for operation under high temperature and pressure conditions. The flowmeter comprises a body member defining a bore and an electrically insulating sleeve loosely lining part of the bore. The sleeve is designed so that fluid may penetrate between the sleeve and body to balance the pressure across the sleeve. Two diametrically opposed electrodes are arranged to contact the fluid to measure the induced emf. (D.L.C.)

Construction and Operation of a Sodium Circulation [System] 12

Lutz, Otto and Rex, Dietrich
(Technische Hochschule, Braunschweig, Ger.)
VDI Zeitschrift, 104:581-7 (1962) (In German)

A test plant was built which made it possible to circulate liquid sodium in a closed circuit and to study the behavior of conduction elements which occur in sodium-cooled reactors. The development of the sodium circulation system required special consideration and constructive solutions regarding heat transfer, the sealing of the plant, an oxide-free circulation, fire prevention, electric control, charging with sodium, and startup of the plant. Sodium fire fighting methods are described. (auth)

Nitridation of Lithium 13

McFarlane, E. F. and Tompkins, F. C.
(Imperial Coll., London) Trans. Faraday Soc. 58:99701007 (May 1962)

The kinetics of nitridation of lithium, both in the solid and in the molten state, were investigated in the temperature range 0 to 365°C and at pressures from 10 to 50 cm Hg. With the solid, the rate initially increased with extent of nitridation, an observation that is consistent with hemispherical growth of nitride into the metal; after a critical thickness was attained, however, the growth rate was constant. In this latter stage, the activation energy was negligibly small but the rate was dependent on pressure, suggesting that the rate-controlling process was the rate of passage of nitrogen through the porous nitride layer to the reactant Li/Li_3N interface by both streamline and Knudson flow. There was considerable lack of reproducibility caused by physical changes in the porous layer, these thereby affecting the rate of inward diffusion of nitrogen. With molten lithium, the parabolic law was obeyed, the rate being independent of pressure and associated with an activation energy of 15.5 kcal/mole. The rate-determining process is probably the passage of lithium ions from the Li/Li_3N interface under a chemical potential gradient through a uniform lithium nitride layer. (auth)

Heterotripolyhalides of Closely-Related Alkali Metals and Their Significance in the Preparation of Pure Cesium and Rubidium Compounds. 14

Plyushchev, V. E., Stepina, S. B., Stepin, B. D. and Lepeshkova, L. I.
(Moscow Univ.) Doklady Akad. Nauk S.S.S.R., 143:1364-7 (April 21, 1962). (In Russian)

The relative polarization or deformability of K = 0.87, Rb = 1.87, and Cs = 2.79. Thus, the trihalides can be used to effect separations between K, Rb, and Cs, even though the ionic

radii of these alkali elements are almost equal. The compounds of a series containing iodine such as CsI_3, $CsBrI_2$, CsClBrI, and $CsCl_2I$ are generally more stable than those of the series containing bromine such as $CsBr_3$, $CsClBr_2$, and $CsCl_2Br$. The Cs compounds are more stable than the K or Rb compounds. Thus, the Rb(IClBr) compound is used to purify Rb from K. The content of K in a RbCl salt containing 2 to 3% potassium was reduced to 0.0002% K by this method. Precipitation of $CsBrI_2$ from an aqueous alcoholic solution was similarly used to reduce the Rb content of the initial salt from 5.0% to 0.02% Rb. The process is simple and selective.

Solid Solutions of Sodium and Potassium Hydrides in the Hydroxide 15

Mikneeva, V. I. and Shkrabkina, M. M.
(Kurnakov Inst. of General and Inorgania Chemistry, Academy of Sciences, USSR)
Doklady Akad. Nauk. S.S.S.R., 143: 1362-3. April 21, 1962. In Russian.

