Sent to Fins 1, 8, 9, 11 and Ceramics Technical Committee

LEAD INDUSTRIES ASSOCIATION

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To Members of the Lead Industries Association:

Attached is a reprint of the section on Lead and Its Alloys prepared by E. J. Mullarkey, Technical Director of Lead Industries Association, and published in the September, 1958 issue of "Industrial and Engineering Chemistry," official publication of the American Chemical Society. The section is part of the Annual Materials of Construction Review.

This year's review marks a significant departure from past issues in extent of coverage as well as technical involvement, in keeping with present day trends and L.I.A.'s over-all program in research and development.

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Very truly yours,

Robert L. Ziegfeld

Secretary

AN IEC REPRINT

Lead and Its Alloys

EDWARD J. MULLARKEY
Lead Industries Association, New York 17, N. Y.

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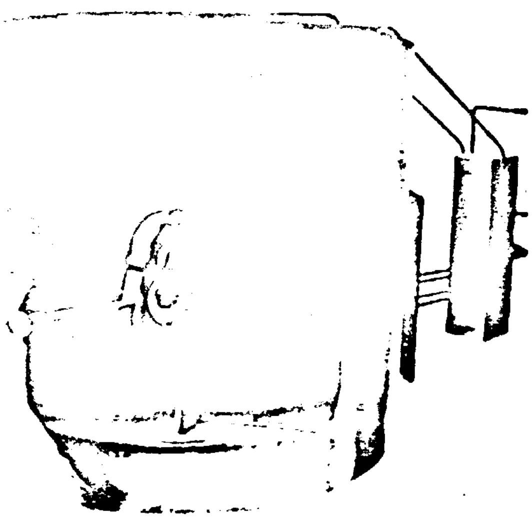

Cutaway of miniaturized atomic energy research reactor. This unit is only 8 feet high and 8 feet in diameter. The 3500-pound pear-shaped lead reflector shield can be seen in center of reactor

engineered for use by American firms, Ebasco in particular, for ship hull, steel pier, and pipeline protection and offers excellent working characteristics. Lead has always been important in general chemical, water, and soil corrosion and its use as an impressed current anode rounds out the applications picture.

In the field of high temperature, an uncommon application area for lead normally, two developments appear significant, both of which involve the benefiting addition of lead to a structural material. In the first case, it has developed that titanium benefits by as much as 2 weight % lead at high temperatures, in the area of 1000° F. Because of diffusion and solubility characteristics, lead has the ability to move with imperfections or dislocations and thereby maintain the properties of the bulk material, which may portend other similar uses. In the second case, ceramic-coated magnet wire for high temperature applications has been made possible by lead additions to the coating material. Some measure of this effect can be obtained from a comparison between the volume resistivities for leaded and nonleaded coatings at 550° F. —130,000 and 335 megohms, respectively. Such coatings include a number of different ceramic compositions that can withstand continuous operation at temperatures to 1000° F. They can also be used to bond electronic components such as transistors, diodes, and relays under similar circumstances (*1*).

The Russians may have taken another jump in the field of alloying. They claim to have accomplished what long has been considered impossible—the true alloying of lead and iron (*6*). Experiments carried out at the Central Research Institute of Ferrous Metallurgy have shown that the properties of crystallizing metals may be altered substantially by subjecting it to ultrasound treatment (this is not new) and that such treatment also opens up far-reaching prospects for forming alloys unobtainable by ordinary methods. Little is known about the merits of such an alloy commercially and the proof of both remains to be seen in this country.

Lastly, Minneapolis-Honeywell Regulator Co.'s new Inertial Guidance Center is using the sound-attenuation properties of lead. Concomitant with the demands of the space age, lead has moved into the "white noise" room at this installation where 25 tons balanced on a knife-edge support vibration equipment. This use of lead is unique, as it forms part of a sandwich construction, the purpose of which is twofold: to isolate transmission of vibration to adjacent ground and structure and to assist in preventing undesired planes of vibration in missile component test equipment, so that the vibratory motion will be confined to a single plane.

Research Progress

It seems fitting that the extraordinary features of lead, lead alloys, intermetallics, metalloids, and the like should in treatment precede the more rudimentary though important advances in lead technology. PbS, PbTe, and PbSe have become increasingly popular as semiconductors, particularly as infrared detectors and as working materials for thermoelectric refrigeration and power. With respect to detectors, the merits of lead compounds seem unchallenged, whereas for refrigeration and power, certain efficiency breakthroughs remain to be made before such developments can become commercial. As heat emitters, lead compounds are receiving careful consideration on both a fundamental and an applied basis.

