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LIQUID METALS TECHNOLOGY ABSTRACT BULLETIN

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For the Period January, February and March, 1960

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TECHNICAL INFORMATION DIVISION

LIQUID METALS TECHNOLOGY ABSTRACT BULLETIN

This is the fourteenth 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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Heat Transfer of Molten Sodium Flowing Transversely  
Across a single Cylinder

1

Andre-evskii, A. A.

Atomnaya Energ. 7, 254-6 (1959) September (In Russian)

NSA 14:1611

The local heat transfer dependence on the flow rate, the distribution of heat transfer along a cylinder, and variations of the relative heat transfer coefficient across the cylinder are analyzed. The mean heat transfer in transverse flow across cylinders and tube systems is plotted.

Report of the Sodium-Heavy-Water Reactor Task Force

2

AEC Division of Reactor Development. Civilian Reactors

Evaluation and Planning Branch

TID-8515 May 1959, 29 p.

NSA 14:2225

The sodium-heavy-water reactor concept was evaluated on the basis of (1) its technical feasibility and (2) its potential for the economical production of electric power. Problems such as operational criticality and integrity of fuel assemblies will have to be resolved before the concept can be considered technically feasible. In addition, the costs associated with the fuel cycle and the sodium-to-steam equipment will have to undergo substantial reductions before this concept can compete with other natural uranium systems.

Status Report for Sodium Graphite Reactors

3

Atomics International Div., North American Aviation, Inc.

Canoga Park, Calif.

NAA-SR-Memo-4156 July 1959, 110 p.

NSA 14:4128

The current development status of the Sodium Graphite Reactor concept is described. The development history is summarized and all important areas of development are discussed. The discussions of the SGR development program are broken into three categories, (1) general research and development, dealing with reactor physics, fuel and materials, components, etc., (2) experimental reactors operating, in some design phase, or under construction, and (3) power demonstration reactors, operating or in a design or construction phase. Reactors discussed include the SRE, SCRE, HNPF, SIR, and the 300 MW Canned Moderator Reactor.

Liquid Metal Fuel Reactor Experiment, Quarterly Technical  
Report for October - December, 1957

4

The Babcock & Wilcox Co., Atomic Energy Div., Lynchburg, Va.

B&W-1041, Contracts AT(30-1)-1940 and AEJ-46, 102 p.

U.S. Gov. Res. 32:414

Liquid Metal Fuel Reactor Experiment, Quarterly Technical Report for July through September 1958 5

The Babcock & Wilcox Co., Atomic Energy Div.  
B&W-1125 1958, 172 p. Contract AT(30-1)-1940  
U.S. Gov't. Res. Repts. 33:108

Liquid Metal Fuel Reactor Experiment. Annual Technical Report, March 25, 1959 6

The Babcock & Wilcox Co. Atomic Energy Div.  
B&W-1136 Contract AT(30-1)-1940 186 p.  
U.S. Gov't Res. Repts. 33:108

Status of Liquid-Metal-Heated Steam Generator Technology 7

Bischel, Nyle A

The Babcock & Wilcox Co., Atomic Energy Div. Lynchburg, Va.  
B&W-1105, Contract AT(30-1)-1940 and AEJ-46, Sept. 1958, 59 p.  
U.S. Gov't Res. Repts. 32:414

Compatibility Tests of Various Materials in Molten Sodium 8

Carlander, R. and Hoffman, E. E.

Oak Ridge National Laboratory, Tennessee  
CF-57-3-126, 25 March 1957, Decl. 9 October 1959, 10 p.  
NSA 14:2692

Compatibility tests of materials in contact in sodium under 500 psi pressure were conducted for 716 hr at 1500 F. Of the diffusion couples studied, the Inconel-beryllium system showed the largest amount of alloying. The reaction between molybdenum and beryllium resulted in the formation of two compounds, both of which were severely cracked in several areas. The molybdenum-Inor-8 and the Inor-8-type 315 stainless steel interfaces showed little alloying. A compatibility test system was prepared by placing 1/4 x 1/2 x 1 in. specimens of Inconel, beryllium, molybdenum, Inor-8, and type 316 stainless steel together in sodium.

Determination of Oxygen in Sodium. The Mercury Method: Its Use in the Case of Very Low Concentrations 9

Champeix, L., Darras, R., and Duflo, J.