Thermal analysis and X-ray analysis were used to investigate the phase diagram for NaH-NaOH mixtures at elevated temperatures. The initial materials were prepared by directly hydriding sodium and potassium metals, and by dehydrating NaOH and KOH at 500°C. It was found that the NaH-NaOH system holds about 60% NaH, and that the KH-KOH system holds about 48% KH. There is rapid thermal decomposition at higher hydride contents. Solid solutions containing a lower hydride content are stable at 600 to 650°C. The hydride does not react with the hydroxide up to 600°C, but breaks down by thermal decomposition with the evolution of H_2: $2MeH = 2Me + H_2$. The hydroxide stabilizes the decomposition of the hydride. For example, a solution containing 18.5% NaH retained 12.4% NaH after heating to 530°C, and a solution containing 20% KH had 17% KH left. The pure hydrides decomposed at 421 and 428°C, respectively. Thus, a solution of the hydride in the hydroxide can be used as a reductant for refractory compounds. (TTT)

(AEC-TR-4457, p. 294-8) Preparation of Metallic Cesium from Cesium Fluoride 16

Zhuravlev, N. N.
Translated from Zhur. Neorg, Khim., 3:2210-11 (1958)

Results of a study are presented concerning reduction of CsF to pure metal in vacuo at high temperatures. (J.R.D.)

(NAA-SR-6986) A Device for Continuous Detection of Hydrogen in Sodium 17

Strahl, H.
(Atomics International. Div. of North American Aviation, Inc., Canoga Park, Calif.
May 31, 1962. Contract AT-11-1-GEN-8. 26 p.

A device to detect the presence of H in Na was developed. As little as 1 ppm H (based on flowing Na inventory) can be detected in a flowing Na stream at 500 to 1200°F with response times in the order of 5 seconds. Such a device, installed in a Na-heated steam generator, would signal the presence of water in the Na resulting from a leak in the Na-water carrier.

Advances in Chemical Engineering. Volume II. 18
Drew, Thomas B. and Hoopes, John W. Jr., eds.
New York, Academic Press Inc., 1958. 342 p.

Summaries are presented of recent work in chemical engineering. Topics covered include boiling of liquids, automatic process control, treatment and disposal of wastes in nuclear chemical technology, high vacuum technology, separation by adsorption methods, and mixing of solids. Separate abstracts were prepared for 4 of the 6 papers. (M.C.G.)

The Chemists' Contribution to Nuclear Energy 19
Paulsen, F. R.
Nuclear Energy, 243-6 (June 1962)

The role of chemistry in the development of nuclear energy is discussed. Chemical studies described include: preparation of heavy water, removal of sodium oxide from liquid sodium, production of high-purity alkali metals, evaluation of zirconium behavior in contact with other materials, niobium extraction, chemical separation of radioactive materials, waste disposal, and fuel processing.

(ANL-6477, p. 29-105) Chemical-Metallurgical Processing 20
Steunenberg, R. K., Burris, L. Jr., at al.
(Argonne National Lab. Illinois.)

Pyrometallurgical development is reported on melt refining, processes utilizing liquid metal solvents, supporting chemical investigations, and supporting engineering studies in liquid metal systems. The design and construction of fuel processing facilities for EBR-II are described. Research progress is reported on solubilities in liquid metals, coprecipation studies, liquid-liquid metal distribution studies, and thermodynamic studies.

The Effect of Molten Alkali Metals on Containment Metals and Alloys at High Temperatures 21
Amateau, M. F.
Defense Metals Information Center, Battelle Memorial Institute, DMIC Report 169, May 28, 1962. 54 p.

Extensive review of literature on the effects of Na and NaK alloys, liquid Li and liquid and gaseous K, Rb and Cs on the corrosion, and sliding and bearing properties of pure metals and alloys including stainless steel, superalloys and refractory metals. Topics include types of liquid-metal corrosion, factors affecting liquid-metal corrosion and techniques for investigating such. 71 ref. (R6m, 2-62; SGA-h, SS, EG-d37)

(AD-275 147) Investigation of Liquid Metal Boiling Heat Transfer. Quarterly Progress Report, No. 2 on Phase 2. 22

Balzhiser, Richard E., Barry, Robert E. and others
Michigan U. Coll. of Engineering, Ann Arbor, Michigan. April 1962, 16 p., illus.
Report No. 04526-4-P. Contract AF 33(616)8277.
Unclassified.