Facts brought to light in connection with lead compound semiconductors would include densities (*5.4*) and the interstitial diffusion of nickel (*4.4*) and copper (*2.4*) in lead sulfide single crystals. The microstructure of photoconductive lead sulfide layers seems to consist generally of crystals 200 and 300 A. in size and, for vapor deposited layers, correspond to a regular *f.c.c.* lattice of the sodium chloride type (*8.4*). Photoconductivity in lead selenide, as it relates to the theory of the dependence of sensitivity on film thickness and absorption coefficients, also received attention (*3.4*). In a more applied vein several papers presented at the Electrochemical Society's spring meeting are representative of the attention being given to lead compounds. Scanlon (*14.4*) helped clarify many concepts as to the properties of PbS, PbSe, and PbTe and the understanding of polar semiconductors in general. For this class of compounds, the solid phase cannot be considered separately from its vapor phase, particularly at elevated temperatures.

In compound electroluminescence, lead as an additive appears beneficial. One study indicates that lead enhances the plaque brightness of a 3000° K. calcium halophosphate phosphor (*16.4*); in another, it activates the ultraviolet fluorescence of some ternary silicates (*11.4*); and in another, the wave length of the peak fluorescent emission of tungstate is shown to be dependent on its lead content (*10.4*). The implications are intriguing in terms of new products in the fields of electronics and lighting.

Ceramic materials, ferroelectrics in particular, containing lead have received mention in connection with permanent magnetism (*12.4*), x-ray and neutron diffraction (*9.4*), production and properties of single crystals useful as transistor devices (*15.4*), and basically

A new type of chargeable dry cell, using an alkaline lead oxide-silver system, offers exceptionally long shelf and service life, and relatively constant voltage throughout a wide temperature range

in a number of papers presented at the American Ceramic Society meeting. The revelations are indicative of the attention being given to such materials in varied fields and supplement present knowledge.

Lead superconductivity has had practical use and the normal resistivity of lead coupled with this property has made lead and certain lead alloys attractive in many applications. As a result investigations have been made with respect to alloying (*1A*, *2A*) and effects of hydrostatic pressure on the transition (*7A*). Preston and Templeton (*13A*) have made a precise measurement of the superconducting transition temperature for zone-refined lead—7.175° ± 0.005° K. in zero field, compared with Boorse's previous value of 7.22° K.; the observed transition temperature differential was less than 0.001° K. Exploitation of superconductive phenomena is still in its infancy but startling developments are in the offing.

Still another item of interest is that a lead-zirconium alloy exhibits controllable pyrophoricity in massive form. This feature was tested by the military in arctic areas as an efficient and simple means for igniting gasoline fires. Gas ignition is normally a great problem because of low vapor pressure at such low temperatures. As a striker it would appear to be peerless, and, in the fields of general ignition, have many new and potential uses.

Physical Metallurgy. The lithium-lead system has been looked at recently as a possible means to improve lead structurally. It is known, for instance, that lithium acts as a strengthening agent and marked increases in physicals have been noted. Adding to information on the system, the structures of Li_4Pb and Li_7Pb_2 have been determined (*13B*). The Li_4Pb cell is *fcc*. with a = 6.687 A. and Li_7Pb_2 is hexagonal with a = 4.751 A. and C = 8.589 A. Studies on the crystal structure of KPb_2 show that for a quenched specimen (300° C.) it is a Laves phase with the $MgZn_2$ (C_{14}-type) structure. The lattice parameters are a = 6.66, c = 10.76 A., c/a = 1.61 (*2B*).

Concerning liquid immiscibility in the lead-uranium system, Teitel (*9B*) confirmed previous conclusions by describing in greater detail experiments on which they were founded. New data on uranium solubility in lead and on the crystal structure of UPb_3 by neutron diffraction are also presented. UPb is *bc*. tetragonal with a = 11.04 A., c/a = 0.961. Density is estimated to be 13.7 grams per cc. Certain discrepancies between the values for the cell size of UPb_3 are discussed.

The similarities between carbon steels and silver-lead alloys, in so far as dependence of modulus on composition is concerned, were made evident by Umekawa (*10B*). Young's modulus changes linearly with composition, with its temperature dependence behaving similarly. Elasticity of lead single crystals was studied by the method of diffuse x-ray scattering, using both a Geiger counter and film (*8B*). From known compressibility the various elastic constants are derived and are believed to be more exact than those determined by mechanical methods. Creep of lead single crystals as it relates to activation energies for high temperature creep was studied by Wiseman, Sherby, and Dorn (*12B*). For high purity polycrystalline and single crystal specimens, activation energies of 26,000 and 24,800 cal. per mole, respectively, were reported. It appears that the activation energy is essentially the same for both cases and equal to the respective activation energies for grain boundary shearing. Covering the temperature range of 0° to 250° C. for the entire bismuth-lead system, Mikryukov and Tyapunina (*7B*) investigated the temperature dependence of thermal conductivity, electrical conductivity, and specific heat and cited many important anomalies. Thermal expansion measurements from room temperature to 300° C. by dilatometry and with x-rays were found not be different for lead (*11B*). This was attributed either to the two small concentration of vacancies at high temperatures or the influence of vacancies on the lattice parameter.