Centre études nucléaires Saclay, Gif-sur-Yvette, France  
J. Nuclear Materials 1, 113-19 (1959) (in French)  
cf. CA 53:21369d  
CA 54:5335c

The applicability of microanal. techniques to the classical Hg method of O detn. in Na (cf. Williams and Miller, CA 46:3330c; Pepkowitz, et al. CA 48:5022f) was examd. with a modified app. operating under vacuum. The NaOH formed was detd. by flame spectroscopy

for original O concns. <40 ppm. The lowest concn. measured was 7 ppm, with a reproducibility of  $\pm 1.5$  ppm. It was concluded that the technique could probably be extended to concns. as low as 1 ppm with precision of the same order, providing that the problem of Na sample contamination on transfer can be resolved.

#### Fuel Programming for Sodium Graphite Reactors

10

Connolly, T. J.

Atomics International Div., North American Aviation, Inc.  
Canoga Park, Calif.

NAA-SR-4040 Oct. 15, 1959, 34 p. Contract AT-11-1-GEN-8  
NSA 14:2206

The effect of fuel programming, i.e., the scheme used for changing fuel in a core, on the reactivity and specific power of a sodium graphite reactor is discussed. Fuel programs considered include replacing fuel a core-load at a time or a radial zone at a time, replacing fuel to maintain the same average exposure of fuel elements throughout the core, and replacing and transferring fuel elements to maintain more highly exposed fuel in the center or at the periphery of the core. Flux and criticality calculations show the degree of power flattening and the concurrent decrease in effective multiplication which results from maintaining more exposed fuel toward the core center. Converse effects are shown for the case of maintaining more exposed fuel near the core periphery. The excess reactivity which must be controlled in the various programs is considered. Illustrative schedules for implementing each of these programs in an SGR are presented.

#### A Brief Review of Thermal Gradient Mass Transfer in Sodium and NaK Systems

11

DeVan, J.H. and West, J.B.

Oak Ridge National Laboratory, Tennessee

CF-57-2-146, 11 February 1957, 19 p. Contract W-7405-eng-26  
NSA 14:2691

The fact that material transport does occur under conditions of finite temperature difference in a flowing molten system was established. The rate mass transfer was thought to be either diffusion limited or solution rate limited. It is believed that the mass transfer of structural materials in Na or NaK systems is solution rate limited. The limiting process has not been qualitatively or quantitatively confirmed for the Inconel-Na or Inconel-NaK system. Increasing the maximum system wall temperature increases the amount of mass transfer, at least above 1300 F. The effect of the total temperature difference across the system on the amount of mass transfer was determined.

Zmochuvannya Ridkymy Metalamy Poverkhen' Tuhoplavkykh Spoluk 12  
(Wetting the Surface of High-Melting Alloys with Liquid Metals)

Eremenko, Valentyn Nykyforovych and Yuryy, Vladymyrovych  
Naydych

Kiev, Vyd-vo AN Ukrayins'koyi RSR, 1958, 59 p.

NSA 14:574

Problems of wetting high-melting alloys with molten metal, a process used in the manufacture of heat-resistant materials, are discussed. Results of experimental and theoretical investigations of the wetting process are presented and general thermodynamic principles are described. The book is intended for engineers and scientific personnel working in the physical chemistry of molten metals.

Determination of Oxygen in Bismuth and Other Metals 13

Funston, Earl S. and Reed, S. A.

NEPA Div., Fairchild Engine and Airplane Corp. Oak Ridge, Tenn.

NEPA 1097-SCR-51; ATI-188 825 3 Aug 1949, 8 p. PB 137 030

U S. Gov't Res. Repts. 32:313

A method is presented for quantitatively measuring traces of oxygen in bismuth, arsenic and other metals whose oxides are reduced by hydrogen in the temperature range 200-900 C. An indirect determination is made by measuring the volume loss of hydrogen after reduction of the metal oxides in a closed system. (Amounts of oxygen from 2-500 ppm can be readily determined with an absolute error of  $\pm 1$  per cent).

Sodium--Reactor Coolant 14

Harbourne, B. L.

United Kingdom Atomic Energy Authority, Risley, Lance, Eng.

Chem. & Proc. Eng. 40, 347-51 (1959) October

NSA 14:3175

The advantages of using liquid sodium for a reactor coolant are discussed. The various practical considerations involved in designing sodium-cooled reactor systems such as sodium handling, materials selection for the circuit, and the destructive properties of sodium on the circuit are discussed.

Control of Oxygen Concentration in a Large Sodium System 15

Hinze, R. B.

Atomics International Div., North American Aviation, Inc.

Canoga Park, Calif.

NAA-SR-3638 1 December 1959, 45 p.