Experimental equipment specifications are being completed for the study of quality and flow rate effects on heat transfer coefficient of boiled K in a forced circulation loop. Pressure drop and void fraction measurements will be made in a second test section to study 2 phase flow behavior with metallic fluids. A pool boiler will be used to study pressure effects and to increase the temperature and flux levels beyond the 1800 F and 10 to the 6th power Btu/hr-sq ft anticipated in the loop. Film boiling of K will be studied using condensing Na or La as a heat source. A Nb vessel will be used thus making it possible to increase the range of surface temperatures. Initial agravic experiments will utilize Hg pool boiling from a stainless surface with normal accelerations up to 20 g's. (Author)

(AD-282 370) Investigation of Liquid Metal Boiling Heat Transfer. Quarterly Progress Report No. 3 on Phase 2A 23

Balzhiser, Richard E., Colver, C. Philip, and others. July 1962.
Michigan U. Coll. of Engineering, Ann Arbor

Potassium will be boiled from the outside of a 3/8 in. OD Haynes-25 tube at temperatures up to 2000 F and heat fluxes of 10 to the 6th power Btu/hr sq ft. This study is intended to obtain experimental data for the nucleate boiling of potassium at fluxes near the critical. The effect of pressure on the critical flux will be investigated. Film boiling studies employing potassium as the test fluid and sodium as the heating fluid will be conducted. Boiling will occur from a 0.200 in. Nb-1% Zr disk in a 1 in. Nb-1% Zr tube. A forced circulation liquid metal loop will circulate potassium at liquid flow rates up to 2 gpm. The maximum fluid temperature in the loop will be 1800 F. Potassium will be preheated to various qualities using clamshell heaters. Condensing sodium is used to boil the potassium in the test section. Fluxes of up to 10 to the 6th power Btu/hr sq ft are anticipated. Two phase flow

studies will be conducted as a part of the forced circulation investigation. Pressure drop and void fraction measurements will be made for different qualities and flow rates. Loop instrumentation will be used in conjunction with the pool boiling studies. Agravic studies with mercury are scheduled. Studies will be from 1 - 20 g's with the liquid level varied to insure uniform pressures at liquid-vapor and liquid-solid interfaces. (Author)

(N62-15836) Studies of Liquid Sodium by Inelastic Scattering of Slow Neutrons 24

Cocking, S. J. (A,E,R.E., Harwell, Gt. Britain)
1962. International Atomic Energy Agency, Vienna (Austria)

A study is made of the near elastic peak to provide data on diffusive motion in the liquid state. The use of slow neutrons (wavelengths 4.0Å and 4.5Å) permits studying the region of small momentum transfer; in this region the coherent effects can be, to some extent, separated from the near elastic peak. Spectra of neutrons scattered by the solid and liquid states of sodium have been compared. In the spectra at energy transfers greater than $\sim$4 mev, incoherent scattering dominates. For the solid, this region of the spectrum may be calculated within the present experimental error using the frequency distribution given by Bhatia. The corresponding spectrum for the liquid is similar to that for the solid, suggesting that the frequency distribution of motions of the atoms in the two phases are similar to that for times less than $\sim 1.5 \times 10^{-13}$ seconds. The experimental quasi-elastic peaks have been compared with predictions of the theory of Egelstaff and Schoffield and values for the interaction time at three temperatures have been derived. The interaction time increased with increasing temperatures, suggesting the dominance of free diffusion in the liquid. At the highest scatter angles, where coherent effects appear in the quasi-elastic scattering, a test of Vineyard convolution approximation is made. It is shown that the approximation gives agreement with the observed data when the coherent effects appear at small energy transfers.

