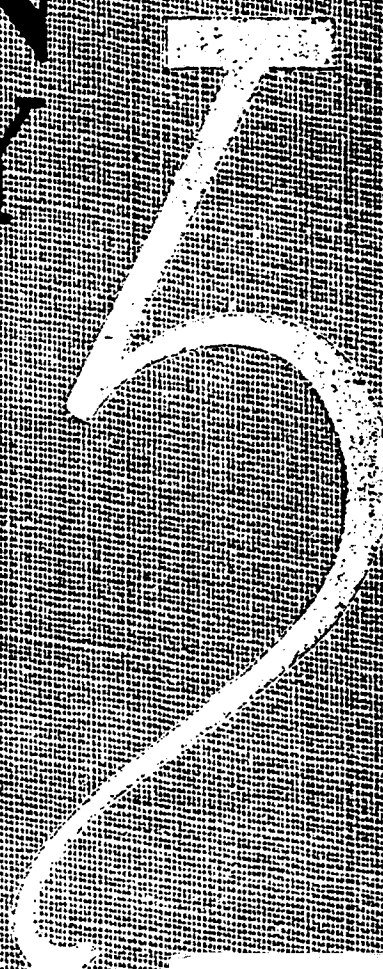


LEAD

**In MODERN
INDUSTRY**





LEAD

In Modern Industry

MANUFACTURE, APPLICATIONS AND PROPERTIES
OF LEAD, LEAD ALLOYS, AND LEAD COMPOUNDS

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Foreword

NO METAL, perhaps, has as wide a variety of uses as lead nor contributes more broadly to our modern way of life. Lead is vital to all our modern means of rapid transportation—airplane, automobile, railroad and ship; it is essential to modern methods of communication and electrical power transmission, and to the use of X-rays and radium; it plays a vital rôle in the development and utilization of atomic energy; it is a part of the finest plumbing, one of the greatest contributions to the comfort and sanitation of modern homes; it makes possible the economical production of many of the most useful chemicals and their derivatives of this chemical age. The list could be extended almost indefinitely.

The interesting thing is that these varying uses depend not upon a single property or characteristic of lead but upon many different properties. It is employed in some instances primarily for its weight, in others because of its resistance to corrosion, or its softness and malleability, or its atomic weight, or its ability to alloy readily with certain other metals to change or modify its properties. Lead is particularly unusual among the metals in that about a third of all the lead used is the result of properties of its chemical compounds, many of which, like white lead, red lead, litharge and tetraethyl lead, are of immense industrial importance.

Old as the use of lead is, its age has merely enabled us to learn more about it and thus adapt the metal to our needs. Many of its most important applications are developments of very recent years. Tetraethyl lead, lead azide and lead soaps for greases, lead in steel, lead alloys for stamping aluminum, lead molds and lead compound stabilizers for plastics, lead counterweights in aircraft are just a few of these recent applications that are leaving a decided impression on modern living.

Modern research, too, has broadened the application of old and established uses of lead. The field of lead-base bearing alloys has been substantially widened, lead and lead-alloy coatings for other metals have stepped into the limelight and new formulations for metal primer paints have increased the importance of red lead, to name only a few.

This book has been prepared to gather in one place a large amount of technical and general data regarding lead and its compounds so that metallurgists, chemists, engineers, executives and others may determine more readily whether lead has properties that can help them in these rapidly changing times. No claim is made that the data are complete or that new developments may not make some of it obsolete from time to time. Therefore, the Lead Industries Association stands ready to help further if this book does not answer all questions.

In peace and in war, lead has been and will continue to be one of mankind's most useful metals. Despite its antiquity, we have only begun to learn what lead can do for us in modern living. Lead has many personalities. Understanding them enables us to put lead to use for the greatest good of the greatest number of people.

CHAPTER ONE

The History of Lead

LEAD is one of the oldest metals known to man and many of its modern uses have persisted through centuries. It was utilized in many ancient lands and for strangely varied purposes. The earliest known specimen of lead, dating from 3000 B.C., is a figure found at the Dardanelles on the site of an ancient city called Abydos. The heavy gray metal was evidently well known in Biblical times for it is mentioned in Exodus and several other places in the Old Testament. In the days of the Pharaohs lead was used to glaze pottery, to make solder and ornamental objects. Old lead pipes have also been found in Egypt. In ancient India red lead was used as a cosmetic by women, while the metal itself was employed for weights of various kinds, for purifying silver, as a charm, and as an early monetary medium. The Assyrians had many uses for lead, and the hanging gardens of Babylon were floored with sheets of lead soldered together to retain the moisture which the vegetation demanded. Babylonians also used lead for calking purposes and to fasten iron bolts in the masonry of bridges, dams, and other stone structures, much as it is used to-day.