On gas content and related property effects, two investigative efforts may be considered. The first is the determination of contents and effects for carbon dioxide, water, and hydrogen (*3B*). Secondly, absorption of hydrogen was shown not to be present in electrolytic or common lead or in lead-copper up to 1% copper (*6B*). Lead-magnesium alloys up to 17% magnesium show an increasing ability to absorb hydrogen, which the authors connect with Mg_2Pb phase. Efforts are being made to connect alloy improvement to the presence of hydrogen or hydrides in the case of alloying with tellurium, selenium, arsenic, and lithium, which form hydrides.

Aging characteristics of lead-antimony alloys with effects of strain were studied by Hooker (*4B*), who explained hardness fluctuations as aggregates of individual changes due to preaging, age hardening, and effects of straining. Properties observed during hardening were explained as being residues of advanced coherent aggregates. The influence of impurities on the macromosaic structures of lead in terms of the properties and characteristics of arrays of low-angle boundaries which appear upon freezing of single crystals was studied by Atwater and Chalmers (*1B*). Effects were shown to be dependent upon the amount and kind of impurities in the freezing liquid.

The application of electroacoustical techniques to determine changes of structure in lead due to thermal or mechanical processes was represented by Kaiser (*5B*) as an excellent complement to conventional methods. Certain representative changes occur during melting and solidification, which are sensed and analyzed by acoustical apparatus.

Mechanical Metallurgy. The influence of small amounts of lead on the tensile and fatigue properties of SAE 1018, 1045, 8620, 4140, and 4340 steel was determined by Brock and Sinclair (*2C*). Lead has little influence on the tensile properties, and the mean fatigue limit of the leaded steel was significantly reduced only at ultimate tensile strengths above 130,000 p.s.i. Notch sensitivity of the steel was affected only slightly. At stresses above the endurance limit, leaded SAE 1018 and 4140 tended to give longer fatigue life with smooth specimens. Similar information is not available in this report on the other steels or on notched specimens. For cast steels contair ing from 0.12 to 0.20% lead, higher machinability ratings and improved finishes are noted over similar nonleaded steels (*6C*). An excellent treatise (*7C*) has been published with a view to extending their use in ordnance applications. The economics of this attitude appears irrefutable.

Effects of stress on recrystallization of lead during creep were studied by Gifkins (*3C*). The strain necessary to initiate recrystallization of high purity lead during creep has been determined for the range of stresses from 300 to 1500 p.s.i. (constant load). Essentially, recrystallization occurs at higher strains with higher stresses, grain size after recrystallization becoming smaller with increased stress. The performance of soft solders at elevated temperatures and pressures indicates the superiority of high-tin alloys under cyclic loads at 257° F. (*5C*). Small additions of manganese, chromium, iron, nickel, germanium, and cerium improve the performance of a 70 tin-30 lead solder, LIA20084

but only the latter three benefited a 30 tin–70 lead solder.

With respect to lead sheath for power cable, Hoaner (8C) lists the pertinent physicals, details of manufacture, uses, aging characteristics, and corrosion behavior of the tellurium-bearing arsenical alloy. A summary is given of data on electroplated metal coatings on titanium with reference to electroplates of lead (9C); effects of lead coatings on titanium in wire drawing, roll cladding, soldering, forging, and in various parts such as camera shutter blades, aircraft gears, bearings, guns, hydraulic cylinders, and landing gears.

Nuclear Physics and Nucleonics

The effectiveness of lead as a gamma shield has been manifestly demonstrated by the attention it is receiving in the literature. One could almost say that if the shield moves, it has lead in it. Studies on the shielding requirements for shipment of metallurgical samples were outlined (5D). Tensile and corrosion samples, irradiated at Materials Testing Reactor for long periods, have to be shipped in carriers to distant laboratories. It is recommended that a lead-shielded carrier be provided that has a minimum lead thickness of 6 inches for the side walls, 6 inches for the top, and 5 inches for the bottom. The inside container space should have a minimum diameter of 1$^{1}/_{4}$ inches and a height of 9$^{3}/_{4}$ inches. Such a carrier provides space and shielding for the shipment of two samples. An "exception" permit must be obtained for shipment of samples having an activity greater than 2.7 curies normally allowed by the Interstate Commerce Commission. Nomograms for gamma attenuation with build-up in lead give attenuation factors for lead and iron shielding slabs used with point gamma sources (2D). Other "mobile" shields are now being used or are slated for use in nuclear-powered ships, aircraft, rockets, and devices essential to the safe movement and handling of isotopes.