(N62-15816, NASA, Ames Research Center, Moffett Field, Calif.) 25
Flow in Direct-Current Electromagnetic Pumps

Rossow, Vernon J.
In National Research Council. Magneto-Fluid Dynamics. Proc. of a Symposium sponsored by IUTAM/NAS-NRC, Williamsburg, Va. and Wash. D.C., Jan. 1960. Repr. from Rev. of Modern Phys., v. 32, no. 4, Oct. 1960. p. 987-991. 2 refs. (See N62-15768 15-21)

A simple model has been devised that permits one to investigate how the departure of the electric and magnetic fields from their one-dimensional character affects the flow of an electrically

conducting fluid. The effect of the ends of the electric and magnetic fields on the flow is studied theoretically and experimentally by means of the direct-current electromagnetic pump. The pump impresses an electric and a magnetic field across the channel to produce a body force on the fluid in a direction along the channel. In order to realize a simple configuration for the experiment, the electrodes are assumed to be at constant potential and to have a length equal to the channel width. A copper sulfate salt solution is used as the working fluid that flows through a clear plastic channel under the action of the electric and magnetic fields. The flow velocity ranges from 1 to 4 in./sec under the influence of a 0.4- to 1.6-amp current and a 4000-gauss magnetic field. Since the induced fields are each about 10^{-3} times smaller than the imposed fields, the analysis is greatly simplified because the effect of the field motions on the imposed electromagnetic fields is negligible. Classical methods can then be used to find the electric-current distribution in the flow field. These results, taken together with the corresponding results for the magnetic field, permit the direct calculation of the body forces in the fluid. Results demonstrated that the finite length of the electromagnetic fields can cause sizable deviations from one-dimensional flow. It is possible, however, to correct for these end effects by either shaping the magnetic field or varying its intensity to fit the electric field, or by combinations of both techniques. (V.D.S.)

(N62-1577, Lawrence Radiation Lab., U. of Calif. Livermore) 26
Hydromagnetic Equilibrium Experiments with Liquid and Solid Sodium

Colgate, S. A., Furth, H. P., and Halliday, F. O.
In National Research Council, Magneto-Fluid Dynamics. Proc. of a Symposium sponsored by IUTAM/NAS-NRC, Williamsburg, Va. and Washington, D. C., Jan. 1960. Repr. from Rev. Modern Phys., v. 32, no. 4, Oct. 1960. p. 744-47. 7 refs. (See N62-15768 15-21. (Sponsored by AEC)

In a homogeneous field varying in time, the magnetic moment of the particle is constant in the first approximation. Expression for the variation of the moment and for the shift of the center of motion in higher approximations are derived. In a constant inhomogeneous field, the secular drift in the constant moment approximation has been given by Alfven and Spitzer. For a few simple field configurations, higher approximations for the drift have been derived.

(ANL-6548) Studies of Metal-Water Reactions at High Temperatures III. Experimental and Theoretical Studies of the Zirconium-Water Reaction. 27

Baker, Louis Jr. and Just, Louis C.
(Argonne National Lab., Illinois.) May 1962.
Contract W-31-109-eng-38. 86 p.

Further studies of the Zr-water reaction by the condenser-discharge method are reported. The reaction was studied with initial metal temperatures from 1100 to 4000°C with 30- and 60-mil wires in water from room temperature to 315°C (1500 psi vapor pressure). Runs in heated water showed markedly greater reactions. This was explained in terms of a 2-step reaction scheme in which the reaction rate is initially controlled by the rate of gaseous diffusion of water vapor toward the hot metal particles and of hydrogen, generated by reaction, away from the particles. At a later time, the reaction becomes controlled by the parabolic rate law, resulting in rapid cooling of the particles. A mathematical model of the reaction of molten metal spheres with water was proposed. Explosive reactions were found to occur with particles smaller than about 1 mm in heated water and 0.5 mm in room-temperature water. The explosive reactions were caused by the ability of the evolving H_2 to propel the particles through water at high speed. The high-speed motion was detected on motion picture film and had the effect of removing the gaseous diffusion barrier (increasing the Nusselt number), resulting in very rapid reaction. Computed results compared favorably with experimental results obtained by the condenser-discharge experiment and with the results of previous investigators. Computations indicated that the extent and rate of reaction depended on the particle diameter and the water temperature, and were relatively independent of the metal temperature so long as the metal was fully melted. This makes it possible to estimate the extent of Zr-water reaction that would occur during a reactor accident in which the particle sizes of the residue could be estimated. Comparisons were made with the results of meltdown experiments in TREAT, and applications to reactor hazards analysis were discussed.