The ancient Chaldeans of Persia were well acquainted with lead; in fact, they were the first to associate metals with gods, the sun, moon and planets. This custom was handed down to the alchemists, predecessors of modern chemists. The alchemists used planetary signs in their writings to represent the metals. Thus their sign for Saturn, ♄, was used to designate lead. Authorities differ as to the reason for connecting lead with Saturn, some saying because the alchemists considered lead to be the oldest of the metals and Saturn, the father of the gods; others

that the dull, heavy metal reminded them of Saturn, the most distant and slowest moving planet.

In 2000 B.C. the Chinese made their first money of lead, and later, when silver coins came into use, the government forbade working the lead mines to stop counterfeiting. Imagine the crippling effect on industry were such a step taken in modern times! In ancient Greece and Rome bronze coinage contained from 3 to 30 percent lead. Counterfeiters and impoverished governments have often made lead coins coated with the precious metals.

One of the most important historical applications of lead was its general use for water pipes by the Roman people. The pipe was made in fifteen standard sizes and regular ten-foot lengths. Many of these pipes, in almost perfect states of preservation, have been dug up in recent years in the ruins of Pompeii and Rome, and in England, where the Romans penetrated during invasions. Roman public baths were often completely lined with sheets of lead. A room in a house in Pompeii has been uncovered in which the walls were completely moisture proofed with lead. The Romans used the word "plumbum," lead, to denote spouts, or water conductors, and the same word finds its modern counterpart in our word plumber. Romans also understood the art of lead burning and soldering.

Lead has always had an important place as an article of warfare. Our modern bullets and shot were preceded by leaden projectiles hurled from slings, and molten lead or great chunks of the solid metal were often thrown down from the battlements of a besieged town upon its invaders. Roman gladiator pugilists wore leaden knuckles to give their blows more authority.

Many famous warriors, among them the Black Prince and Richard II, as well as men prominent in more peaceful walks of life, lie buried in leaden caskets, beautifully decorated and inscribed. Richard Coeur de Lion's heart was for many years kept in a lead casket at Rouen. Another lead casket in the Santo Domingo Cathedral is said to be the resting place of Columbus. Still another, recently found in England, is believed to be that of

teacher of Ptolemy Philadelphus, was so thin that he wore lead soled shoes to keep from being blown over. Greek gamblers used lead-loaded dice.

In medieval times lead was widely used as a material of construction. Many magnificent buildings built in the 15th and 16th centuries still stand under their original lead roofs. Leaden ornaments, statues, leader-heads and cisterns were widely used and lent distinction to the arts of the period. Although many of these old uses were based on some supposed property of lead that did not exist, by far the majority depended on the easy working qualities, the permanence and beauty of lead.

CHAPTER TWO

From Mine to Finished Metal

A DULL colored pig of lead gives no inkling of the romantic story connected with its production. It fails to reveal, for one thing, the risk someone must have taken to discover the lead ore from which the metal was made, or the effort required in mining, the skill necessary to concentrate the ore, and the technique involved in subsequent smelting and refining. Without some appreciation of these items an uninformed reader is apt to imagine that lead mining, in common, perhaps, with other metal mining, is a simple and immensely profitable business with few of the worries plaguing other occupations. The following paragraphs are intended, therefore, to tell briefly those who are interested where lead is mined and how it becomes a raw material of commerce.

Although today reliable figures on lead production and consumption from some countries are not available, it can be estimated that the world produces and uses close to 2,000,000 tons of lead in a single year. Although the United States is the principal lead producing country it only mines about 20 percent of world consumption and practically all this is used within its borders. In addition, it produces almost an equal amount from scrap and imports enough additional lead from Mexico, Canada, Peru, Australia, Europe and elsewhere, to bring United States consumption up to about half of the world's total.

Mexico normally ranks second in world lead mine production, followed by Australia and Canada. Peru, Yugoslavia, Germany, French Morocco, Italy, Southwest Africa, Spain and many other countries are also important producers.