Information on the screening effect of lead and other heavy metals against gamma rays (7D) shows that screening ability depends on the coefficient of adsorption, which is a function of density and atomic number, and for the following metals increases in the order: iron, lead, tungsten-copper-nickel, or tungsten-nickel, tungsten, uranium.

In primary shield materials studied for SIC (3D), shields of lead, mild steel, and lead mild steel combinations were considered. Large quantities of lead can be saved through the use of borated water, if associated corrosion problems can be solved. Results of 1000-hour corrosion studies, boron compound solubilities, and boron compound toxicity studies are given. Corrosion-wise, three proposed configurations for the shield tank, all lead, all mild steel, and a combination of mild steel and lead showed corrosion rates in several borated water solutions to be in the order 0.1 to 0.6, 0.0 to 0.3, and 0.3 to 0.9 mil per year. With respect to galvanic action, chemical action was responsible for most of the corrosion. The maximum calculated penetration for any combination of boron solutions and test configurations was 2 mils per year. Irradiation corrosion tests of the above combination under SIC primary shield tank conditions were also undertaken for two borated solutions. The results, yet to be released by the Atomic Energy Commission, should prove very informative. The anticipated saving in lead is due to the marked reduction of gamma emission emanating from water as the result of neutron knock-on. Lead as a gamma shield per se is not being replaced by borated water in this application. It is a case of reducing the sum total of gamma radiation generated or emitted.

Absolute positron and electron fluxes from lead targets irradiated by bremsstrahlung have been observed at angles between 21° and 74° and energies between 50 and 170 m.e.v. (1D). By use of several target thicknesses, the fluxes from lead have been separated into large angle pair production and scattering of pair particles originally produced at 0°. Photoneutrons ejected from a small lead target by 23-m.e.v. bremsstrahlung x-rays from a betatron were observed by means of recoil protons in nuclear emulsions (8D). The angular distribution of the more energetic photoneutrons was nearly isotropic.

Application of liquid lead and lead alloys for shielding, fuel suspension, and heat transfer has dictated the need for information on working characteristics. Heat transfer coefficients for molten lead-bismuth eutectic are presented for flow in annuli externally heated at a constant rate, by Seban and Casey (6D). Diameter ratios of 1.50 and 1.74 were investigated and results were obtained in Peclet numbers from 400 to 1600. Bismuth-lead eutectic and pure bismuth penetration of graphites of various densities under 500° C. and pressures up to 20 p.s.i. was of the order of magnitude of 1.0 gram per sq. cm. uniform throughout the graphite (9D). Bismuth was absorbed less than the eutectic but the oxidation rate of bismuth would be prohibitive. There was heavy nitriding in nitrogen atmospheres with the bismuth and the eutectic.

In the studies of possible reactor fuels consisting of the fissionable material suspended in a liquid metal, either as a solute or as particles of compounds containing the fuel, investigation of the lead-uranium system has clarified the discrepancy in the literature concerning the solubility of uranium in molten lead, and an experiment involving lead-uranium alloy in contact with iron at 600° C. for 1 month showed that no gross diffusion of uranium into iron occurs (10D). In an effort to understand more fully the problems concerning a slurry reactor, initial experiments using UF_4, UC_2, and UO_2 in liquid lead, 55% bismuth-lead, and bismuth have been completed.

Corrosion

Three articles on the use of lead chemical construction deserve attention. The first deals with its use in handling refinery corrosives, mainly sulfuric acid, new developments in lead construction over the past 5 years, and a general treatment of each of the methods for installing lead for corrosive service (5E). The latter treatment describes the conditions which warrant a particular method and procedures for implementing that method. Pertinent test methods are described and an informative case history is documented. The second article relates the experiences of a large mining and smelting company with lead and antimonial lead in chemical and metallurgical plant construction (11E). Many successful design innovations are described and particular reference is made to the merits of antimonial lead in many applications over other common grades on a corrosion basis. Lastly, a discussion of lead-acid brick construction refutes erroneous conceptions on the limitations of lead as a supplement to acid brick (7E). It further treats the details of this type of construction which contribute to maximum derivable benefit, economics, and the merits of radioactive isotopes in the location of leaks. Leak detection in this type of construction has always been difficult and has led to considerable losses in down time and to wastage of man-hours. It is, however, seemingly resolvable as a drawback, because of the ever-increasing development and use of isotope techniques.

In building construction, the behavior of lead under various conditions of application, including contact with other building materials, particularly concrete, and methods of avoiding or correcting failure, was treated by Jones (5E). Conclusions were drawn on the most efficient use of lead in relation to corrosion problems. A digest of reports over the past 40 years on corrosion of lead in concrete covers normal concrete and those made with cement or special aggregates, effect of addition to mixing water, and external agencies promoting corrosion (1F).