Improvements in or Relating to Electromagnetic Liquid Metal Pumping Systems 27

Blake, Leslie Reginald
(To United Kingdom Atomic Energy Authority)
British Patent 905,940. Sept. 12, 1962

An electromagnetic pump for liquid metals is designed which is of the type comprising primary and secondary ducts in an air gap in a magnetic circuit. When liquid metal is pumped through the primary duct, an emf is generated to provide an electromagnetic pumping action in the secondary duct. The ducts are longitudinally shaped to increase in width and decrease in thickness going away from the center of the magnetic circuit, in order to minimize efficiency losses due to by-pass current. (D.L.C.)

(NAA-SR-7325) Sodium Condensing Heat Transfer. An Experimental Study of One Aspect of Sodium Cooled Reactor Safety. 28

Reed, G. L., and Noyes, R. C.
(Atomics International, Div. of North American Aviation Inc., Canoga Park, Calif.) Dec. 15, 1961. Contract AT(11-1)-Gen-8. 55 p.

A problem of emergency heat removal in Na-cooled reactors is concerned with the condensing of Na vapors that might be generated as a result of a hypothetical loss-of-heat-sink accident. An evaluation, in which the Na vapor condensing in the restricted region below the loading face shield of the Hallam Nuclear Power Facility was made, to determine heat removal capability. Experimental determinations of condensing heat transfer rates in a model of this region were made. The primary resistance to heat transfer was found to be noncondensable gases present in the system. The gas(usually He) would be present because of its normal use as a cover gas in the core tank. A theoretical equation based on gaseous diffusion was derived, and the heat transfer rate is predictable provided the quantity of noncondensable gas is known. Further experiments were used to study the venting behavior of the gas space below the HNPF loading face shield during simulated accident conditions. These experiments provide information required to predict the quantity of noncondensable gas left in the system after a postulated accident and to predict associated heat transfer rates. Two venting methods were studied to determine the most efficient emergency venting procedure. It was found that if the region immediately below the top shield is vented, sufficient heat removal capability exists to condense all Na vapor that could be generated by afterglow heat. This would assure safety of the systen by eliminating the possiblity of any pressure buildup as a result of the postulated accident. (auth)

On the Load Capacity of the Hydromagnetically Lubricated Slider Bearing 29

Osterle, J. F. and Young, F. J.
(Carnegie Inst. of Tech., Pittsburgh)
Wear, 5: 227-34 (May-June 1962). In English.

The load capacity of liquid metal lubricated slider bearings subject to an applied magnetic field transverse to the film is investigated. The optimum profile is determined and found to be the Rayleigh step form with the riser location and step height ratio dependent on the strength of the magnetic field. Load capacity is favored by large magnetic fields, small film thicknesses, and electrically insulating bearing surfaces. Only modest load increases can be obtained from conventional magnets of reasonable size. Substantial load increases could be accomplished by the recently developed superconducting electromagnets. (auth)

Magnetohydrodynamic Journal Bearing 30

Hughes, W. F. and Elco, R. A.
(Carnegie Inst. of Tech., Pittsburgh)
ARS (Am. Rocket Soc.) J., 32:776-8 (May 1962)

An analysis is presented for a magnetohydrodynamic pressurized journal bearing using a liquid metal lubricant. An

external magnetic field is applied axially along the journal, and current is allowed to flow between the journal and bearing. It is found that significant increases in load carrying capacity can be achieved by supplying power from an external source. Open circuit conditions give no additional pressurization, and short circuit conditions result in a pressure decrease. (auth)

Magnetohydrodynamic Pressurization of Liquid Metal Bearings 31

Elco, R. A. and Hughes, W. F.
(Carnegie Inst. of Tech., Pittsburgh)
Wear, 5: 198-212 (May-June 1962) In English