Contract AT-11-1-GEN-8

NSA 14:5071

Data on the performances of two types of cold traps in the 50,000 lb radioactive sodium system at the SRE are tabulated. The rates were determined when trap inlet oxygen concentrations were at 8 to 10 parts per million. Oxygen concentration was readily controlled to 8 ppm using a cold trap. Extraction of oxygen from sodium by zirconium at 1200 F (hot trapping) reduces the concentration below the limit of detection, i.e., oxide solubility saturation temperature below 225 F. The theoretical limit for the equilibrium oxygen concentration was calculated to be less than  $7 \times 10^{-6}$  ppm. The observed extraction rate of 0.009 lb oxygen/hr was one-half of the rate predicted from material behavior studies.

Mass-Transport and Corrosion of Iron-Based Alloys in Liquid Metals

16

Horsley, G. W.,

Atomic Energy Research Establishment, Harwell, Berks, Eng.

Reactor Technol. 1, 84-91 (1959) August

NSA 14:587

The application of mass-transport equations to the corrosion of metals by liquid metals is discussed. Calculated corrosion rates are compared with experimentally determined rates. It is concluded that diffusion controlled solution attack, although significant, may not under conditions of interest to reactor engineers be as serious as either inter-granular attack or chemically assisted mass-transport. The mechanism of intergranular attack, the thermodynamics of an example of chemically assisted mass-transport, the role of oxygen in sodium-stainless steel circuits, and methods of reducing mass-transport of iron are discussed.

Thermodynamics of the Lead-Tin System

17

Kendall, Weston B. and Hultgren, Ralph

University of California, Berkeley

J. Phys. Chem. 63, 1158-9 (1959)

CA 54:61d

The heats of formation of solid solns. of Sn in Pb were measured at 450 K by liquid Sn soln. calorimetry. The data were correlated with published thermodynamic data and with the phase diagram in order to establish a set of thermodynamic properties for both the liquid and the solid alloys.

Determination of Sodium Vapor Pressure at Temperatures from 880 to 1300 C

18

Kirillov, P. L. and Grachev, N. S.

Inzhener, -Fiz. Zhur., Akad. Nauk Belorus, S.S.R. 2,

No. 5, p. 3-7 (1959) May (In Russian)

NSA 14:4291



A method for determining the saturated vapor pressure of sodium at 880 to 1300 C is described. The results are compared with the work of other authors. An equation is proposed for calculating saturated vapor pressure at various temperatures.

Liquid Metal Heat Transfer Media

19

Kutateladze, S. S. et al.

Translation of Atomnaya Energ. Suppl. No. 2, 1958

New York, Consultants Bureau, Inc. 1959, 152 p.

NSA 14:287

The thirteen chapters in this volume cover the following subjects: basic properties of liquid metals, application of liquid metal heat transfer media, hydraulic resistance in the flow of liquid metals, turbulent heat transfer in liquid metals, heat transfer during flow in tubes, heat transfer during the longitudinal flow around a plate, heat transfer during transverse flow around cylinders, heat exchange during free convection, heat transfer during vapor condensation, heat exchange during boiling, heat-exchanging equipment, stability of heat-resistant materials in liquid metals, and instrumentation.

Effect of 1200 F Sodium on Austenitic and Ferritic Steels

20

Bi-Monthly Progress Report No. 1 for July and August 1959 on

Thermal Shock, Nitriding, Stressed Corrosion, Unstressed Corrosion

Mausteller, J. W. and Werner, R. C

MSA Research Corp., Callery, Pa.

MSAR 59-99, Sept. 16, 1959, 22 p. Contract AT(11-1)-765

NSA 14:2695

Completion of preliminary designs for a thermal shock loop, a corrosion loop, and a nitriding loop is reported. Stressed and unstressed corrosion studies are scheduled to be carried out in the same system. A literature search was started, and various sites were contacted to avoid duplication of effort. It was found that some work has been done at 1200 F sodium temperature with various oxygen concentrations, however, part of the data is not consistent. Test plans include corrosion testing of Croloy and stainless steel samples as well as similar and dissimilar welds of these materials in 1200 F sodium.

Solubility of Oxygen in Sodium and Sodium-Potassium Alloy

21

Noden, J. D. and Bagley, K. Q.