Electrochemical. Pourbaix (9E) has developed an equilibrium diagram for the lead-water system which is useful in estimating the passive or nonpassive behavior of lead in solutions of varying pH and at varying potentials. But, as brought out by various researchers, its use should be modified in terms of the invariable existence of nonequilibrium in practical applications. Burbank (2E) has expanded on the potential-pH phase diagram for lead by definition of the crystalline phases present as electrode species. The lamellar nature of the anodic product formed on lead under conditions obtained in the lead-acid cell is further interpreted on the basis of the diagram. On the subject of the electric and electrochemical properties of alpha and beta forms of PbO_2, their dependency on these oxygen lattice defects was considered by Ruetschi (11E). Anodic polarization of lead in sulfuric acid under conditions of oxygen evolution leads to layers of alpha-PbO_2 with excess oxygen in the surface. The amount of excess oxygen is related to oxygen overvoltage and corrosion; included in the study are a large number of lead alloys.

Underground. An excellent contribution to a better understanding of underground corrosion problems, made by Romanoff (10E), comprises the final report on studies conducted from 1910 to 1955 in an extensive field burial program and laboratory studies of electrical and electrochemical aspects. The data on lead are very valuable and recommended to those interested or active in the mitigation of lead corrosion problems.

Adding to the "phenol corrosion" controversy is the paper of Sears and Pichimory (12E). They characterize the white corrosion of lead sheath as the result of attack by volatile fatty acids present in the form of esters in raw jute used to pack cables. Again, the effect is attributed to the action of bacteria which hydrolyze the esters, and not to phenol.

Environmental. Another extensive investigation initiated in 1940 in the Panama Canal Zone reveals the corrosion properties of lead and other metals and alloys exposed to five natural tropical environments for 1, 2, 4, 8, and 16 years (1E). Up to 1957 specimens through the 8-year period were removed and examined. The report compares lead with respect to rates for aluminum, nickel, zinc, copper and structural steel.

Chemical. A relation between the catalytic effect of copper on oil oxidizability and corrosiveness of oils with respect to lead and antifriction bearing platings of lead and indium is reported by Drozhinina and Lartsanian (4E). A treatment of anticorrosive additions is also given. The corrosion properties and electrolytic deposition techniques for lead-nickel alloys containing up to 6% lead were outlined by other Russian investigators (7E).

That aluminum enamels resist corrosion by boiling alkaline water was amply demonstrated by King and others (6E). The enamels for aluminum which exhibited corrosion rates of about 1% that of bare aluminum when exposed to boiling water for 100 hours are lead bearing.

Ceramics

Basically, the number of papers presented at the American Ceramic Society's annual meeting and their titles best represent the scope of present lead usage or contemplated future usage in ceramics:

Phase relations in lead niobate, $PbNb_2O_6$	(1F)
Ceramic and dielectric properties of lead metaniobate electrical ceramics	(2F)
Polymorphism and ferroelectricity of lead metatantalate	(6F)
Dense aluminosilicate bodies having low firing shrinkage	(1F)
Phase equilibria in the binary system $PbO-Nb_2O_5$ and compounds of niobia and tantala with PbO, BaO, and SrO	(5F)
Piezoelectric ceramics	(8F)

Chemistry

The composition and isotopic constitution of the gaseous products of the pyrolysis of lead oxalate have been studied for reactions between 350° and 625° C. (4G) Thermal decompositions of alpha-lead azide and lead carbonate were studied by Griffiths and Groocock (1G) and Peretti (2G). The study of lead azide entails kinetics and the reaction mechanism, whereas for lead carbonate, the solid phases formed by three stages of decomposition were found to be $PbO \cdot PbCO_3$, $2PbO \cdot PbCO_3$, and PbO in order of increasing temperatures. Growth of lead nitrate crystals was further investigated by Williams (3G).

New Publications

The Lead Industries Association publishes quarterly the magazine *Lead* (1H), which covers many new uses as well as new slants on the old. Annual review articles were prepared for *Engineering and Mining Journal* (12H), *Steel* (13H), Industrial and Engineering Chemistry (5H), and the "Year Book of the American Bureau of Metal Statistics" (3H). "Use Lead to Control Refinery Corrosion" (9H) deals with the latest practices in lead chemical construction which explain how to get best results with lead-lined equipment. A treatise on leaded steels (11H) was published by the Office of Technical Services, U. S. Department of Commerce, with the view of extending industrial uses.