The concept of the magnetohydrodynamic bearing is introduced and two types of bearings are analyzed. First a hydrostatic thrust bearing with an axial current-induced pinch is considered. It is shown that the load capacity can be increased and with no flow or external pressurization a load can be sustained because of the "pinch" effect. However, the magnitude of this pressurization is very small for physically practical values of current. The second bearing considered is the infinite inclined slider with an applied magnetic field parallel to the bearing surface and perpendicular to the direction of motion of the slider. For this type of bearing the pressure distribution, load capacity, and electrical characteristics are calculated and it is shown that useful electromagnetic pressurization can be obtained with reasonable values of magnetic field strength and current. (auth)

(KAPL-M-LRM-2) Static Sodium Corrosion Tests of Ceramic Materials 32

McCreight, L. R.
(Knolls Atomic Power Lab., Schenectady, N. Y.)
July 6, 1951. Contract W-31-109-Eng-52. 5 p.

Static corrosion tests using aged and filtered sodium were run on 68 different specimens of non-metallic material. All specimens were tested at 500°C for one month, then thirteen were selected for retesting at 750°C for another month. No definite correlation of corrosion rate and chemical composition between similar compositions was found. Data are tabulated. (P.C.H.)

(AGC-0584-04-2) Mercury Corrosion Loop Testing Program. Quarterly Report, January 1 through March 31, 1962. 33

(Aerojet-General Corp., Azusa, Calif.)
April 27, 1962. Contract NAS 3-1925. 34 p.

The Mercury Corrosion Loop Testing Program was continued. Materials to be tested in the 10 forced-convection test loops were selected; the materials are: Haynes 25, 9 Cr-1 Mo alloy clad with Type 316 stainless steel, AM 350 stainless steel, and 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. (auth)

(AGC-0584-04-3) Mercury Corrosion Loop Testing Program. Third Quarterly Report, April 1 - June 30, 1962. 34

(Aerojet-General Corp. Power/Equipment Div., Azusa, Calif.) August 6, 1962. Contract NAS 3-1925. 26 p.

The fabrication and testing in the Dynamic Mercury Corrosion Loop Testing Program are reported. Operation of the first ten loops to be tested was begun, and a second loop was fabricated. Four of the test loops will be fabricated from Haynes 25 alloys while the remaining six will be fabricated from 316 stainless steel - clad (or unclad) Cr-Mo alloys or 316 stainless steel-clad Nb. (J.R.D.)

The Liquid Metal Jet System 35

Inall, E. K.

(Australian National Univ., Canberra) Atomic Energy 5, No. 3: 6-8 (July 1962)

The handling and decontamination of the NaK alloy used as liquid-metal slip-rings (brushes in the Canberra homopolar pulse generator) is described. The alloy is sprayed through jets into the faces of the generator rotors. The conditions of use of the alloy (about room temperature, velocities in the jets around 20 m/sec, peak current densities over 40 ka/cm^2, etc.) are outlined. (T.F.H.)

(AEC-TR-5310) Preliminary Design for a Test-Component Loop with Liquid Sodium at Elevated Temperature 36

Colombo, P.

(Italy, Comitato Nazionale per l'Energie Nucleare. Laboratorio Ingegneria e Servomeccanismi Reattori, Ispra.) Translated for Oak Ridge National Lab., Tenn. 1962. 12 p.

The liquid sodium loop and its principal components are described. The loop will permit operating experience to be acquired on liquid metal systems, particularly with regard to their manipulation and control of oxide content, and will furnish principles for the evaluation of the behavior of the components and the instrumentation. The loop (with a maximum temperature of 770°C) essentially consists of a hot section supplied by a 50 kw resistance heater and a cold section in which the heat supplied by the heater in the loop

contains two dismountable test sections for evaluating components in liquid sodium. The system will be connected to a sodium melting furnace and will be equipped with an auxiliary inert gas system (argon or helium). (N.W.R.)