U. K. At. Energy Authority, Ind. Group

R & DB (C) TN-80, 7 p. (1958) (Declassified reprint)

CA 53:21057i

The soly. of O in Na was detd. in the temp. range 130-540°; soly. of O in Na-K alloy was detd. in the temp. range 130-540°; soly. of O in Na-K alloy was detd. in the range 30-176°. App. of both glass and stainless steel was used. The results suggest that the soln. formed approximates an ideal soln., but that the partial heat of soln. changes abruptly at 260-70°. Sources of error encountered during the use of the glass app. were investigated.

Performance of the Sodium Reactor Experiment 22

Owens, J. E., Morgan, W. T., and Glasgow, L. E.  
 Atomics International Div., North American Aviation, Inc.  
 Canoga Park, Calif  
Power App. and Systems No. 42, 170-5 (1959)  
 NSA 14:6056

The performance of the Sodium Reactor Experiment on four power runs between July 1957 and May 1958 is compared and discussed. Operational procedures maintained during the four runs are described.

Chemical Processing Methods and Economics for Various Liquid Metal Fuel Reactors 23

Pierce, R. D., Miller, W. E. and Zellnik, H. E.  
 The Babcock & Wilcox Co., Atomic Energy Division  
 B&W-1048 March 1958, Contract AT(30-1)-1940, 94 p.  
 U.S. Gov't Res. Reports 33:108

The Solubilities of Niobium, Cerium, and Strontium in Liquid Bismuth 24

Pleasance, R. J.  
 Natl. Phys. Lab., Teddington, England  
 J. Inst. Metals 88, 45-8 (1959)  
 CA 54:2115b

Soly. of Nb in liquid Bi is very low and no intermetallic compds. are formed. Equil. diagrams for Bi-Ce to 17.5 wt % Ce and for Bi-Sr to 12.5 wt % Sr are given. No eutectic was found at the Bi end of Bi-Ce, but a eutectic occurs at approx. 0.2% Sr in Bi-Sr.

Final Report - A Review of Work from December 1953 to December 1958 with Abstracts of Reports Issued 25

Posey, W. J., Editor  
 MSAR 59-29, 20 March 1959, 73 p.  
 Contract NObs-65426  
 NSA 13:12088

This report completes the task orders for research and development work on liquid metals, organics and water technology under Contract NObs-65426. A brief general review of the work accomplished during the 5-year life of the contract is followed by a list of all reports issued, along with an abstract of each.

Monthly Technical Report for Period July, 1959

26

Power Reactor Development Co., Detroit, Mich.  
PRDC-TR-25 27 p. Contract AT(11-1)-476  
NSA 14:2222

Progress in core design, materials, nuclear engineering, reactor vessel engineering, mechanical handling, electrical and instrumentation, liquid metal and steam systems, and test operations are summarized. Environmental radioactivity reports for the Enrico Fermi Reactor are included.

Monthly Technical Report for Period August, 1959

27

Power Reactor Development Co., Detroit, Mich.  
PRDC-TR-26 28 p. Contract AT(11-1)-476  
NSA 14:2223

Progress in core design, materials, nuclear engineering, reactor vessel engineering, mechanical handling, electrical and instrumentation, liquid metal and steam systems, and test operations are summarized. Environmental radioactivity reports for the Enrico Fermi Reactor are included.

Thermodynamic Investigations of Liquid Lead-Zinc Alloys

28

Predel, Bruno  
University of Munster, Germany  
Z. Physik, Chem. (Frankfurt) 20, 150-65 (1959)  
CA 54:1999e

The thermodynamic activities of Zn in the total concn. range of the system Pb-Zn between 600 and 850° were detd. by the dew-point method. The activity isotherms exhibit strong pos. deviations from the straight line postulated by Raoult's law. From the thermodynamic activities and the temp. eoffs., partial and integral enthalpies of mixing, free energies of mixing, and entropies of mixing are calcd. The max. integral molar enthalpy of mixing lies in Pb-Zn alloys at  $X_{Zn} = 0.7$  and is 1590 cal/g.-atom. The integral molar entropies of mixing are, in the total concn. range higher than the resp. ideal values. The normal boiling diagram also was detd. by aid of the activities.

The Thermodynamics of Bismuth-Lead Alloys

29

Roy, Prodyot, et al.

Minerals Research Lab., U. of Calif. Berkeley  
Technical Report No. 2 1 January-31 March, 1959  
15 June 1959, 27 p. incl. illus. tables, 18 refs. (Series  
No. 126; Issue No. 2)  
Contract No. DA 04-200-ORD-171, T.O. 15 AD 220 127  
TAB 1 October 1959; 5117

Heats of formation of six bismuth-lead alloys at 400 F have been measured in a liquid lead solution calorimeter. A complete evaluation of the thermodynamic functions in the solid beta and epsilon phases has been presented in this paper. The heat contents of four alloys have also been measured in the diphenyl ether calorimeter verifying the validity of Kopp's law for these alloys. The phase diagram has been critically studied and has been corrected at the solid phase boundary between epsilon and epsilon plus beta phases.