Red Lead Technical Letter (4H) offered highway engineers specifications for complete paint systems to be used in protecting highway structural steel. *Lead Building Construction Bulletin* (2H) offered specifications for lead chemical laboratory drainage systems. "Lead in the Ceramic Industries" (3H) was supplemented by sections devoted to enamels for application to glass, and low-temperature glasses as bonding materials for crystals, information useful in the industry.

The new supplement to the "Encyclopedia of Chemistry" contains a section on annealing metals which gives additional metallurgical data (7H). And filling the need for a compiled source of data in so far as underground corrosion is concerned is Romanoff's (10H) "Underground Corrosion," covering 45 years of research and testing. Finally, another engineering materials handbook contains a section on lead with useful data on corrosion as well as other application areas (6H).

Literature Cited

Engineering Advances

(1) *Chem. Week*, 82, 55 (May 10, 1958).
(2) *Corrosion Prevention and Control* IV, 35-6 (August 1957).
(3) Flora, J. W., "Educational Uses of the Small 5-Watt Laboratory Reactor," Paper 57-NESC-73, 2nd Nuclear Engineering and Science Conference, Philadelphia, 1957.
(4) Kurtz, J. A., *IBM J. Research and Development* 1, 373 (October 1957).
(5) *Lead* 21, No. 1 (1957).
(6) *McGraw-Hill World News*, May 4, 1958.
(7) Reed, H. B., Jr., Goldberg, M. B., "Unique Dry Battery," 112th Meeting, Electrochemical Society, Buffalo, October 1957, (to U. S. Government) U. S. Patent 2,697,736.

Research Progress

(1A) Akers, P. B., *Phys. Rev.* 105, (1) 104-8 [n] (1957).
(2A) Barth, N., *Z. Physik* 148, No. 5, 646-52 (1957).
(3A) Bloem, J., Kroger, F. A., *Philips Research Repts.* 12, 281-302 (August 1957).
(4A) *Ibid.*, pp. 303-8.
(5A) Brebrick, R. F., "Density of Lead Sulfide, Lead Selenide, and Lead Telluride," U. S. Naval Ordnance Laboratory, Navord Rept. 4429 (October 1956) (11570 ; 35 5 Contin).
(6A) Felczmarski, A., Glass, I., Piwkowski, T., Turski, A., *Acta Phys. Polon.* 15, No. 5, 275-82 (1956).
(7A) Hake, R. R., Mapother, D. E., *Physics & Chem. of Solids* 1, 199-208 (November 1956).
(8A) Humphery, J. N., Petritz, R. L., *Phys. Rev.* 105, Ser. 2, 1192-7 (Feb. 15, 1957).

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(9A) Jona, F., Shirane, G., Mazzi, F., Pepinsky, R., *Ibid.*, 105, pp. 849-56 (Feb. 1, 1957).
(10A) Jones, E., *J. Electrochem. Soc.* 105, 37-40 (1958).
(11A) Kloerss, H. A., Harbarra, A. H., Coe, A. P. M., *Ibid.*, 104, 93-108 (1957).
(12A) Pawlek, F., Roeslel, K., *Arch. Eisenhütten.* 28, 241-4 (April 1957).
(13A) Pearson, W. B., Templeton, I. M., *Phys. Rev.* 109, 1094 (Feb. 15, 1958).
(14A) Scanlon, W. W., "Recent Studies of the Properties of PbS, PbSe, and PbTe," Electronics Division, Electrochemical Society, New York, 1958.
(15A) Shakhtarsch, M. L., Ivanko, K. G., Kramarov, O. P., Khotakov, A. L., *Doklady Akademii Nauk S.S.S.R.* 111, 1025-8 (Dec. 11, 1956).
(16A) Wachtel, A., "Effect of Impurities on the Plaque Brightness of a 3000° K. Calcium Halophosphate Phosphor," Electronics Division, Electrochemical Society, New York, 1958.

Physical Metallurgy

(1B) Atwater, H. A., Chalmers, B., *Can. J. Phys.* 35, 208-15 (1957).
(2B) Goble, D., *Z. anorg. Chem.* 284 (1/3), 142-3 (1956).
(3B) Hofmann, W., Maatsch, J., *Z. Erzbergbau u. Metallhüttenw.* 10, 313-17 (July 1957).
(4B) Hooker, E. J., *J. Inst. Metals* 86, Pt. 2, 98-107 (October 1957).
(5B) Kaiser, J., *Forsch. Gebiete Ingenieurw.* 23, No. 1-2, 38-42 (1957).
(6B) Mannchen, W., Baumann, M., *Metall* 9, 686-688, (August 1955) (in German).
(7B) Mikryukov, V. E., Tyapunina, N. A., *Fiz. Metal. Metalloved.* 3 (1), 31-41 (1956) (in Russian).
(8B) Prasad, S. C., Wooster, W. A., *Acta Cryst.* 9 (1), 38-42 (1956) (in English).
(9B) Treul, R. J., *J. Inst. Metals* 85 (9), 409-12 (1956-57).
(10B) Umekawa, S., *Nippon Kinzoku Gakkai-Si* 19 (8), 473-475 (1955) (in Japanese).
(11B) Van Duijn, J., Van Galen, J., *Physica* 23, 622-4 (July 1957).
(12B) Waseman, C. D., Sherby, O. D., Dorn, J. E., *Trans. Am. Inst. Mining Met. Engrs.* 209 (1), 57-59, (1957); *J. Metals* 9 (1957).
(13B) Zalkin, A., Ramsey, W. J., *J. Phys. Chem.* 60, 234-6 (1956).