Friction and Wear Behavior of Possible Bearing Materials in High Purity Liquid Sodium at Temperatures up to 500°C 37

Roberts, W. H.
(United Kingdom Atomic Energy Authority, Risley, Lancs., Eng.) Preprint Paper No. 3. London, The Institution of Mechanical Engineers, 1962. 10 p.

A crossed-cylinder apparatus is described which enables basic friction and wear data for materials immersed in liquid metals to be obtained. Results are presented for a selection of chromium alloys rubbed under boundary lubrication conditions in high-purity sodium in the temperature range 200 to 500°C. The behavior of these combinations is compared with that in gases (carbon dioxide and helium), under corresponding conditions of load, rubbing speed, and temperature. Friction coefficients and wear rates were generally lower in sodium, implying that the liquid metal provides a measure of lubrication between the rubbing surfaces. A striking feature of the results in sodium is the manner in which wear rate increased fairly regularly with increasing temperature for all the rubbing combinations examined. This behavior is in complete contrast to that in carbon dioxide and helium, where the wear-temperature curves varied markedly for different combinations. Experiments are described which were aimed at establishing that hydrodynamic lubrication did not materially contribute to the observed effects in sodium. (Author)

(AD-284 340) High Temperature Properties of Sodium and Potassium, Progress Report No. 7, April 1 - June 30, 1962 38

Ewing, C. T., Stone, J. P., and others.
(Naval Research Lab., Washington, D. C.) August 27, 1962. 6 p., incl. tables. 4 refs. (NRL Report No. 5844)

An experimental program is underway to measure several thermophysical properties of sodium, potassium and their vapors, at elevated temperatures. The status of each property test is discussed, and preliminary values are reported for the density of liquid potassium from 1564 to 2282 F and for the equilibrium solubility of columbium and zirconium in liquid sodium from 1470 to 2507 F. (Author)

Reaction of Construction Materials with Liquid Metals 39

Nikitin, V. I.

Teploenergetike, No. 2, 90-2 (1962) In Russian.

The utilization of liquid metals (sodium, potassium and their alloys, bismuth, and lead) as reactor coolants was analyzed, and the mechanism of their reaction with construction materials was studied. The properties of coolants and construction materials, the temperatures and temperature gradients in the system, the rate of flow, and the presence of admixtures are discussed. The corrosion factors for bismuth and lead depend on their affinity to simple diffusion while for sodium and potassium, corrosion depends mostly on the amount of oxygen present. A table is included of maximum permissible temperatures for various construction materials, showing not more than 0.012 mm corrosion after 1000 hr, in molten sodium and lithium. (R.V.J.)

Liquid Metal Heat Transfer in Nuclear Power Reactors 40

Friedland, Aaron J.

(Atomic Power Development Associates, Inc. Detroit) Preprint Paper No. 90. New York, Engineers Joint Council, 1962, 26 p.

The status of liquid metal heat transfer studies is briefly reviewed. The sodium cooled Enrico Fermi Fast Breeder Reactor is described, with emphasis on the aspects of design and operation relating to heat transfer. (46 references) (auth)

Design, Production and Testing of Nuclear Valves for Liquid Coolant Reactors 41

Valen, A. K.

(Valen Engineering Ltd., Montreal) Preprint. Ottawa, Canadian Nuclear Association, 1962. 26 p.

The extremely stringent requirements for leaktightness and material behavior of valves to be used in the primary coolant system of a nuclear power plant are summarized. Tables of recommended types of materials are given. Special design features, fabricating methods, and testing procedures are discussed. (A.G.W.)

Dynamic Shaft Seals in Space. First Quarterly Report for Period ending July 15, 1962 42

General Electric Co., Spacecraft Dept., Cincinnati. Contract AF 33(657)-8459. 80 p.

The development of dynamic shaft seals for space applications is considered. The seals considered must operate on high speed rotating shafts under conditions of high temperature liquid

metals and vapors, and near-vacuum environments of space. The 20,000 rpm water seal teat rig was designed and analytical investigation of screw seals started. Design layouts were completed on various configurations of the stationary housing-rotating disk and the squeeze seal. The design of the high speed test rig to be used for liquid metal (potassium) testing and its auxiliaries required for liquid operation is described. Water pretesting of rotating fluid ring seals is evaluated. (N.W.R.)