Degassing Sparger Plate, Screening Tests

30

Starkweather, D.C.

The Babcock & Wilcox Co., Atomic Energy Div.  
Lynchburg, Va.  
B&W-1063, Contracts AT (30-1)-1940 and AEJ-46,  
September, 1958, 20 p.  
U.S. Gov't. Res Repts. 32:414

Test Results and Design Comparisons for Liquid Metal-to-Air Radiators

31

Stumpf, H. J., et al.

Oak Ridge National Laboratory, Tennessee  
CF-54-7-187, 19 July 1954, Decl. 9 October 1959, 84 p.  
Contract W-7405-eng-26  
NSA 14:2535

Test data for an ORNL radiator core element with 14 strip fins per inch Colburn modulus  $j$  and friction factor  $f$  for the test unit are plotted against Reynolds number and compared with data for other compact surface heat exchangers. In addition, a time saving method for designing liquid metal-to-air radiators is presented.

Some Relationships in Heat Transfer to Boiling Mercury in Forced Convection

32

Styrikovich, M. A. and Semenovker, L. E.

AEC-tr-3868 Translated for Atomics International from  
Zhur. Tekh. Fiz. 10, 1331-9 (1940) 21 p.  
NSA 14: 1609

The heat transfer to boiling Hg was studied in forced convection flow.

The Oxidation of Lithium - Report of Progress to 5.4.55

33

Tyzack, C. and Longton, P. B.

United Kingdom Atomic Energy Authority (Gt. Brit.)

R & DB (C) TN-131 15 June 1955, declassified 1958,

3 p. illus.

AD 213 169

TAB 1 Oct. 1959:4951

Conclusions: The reaction between freshly filtered lithium and cylinder oxygen has been found to be immeasurably small unless ignition occurs. The ignition temperature has been found to vary with pressure, showing a minimum value of 630-650 C over the pressure range 100-500 mm Hg. Outside these limits the ignition temperatures increase with both lower and high pressures.

A Method for the Determination of the Intensity of Heat Exchange in Molten Metals by Free Convection

34

Veynik, A. I.

Trudy Inst. Energet. Akad. Nauk Beloruss, S.S.R.,

No. 3, 62-7 (1957)

(Translated from Referat. Zhur. Met., No. 10, 1958, 187 p.)

NSA 14:297

To determine the intensity of heat exchange in molten metal by free convection the use of the method of an immersion method is proposed in which a specimen (S) of suitable shape and possessing a specified thermal resistance on the surface is immersed in the melt. During the interaction of S with the molten metal the heat flow passing into the S at first is considerable, which causes the formation of a hardened crust of a certain thickness on the surface of S. Then, with progressive heating of the S, the heat flow decreases and the hardened crust gradually melts. This is explained by the fact that the amount of heat entering the S through the crust becomes smaller than the amount of heat transferred to the crust from the molten metal. The resulting excess of heat is expended on the melting of the crust. If the S is removed from the molten metal bath before the crust is completely melted, then it is possible to judge the magnitude of the heat flow and the value for the coefficient of heat transfer from the thickness (or weight) of the remaining solid metal. To put the proposed method into practice formulas are developed for the relationship between the thickness of the hardened crust and the value of the heat-transfer coefficient. To simplify the problem it is assumed that the thickness of the hardened crust is small compared to the dimensions of the S, and, therefore, in the thermal sense, the crust is regarded as a plant partition. Moreover, the temperature drop occurring within the crust as a result of the cooling of its inner surface (in contact with S) below the temperature of crystallization is disregarded.

Liquid-Metal-Fuel-Reactor Experiment. Effect of Slurry  
Inhomogeneity on Nuclear Stability of Metal-Fuel Reactors

35

Zellnik, H. E., Miller, W. E. and Thomas, C. E.

U.S. At. Energy Comm.

B&W-1142, 36 p. (1959)

CA 54:4181f

In order to obtain an operating condition where reactivity will decrease with changes in slurry concn. U. must be present in both the liquid and solid phases of insol. slurries in liquid Bi. For sol. (ThBi<sub>2</sub>) slurries the distribution coeff. of U between the phases must be alterable in order to achieve stable conditions. For 2-region breeder reactors insol. slurries must be used.