LIQUID METALS TECHNOLOGY
ABSTRACT BULLETIN

September 7, 1956

(For the Period July 1 to August 31, 1956)

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MINE SAFETY APPLIANCES COMPANY
Callery, Pennsylvania

MINE SAFETY APPLIANCES COMPANY

TECHNICAL INFORMATION DIVISION

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Issued by the Technical Information Division of Mine Safety Appliances Company as a service to industry.

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LIQUID METALS TECHNOLOGY ABSTRACT BULLETIN

This is the first issue of a series of abstract bulletins covering current literature on liquid metals, which are being prepared by the Technical Information Division as a service to industry.

The quickening pace of research and development in liquid metals has led to an increasing amount of literature in the field. Mine Safety Appliances Co., as a pioneer in liquid metals technology, feels that other interested companies could benefit from a current and up-to-date abstract bibliography on liquid metals literature.

These bulletins will be issued at approximately monthly 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.

Interested parties may be placed on the mailing list by writing to Mine Safety Appliances Co., Technical Information Officer, Callery, Pa.

Eugene P. Meckly

Eugene P. Meckly
Technical Information Officer

1

Liquid Metals. Part IV. The Wetting of Zinc by Liquid Sodium: The Significance of Critical Wetting Temperature
Addison, C. C. et al
J. Chem. Soc. 1956, 1454-61.

The wetting of metallic zinc by liquid sodium has been studied by measurement of contact angles under ranges of time and temperature. Electropolished zinc surfaces show a critical wetting temperature near 160°, and chemical reaction between sodium and the zinc phosphate film deposited during electropolishing is shown to be responsible for this. No critical wetting temperature is observed for abraded zinc plates. Rates and mechanisms of wetting are discussed from the point of view of diffusion through surface films of zinc phosphate and zinc oxide and the formation of the intermagnetic compound $Zn_{13}Na$. The condition of the surface of zinc after wetting by sodium has been studied microscopically.

2

Alplaus Atmospheric-Pressure Sodium Still
Baldwin, E. E.
U. S. A. E. C. KAPL-337, 29pp. (1950) (Declassified Nov., 1955).

Results of metallographic examination of an 18-8 stainless steel, atmospheric-pressure Na still, operated for a total of 55 days and with about 230 hours at 1600°F., are reported. Two fires occurred at the inlet argon-line connections. A sponge-like plug was found in the portion of the inlet line which projected below the surface of the liquid Na. This was attributed to localized oxygen contamination of the Na and resulting attack of stainless steel. It was also concluded that liquid Na at 1600°F. produces negligible attack on 18-8 stainless steel.

3

Treating Valves for Handling Molten Calcium
Banus, Mario D. (To Metal Hydrides Inc.)
U. S. 2,740,730, April 3, 1956.

Stainless steel valves handling molten Ca tend to freeze together. This freezing can be overcome by heating either the plugs or the seats of the valves in molten Ca at 1000° for 24 hours to diffuse Ca into their surface and then cleaning with HNO_3. Heating at a higher temperature corrodes the valves.

4

An Ion-Sieve Reagent for Cesium-Alkali-Metal Separations
Barrer, R. M. and D. C. Sammon
J. Chem. Soc. 1956, 675-82.

The use of Ag analcite as an ion-sieve reagent for separations of Na, K, and Rb from Cs has been studied. The removal of Na and K from mixtures with Cs (all as chlorides) occurred quantitatively, and readily at about 100°, according to the equation MCl + xAgA(s) $\longrightarrow$ AgCl(s) + $MAg_{(x-1)}A_x(s)$ where A denotes the anionic framework of analcite and M is Na or K. In the removal of Na, no Cs entered the Ag analcite and the method is suitable for quantitative analysis. In the C-Cs separation, a phase change occurs involving a minor rearrangement of the Ag analcite to the K analcite (leucite) structure, a little Cs may be incorporated during the process: a correction is thus needed in quantitative analysis, but this method is available for the removal of K^+ from Cs^+. The Rb-Cs separation is more difficult and requires the use of MeOH (or EtOH) as solvent; again a little Cs may be incorporated during the phase change owing to modification of the Ag analcite framework to the Rb analcite one: the method may be useful in certain circumstances for purifications. H^+ exchange was observed when solutions of CsCl, tetramethylammonium bromide, or tetraethylammonium iodide were treated with Ag analcite: H_2O + MX + xAgA(s) $\longrightarrow$ AgX(s) + $HAg_{(x-1)}A_x(s)$ + MOH. By using the iodide this exchange was followed up to 60% completion. It can only proceed when the crystal acts as a sieve or semi-permeable membrane towards the cations in solution and when the ion displaced is proportioned as an insoluble compound.