Mechanical Metallurgy

(1C) Beach, J. G., "Status of Electroplated Metal Coatings on Titanium," NP-6379, Battelle Memorial Institute, Titanium Metallurgical Lab., Columbus, Ohio, May 10, 1957.
(2C) Brock, G. W., Sinclair, G. M., "Investigation of Fatigue Characteristics of Leaded Alloy Steel" (Contract NOrd 16417, Final report, ILU TAM 105), Illinois University, Dept. of Theoretical and Applied Mechanics, Urbana, Ill., September 1956 (Office of Technical Services, PB 121834).
(3C) Gifkins, R. C., *J. Inst. Metals* 86 Pt. 1, 15-6 (September 1957).
(4C) Hoover, H. A., *Trans. Am. Inst. Elec. Engrs.* 75 (Power Apparatus & Systems), No. 28, 1517-25 (February 1957) (Paper 56-933).
(5C) Pattee, H. E., Evans, R. M., "Performance of Some Soft Solders at Elevated Temperatures and Pressures," Symposium on Solder, ASTM Spec. Tech. Pub. 189, Am. Soc. Testing Materials, pp. 103-14, 1957.
(6C) Phillips, W. J., Barron, D. B., *Iron Age* 180, 102-3 (Aug. 15, 1957).
(7C) U. S. Dept. Commerce, Office of Technical Services, "Literature Survey on Leaded Steels," PB 111917 (1957).

Nuclear Physics and Nucleonics

(1D) Brookhaven National Lab., Upton, N. Y., "Classified Progress Report of Reactor Science and Engineering Department, Jan. 1-March 31, 1956," BNL-32, (declassified Feb. 14, 1957) (Office of Technical Services).
(2D) Chappell, D. G., *Nucleonics* 15, 52-3 (January 1957).
(3D) Lewis, G. P., "Primary Shield Materials Study," CERD-SIC-106, Combustion Engineering, Inc. Reactor Development Div., Windsor, Conn., Contract AT(30-3)-170 (SIC MD/56-102) (decl. April 4, 1957) (Office of Technical Services).
(4D) Muller, R. C., Robinson, C. S., *Am. Proc.* 2, 129-36 (August 1957).
(5D) Phillips Petroleum Co., Atomic Energy Div., Idaho Falls, "Shielding Requirements for Shipment of Metallurgical Samples," Idaho, IDO-16064, Contract AT(10-1)-205 (decl. July 27, 1956) (Office of Technical Services).
(6D) Seban, R. A., Casey, D. F., "Heat Transfer to Lead Bismuth in Turbulent Flow in an Annulus," AECU-3164, California Univ., Berkeley, Inst. of Engineering Research, Conversion Research Project, Contract AT-11-1-GEN-10 (June 22, 1956) (Office of Technical Services).
(7D) Seeliger, K., *Planseeber. Pulvermet.*, 4 (2), 37-42 (1956).
(8D) Tomm, M. E., Stephens, W. E., *Phys. Rev.* 108, Ser. 2, 77-81 (Oct. 1, 1957).
(9D) Strand, W. G., "Penetration of Graphites of Different Porosity by Lead Bismuth Eutectic," CP-2262, Chicago Univ. Metallurgical Lab., Final Report (decl. Feb. 18, 1957) (Office of Technical Services).