(BM-IC-8053) Lithium. A Materials Survey 43

Schreck, Albert E.
(Bureau of Mines, Washington, D.C.)
September 1960. 81 p.

Data on the use, technology, statistics, and history of lithium are presented for the period from its discovery up to December 1959. Information is also presented on resources, material forms, properties, supply and distribution, structure of the industry, research and development, legislation and government, and strategic factors. (N.W.R.)

(NAA-SR-Memo-6798) A Modular, Low-Cost, Sodium-Heated Steam Generator 44

(Atomics International. Div. of North American Aviation, Inc., Canoga Park, Calif.) Oct. 23, 1961. Contract AT(11-1)-Gen-8. 16 p.

A proposed design and development program for a potentially economical, high-performance, sodium-heated steam generator is described. The concept employs modular units grouped together to provide for any combined power level desired. Fabrication expense is shown to be reduced by the reduction in heat transfer area requirements. This reduction is achieved through improved heat transfer coefficients which exist under supercritical steam conditions. The testing of two small units ($\sim$18 Mw total) is shown to be sufficient to verify performance for any size unit because of the modular concept employed. (auth)

Determination of Rubidium and Cesium by Flame Photometry 45

Rezáč, Zdeněk and Dvořák, Josef.
Acta Chim. Akad. Sci. Hung., 30: 375-84 (1962).
In German.

A quantitative method for the determination of rubidium and cesium by flame photometry suited for the analysis of various substances is presented. On previously destructing and preparing the sample to be analyzed, the intensity of the light emission of both elements is established by a spectrometer of the Hilger Uvispek type, equipped with an adapter for flame photometry. The evolved method

makes possible the determination of quantities of rubidium from 5 to 200 ppm and those of cesium from 10 to 200 ppm. Also the effects of alien elements and the adequate flame temperatures are discussed.

(CEA-2173) Etude d'un Echangeur NaK-Eau en Regimes Permanents et Transitoires. (The Study of a NaK-Water Exchanger in Steady and Transient States). 46

List, D. and Schwab, B.
(France. Commissariat a l'Energie Atomique. Centre d'Etudes Nucleaires, Saclay). 1962. 40 p.

In a study on a NaK-water heat exchanger, the temperature variations, in the transient states, along the metallic wall separating the two fluids were examined. The basic equations (partial differential equations) are established and transformed into a differential equation system for which the various coefficients are calculated. These equations can be set up on an analogic computer for use in exchanger behavior studies. The steady states of the exchanger are studied first and it is then submitted to various types of perturbations. (auth)

Heat Transfer Through Molten Materials 47

Inco Corrosion Reporter, v. 9, no. 2, Oct. 1962, 13 p.

Mechanism of liquid metal corrosion at high temperatures and under pressure in nuclear reactors as a function of solution rate and solubility limit of the solid metal in the liquid. Advantages and limitations of liquid metals as heat transfer media and use of 18-8 stainless steel with Na and NaK and Ni alloy Inor 8 with fluoride salt mixtures. 5 ref.

Impurities in a Liquid Metal Coolant and Their Effect on the Fuel Element Canning Materials Niobium and Vanadium 48

Sinclair, V. M., Pool, R. A. H. and Ross, A. E.
Nuclear Reactor Chemistry (Second Conference, Gatlinburg, Tenn. Oct. 10-12, 1961. No. TID-7622, July 1962. p. 35-56

Review of the properties of H_2, N_2, O_2 and C in the primary coolant (70% Na - 30% K) and effects of these nonmetallic impurities on the Cb and V fuel cans from 200°C to 800°C. 16 ref.

(KAPL-200-19) Reactor Technology Report No. 22 - Chemistry 49

Knolls Atomic Power Lab., Schenectady, N. Y. Sept. 1962. Contract W-31-109-eng-52. 107 p.

Five sections are included for which separate abstracts were prepared. (J.R.D.)