5
Cohesive Energy of Potassium
Berman, Sam et al
Phys. Rev. 101, 1467-8 (1956).

The cellular method was applied to a calculation of the cohesive energy of metallic K. The crystal potential was taken from a self-consistent field with exchange for the K ion. An approximate exchange interaction between the valence and the core electrons was included. The cohesive energy was 18.5 or 19.3 cal./mole, depending on whether Pines' or Wigner's expression for the correlation energy was used. The effective mass was assumed to be 86% of the free-electron mass. The experimental value was 22.6 cal./mole.

6
Use of Zirconium in Liquid Sodium Systems
Bowman, F. E., and D. D. Cubicciotti
A. I. Ch. E. J. 2, 173-6 (1956).

The attractive nuclear properties of zirconium make it a highly desirable core material for sodium-cooled reactors. The elevated temperature strength, while low, is sufficient for certain applications. Development of higher strength alloys is underway. Sodium in itself is completely compatible with zirconium; however, the nonmetallic contaminants, namely oxygen, hydrogen and nitrogen, can effect serious damage. The primary problem in the use of zirconium in a sodium system, then, lies in controlling these impurities in the sodium.

7
Purity Control in Sodium Cooled Reactor Systems
Bruggeman, Warren H.
A. I. Ch. E. J. 2, 153-6 (1956)

Recent advances in purity control in sodium systems are covered. Emphasis is placed on results from the prototype S. I. R. system as well as other unpublished data. Included are chemical and nuclear activation analyses of sodium, filtration data, and details and operation of cold traps and plugging indicators.

8
Oxidation Characteristics of the Alkali Metals. I. Oxidation Rate of Sodium Between -79 and 48°C.
Cathcart, J. V., L. L. Hall and G. P. Smith
Oak Ridge National Laboratory Contract W-7405-eng-26, June 14, 1956 ORNL-2054
10p.

The oxidation of sodium was measured at 5 temperatures: -79, -20, 25, 35, and 48°C. The reaction rate in dry O_2 was found to be small, and the oxide films were highly protective. A slight increase in the oxidation rate at 48°C occurred after 25,000 to 30,000 minutes of oxidation. No explanation has been found for this phenomenon.

9
Small Liquid Metal Fuel Reactor Systems
Chernick, Jack
Nuc. Sci. Eng. 1, 135-55 (1956).

The nuclear properties and potentialities of small liquid metal fueled reactors (LMFR) are presented. Plutonium is discussed as an alternate fuel to uranium isotopes, lead as alternate carrier to bismuth, and beryllium as alternate moderator to graphite. Breeding potentialities of U^{233} and Pu^{239} fueled liquid metal systems are discussed.

It is shown that non-breeder cores can be reduced to about 1 to 4 ft. in diameter, depending on fuel concentration and core and reflector compositions. Internal versus external cooling and internal versus external moderation of the small LMFR are compared. Internally moderated reactors have a more complex core but require less fissionable material. For LMFR cores externally moderated by graphite, the critical mass requirements are found to be relatively constant over a wide range of fuel concentrations with a minimum of about 10 kg for U^{233} fuel. For small LMFR cores, heat transfer rather than heat transport is the only bar to extremely high specific power in power applications and to high neutron flux in research applications. Externally cooled reactors, coupled to conventional heat exchangers require a large external holdup of the liquid metal, thus putting a premium on low fuel concentrations. Internally cooled LMFR's with a graphite (or beryllium) moderator and heat exchanger require advances in present technology. Sodium is an attractive coolant for an internally cooled, externally moderated version of the LMFR with slurry type fuel elements.

It is pointed out that, for research applications, the flux level achievable in a thermal reactor with a fixed power output has about reached its practical limit. This is not the situation for intermediate energy reactors. In particular, it is shown that an intermediate energy LMFR can achieve an average core flux of 10^{15} neutrons/cm^2-sec at 10 Mw power output. Finally, integral experiments and neutron cross sections needed for firm estimates of the conversion rations and critical mass requirements of LMFR systems, especially for weakly moderated systems, are discussed.