Corrosion

(1E) Alexander, A. L., others, "Corrosion of Metals in Tropical Environments. Pt. 1. Test Methods Used and Results Obtained for Pure Metals and A Structural Steel," NRL-4929, Naval Research Lab., Washington, D. C., 1957.
(2E) Burbank, J., "Anodic Oxides on Lead," 112th meeting, Electrochemical Society, Buffalo, October 1957.
(3E) Druzhinina, A. V., Tarmasian, O. S., *Khim. Tekhnol. Topliva i Masel*, No. 7, 43-49 (July 1957) (in Russian).
(4E) Halsted, P. E., *Chem. & Ind.* (*London*), 1957, pp. 1132-7.
(5E) Jones, F. E., *Ibid.*, pp. 1050-63.
(6E) King, B. W., Duckworth, W. H., Schultz, J., Tripp, H. P., *Ceram. Ind.* 69, 82-4 (October 1957).
(7E) Mullarkey, E. J., "Lead Acid Brick Construction," Chemical Industry Symposium, National Association of Corrosion Engineers, San Francisco, 1958.
(8E) Mullarkey, E. J., *Petrol. Refiner* 37, 201-6 (April 1958).
(9E) Pourbaix, M., Lessons on Electrochemical Corrosion, Centre Belge d'Étude de la Corrosion, Rapport Technique, No. 49 (July 1957) (FA 442 (23e Via.) (French).
(10E) Romanoff, M., Natl. Bur. Standards, Circ. 579, (1957).
(11E) Ruetschi, P., "Electrochemical Properties of PbO_2 and Anodic Corrosion of Lead and Lead Alloys," 112th Meeting, Electrochemical Society, Buffalo, October 1957.
(12E) Simon, J. C., Pichamaty, F., *Corrosion et anticorrosion* 5, 203-9 (July-August 1957) (French).
(13E) Tomina, K. M., Kurbatova, N. T., *Doklady Akad. Nauk S.S.S.R.* 115, No. 3, 280-82 (July 21, 1957) (Russian).
(14E) Turner, A., Wellington, J. R., Williams, L., "Use of Lead in Chemical and Metallurgical Plant Construction," U. S. Chemical Engineering Conference, Montreal, Canada, April 1958.

Ceramics

(1F) Arlett, R. H., Swoke, E. J., DeVita, S., "Dense Aluminosilicate Bodies Having Low Firing Shrinkage, Part II," 60th Annual Meeting, American Ceramic Society, Pittsburgh, 1958.
(2F) Cook, W. R., Jr., "Phase Relations in Lead Niobate, $PbNb_2O_6$," 60th Annual Meeting, American Ceramic Society, Pittsburgh, 1958.
(3F) Jaffe, H., "Piezoelectric Ceramics," 60th Annual Meeting, American Ceramic Society, Pittsburgh, 1958.
(4F) Nelson, K. E., Cook, R. L., "Ceramic and Dielectric Properties of Lead Metaniobate Electrical Ceramics," 60th Annual Meeting, American Ceramic Society, Pittsburgh, 1958.
(5F) Roth, R. S., "Phase Equilibria in the Binary System PbO-Nb_2O_5 and Compounds of Niobia and Tantala with PbO, BaO, and SrO," 60th Annual Meeting, American Ceramic Society, Pittsburgh, 1958.
(6F) Subbarao, E. C., Shirane, G., Jona, F. P., "Polymorphism and Ferroelectricity of Lead Metatantalate," 60th Annual Meeting, American Ceramic Society, Pittsburgh, 1958.

Chemistry

(1G) Griffiths, P. J. F., Groocock, J. M., *J. Chem. Soc.* 1957, 3380-9.
(2G) Perrott, E. A., *J. Am. Ceram. Soc.* 40, 171-3 (May 1957).
(3G) Williams, A. F., *Phil. Mag.* 2, Ser. 8, 217-22, (March 1957).
(4G) Yankwich, P. E., Copeland, J. L., *J. Am. Chem. Soc.* 79, 2081-6 (1957).

New Publications

(1H) Lead Industries Assoc., 60 East 42nd St., New York, N. Y., *Lead*.
(2H) Lead Industries Assoc., *Lead Building Construction Bull.* 5 (1957).
(3H) Lead Industries Assoc., "Lead in the Ceramic Industries," 1956.
(4H) Lead Industries Assoc., *Red Lead Tech. Letter* 12 (1957).
(5H) Lead Industries Assoc., in "Year Book of American Bureau of Metal Statistics," pp. 39, Maple Press, York, Pa., 1958.
(6H) Mantell, C. L., ed., "Engineering Materials Handbook," McGraw-Hill, New York, 1958.
(7H) Mullarkey, E. J., "Annealing Metals," Encyclopedia of Chemistry, ed. by G. L. Clark, G. G. Hawley, Reinhold, New York, 1958.
(8H) Mullarkey, E. J., Ind. Eng. Chem. 49, 1607-11 (1957); *Lead Industries Assoc. Bull.* 19.
(9H) Mullarkey, E. J., *Petrol. Refiner* 37, 201-6 (April 1958).
(10H) Romanoff, M., Natl. Bur. Standards, *Circ.* 579 (1957).
(11H) U. S. Dept. Commerce, Office of Technical Services, "Literature Survey on Leaded Steels," PB 111917 (1957).
(12H) Zingeleld, R. L., *Eng. Mining J.* 159, 133-5 (February 1958).
(13H) Zingeleld, R. L., *Steel* 142, 247 (Jan. 6, 1958).

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