10
Sodium-Rubidium Alloys
Menke, John R.
Clinton National Lab., Oak Ridge, Tennessee. CNL-5
Contract W-35-058-eng-71. Declassified Dec. 21, 1955. 8pp.

Attention is directed to the liquid metal alloy systems Na-Rb as coolants for piles, especially thermal piles. The reported thermal neutron absorption sections of Rb are significantly lower than those for K. Physical constants are collected from the literature which indicate macroscopic physical properties similar to the Na-K alloys. Investigation of the ternary system Na-Rb-K is suggested.

11
An Explanation of the Effect of Added Metals on the Distribution of Rare Earths Between Liquid Bismuth and KCl-LiCl.
Cubiccoitti, D., North American Aviation, Inc., Downey, California
Contract AT-11-GEN-8. Declass. November 9, 1955. 10pp.

An explanation is proposed of experimental results obtained on the distribution of rare earths between liquid Bi and molten LiCl-KCl. It is shown that the mass-action law predictions of the distribution agree with experimental observations, if it is assumed that the equilibrium governing the distribution is the partial reduction of the LiCl by the rare earth metal. The distribution of the rare earth is affected by added metals inasmuch as they affect the equilibrium.

12
The Effects of Contamination by Vanadium and Sodium Compounds on the Air-Corrosion of Stainless Steel
Cunningham, G. W. and Antoine de S. Brasunas
Corrosion <u>12</u>, 389-405 (1956).

The acceleration of high temperature corrosive attack of heat resistance alloys caused by the presence of vanadium compounds is well established. The progressive addition of sodium sulfate to the vanadium contaminant indicates that the most corrosive mixture is approximately 20% sodium sulfate-80% vanadium pentoxide. The survey of the melting temperatures of various vanadium pentoxide-sodium sulfate mixtures shows no direct correlation of corrosive behavior. There appears to be a strong indication, however, that unusually high oxygen solubility in the molten contaminant containing 20% sodium sulfate may be responsible for its unusually high corrosiveness. This makes it possible to postulate a more satisfactory theory of the mechanism of corrosive attack which need not involve a solid phase in the reaction interphase. Addition of carbon oxide, strontium oxide, and carbon were particularly effective in reducing the intensity of the attack. The effectiveness of carbon is restricted to short time intervals during which it became oxidized.

16
The Thermodynamics of Reducibility of Fission Product Oxides by Sodium and Other Elements
Epstein, Leo F. and Joanne Nigriny
Knolls Atomic Power Laboratory, Schenectady, N. Y.
Contract W-31-109-Eng-52. April 27, 1948. Declas. Nov. 3, 1953. MEMO-LFE-1.

Thermodynamic data on the free energies of formation of 58 oxides from the constituent elements are computed at 25, 500 and 1000°C. Reducibility by Na, H_2, and C are shown in tabular form. The application of these computations to the depletion of liquid Na in pile designs using UO_2 fuel and liquid Na coolant in sealed units is discussed, and it is concluded that, if the kinetics of the reaction are favorable, only 7% of the Na will be lost by conversion to Na_2O after 10% burn-up in a system initially containing one atom of Na per molecule of UO_2.

17
Boride Parts Resist Molten Zinc
Evans, R. M.
Materials & Methods 43, No. 6, 132-3 (1956).

Fe boride containing 16 and 24% B, 85 Cr boride-15 Fe, 85 Cr boride-15 Co, 90 mn boride-10 Fe, and 80 Cr boride-15 Co-5% Ni sintered compacts were completely resistant to molten Zn at 1100°F in lab tests.

18
Improved Method for Cleaning Mercury
Fuschillo, N.
Rev. Sci. Inst. 27, 410-11(1956).

A method is described which removes impurities such as zinc, lead and copper and alkali metals by means of atomization through a thin walled soft rubber hose. The fine droplets of mercury pass into a 10% nitric acid solution. Air rapidly sucked into the system through a cotton dust filter creates a turbulence which improves the oxidation of the impurities. Details of construction and diagram of the apparatus are shown.

19
Effect of Gas Entrainment on the Heat-Transfer Characteristics of Liquid Mercury
Hoffman, B. et al
U. S. A. E. C. BNL-2446, 21-34 (1955).

Low heat-transfer coefficients in nonwetted systems have been attributed to random local detachments of liquid metal from the tube wall. Photographs of the detachment effect on a glass tube were taken when linear velocity and pressure were varying on mercury flowing past the tube. It could be seen that the number of detachments could not be reduced by a change in pressure. The possibility of gas entrainment in the mercury was investigated by filling the mercury reservoir slightly above the inlet level; this eliminates the splash effect. Detachments under this condition were only observed at very low pressures and extremely low flow rates. A housing filled with mercury was fitted around the pump shaft to prevent any air being sucked in the stream at the base of the shaft of the pump. Heat-transfer studies were then carried out under conditions of non-wetting, at static pressures from 10 in. of Hg vacuum to 140 lb. per sq. in. gage. No relationship was found to exist between the static pressures and the heat-transfer coefficients. Corroborative tests indicate that mercury is capable of entraining significant quantities of gas; as much as 12% change in density was found for aerated mercury. The gas entrainment may be the cause of variations in the results of different investigations. Tests run on a thermal cell designed to measure quantitatively the effect of entrainment on heat-transfer coefficients gave smooth curves only under wetting conditions, with nonaerated mercury. Since it is not feasible completely to eliminate the entrainment of gases by liquid metals in most systems, it is believed that recent data obtained are truly representative of what can be expected from a system employing liquid metals to transfer energy by sensible heat exchange.

20
Solubility of Hydrogen in Molten Aluminum, Lead and Zinc
Hoffman, Wilhelm and Jurgen Maatsch
Z. Metallkunde 47, 89-95 (1956).

A method is described for determining the solubility of gases in metals to 0.01 ml./100 g. metal. The method was checked by use of the solubility of H in molten Ni and Al. At 518.7° the solubility of H in Ni was 4.74 ± 0.26 ml./100 g. The solubility of H was 0.62 ± 0.03 ml./100 g. in tech. grade Al at 680.7° and 0.99 ± 0.04 ml./100 g. in superpurity Al at 678.6°. The results agreed with values obtained by other methods. The solubility of H in molten Pb at 606.5° was less than the limit of accuracy of measurement. An initial consumption of H was attributed to the reduction of PbO impurity. Negligible solubility of H and N in molten Zn was found.

21
High-Pressure Loop Design for Studies of Reactions Between Heated Metals and High-Temperature Water
Kaulitz, D. C. and J. E. Minor
U. S. A. E. C. Research and Develop. Rept. HW-38876, 21pp. (1955).

A high-pressure loop has been constructed which permits high-temperature water to be brought into contact with a metal specimen heated well above the water temp.

22
Thermal Conductivity of Alkali Solutions
Kharbanda, Om. P.
Ind. Chemist 32, No. 375, 157-166 (1956).

Riedel reported data on the thermal conductivity of aqueous solutions of sodium and potassium hydroxides over a wide temperature and concentration range. The data was tabulated at intervals of 10% and 10°C in temperature. Kharbanda using

40
Conceptual Design for Internally Cooled Liquid-Metal-Fuel Reactor (LMFR)
Teitel, Robert J.
Nucleonics 14, No. 4, 72-7 (1956).

A variant of the liquid-metal-fuel reactor idea is suggested for a 500-megawatt reactor in which cooling and breeding both are accomplished simultaneously with one liquid metal stream containing an intermetallic dispersion of Th_3Bi_5 in liquid Bi. The use of radiogenic Pb, having a thermal neutron cross-section of only about half that of regular Pb, to supplement scarce Bi is suggested as a novel way to increase the power produced per lb. of available Bi. The suggested fuel system is a dispersion of 1.77 wt. % USn_3 in a liquid containing Bi 56.2, Sn 6.0, and Pb 37.8%.

41
Liquid Metal Extraction for Processing of Spent Fuel
Voigt, A. F. et al
A. I. Ch. E. J. 2, 169-73 (1956).

Plutonium and the fission products can be removed from irradiated uranium by liquid-metal extraction by use of another metal immiscible with uranium. Metals studied have been silver, cerium and lanthanum. Plutonium removal by silver is high.

42
Determination of Diffusivities in Liquid Metal by Means of Temperature-Gradient Zone Melting
Wernick, J. H.
J. Chem. Phys. 25, 47-9 (1956).

Diffusivities of liquid alloys of Ge-Al, Ge-Au, and Si-Al have been measured by a new technique called temperature-gradient zone melting. The technique involves passing extremely thin molten zones through a solid crystal by means of a temperature gradient. Preliminary values of the diffusivities fall in the 10^{-5} cm^2/sec range at temperatures of 530°C to 700°C.