In the United States, Missouri mines the most lead, with Idaho, Utah, Arizona, Colorado, Montana and others adding to the supply in the order named. The lead mining districts of the Union

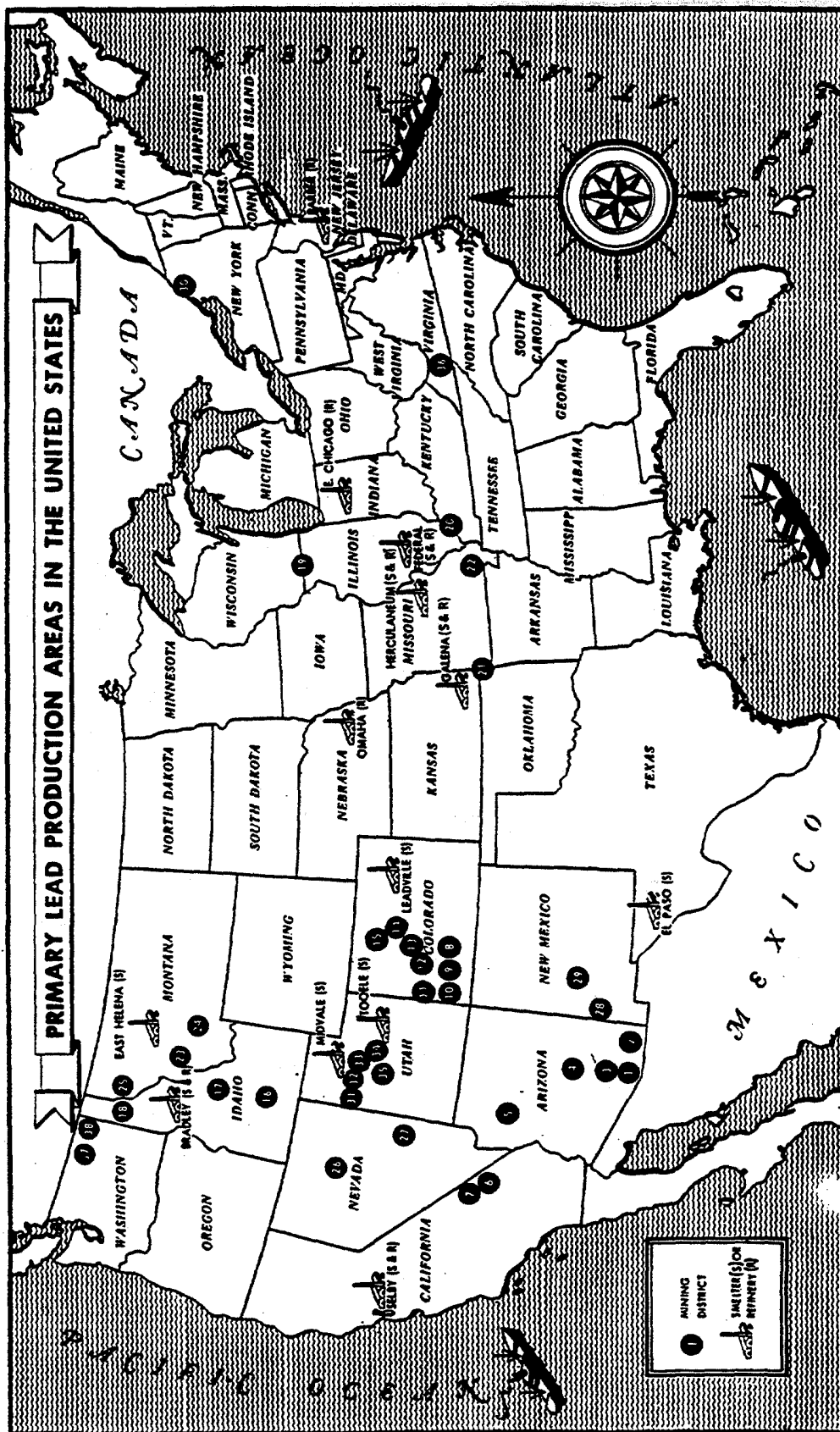
have contributed immeasurably to the welfare and prosperity of their respective States.

Lead occurs in nature usually associated with other metals, notably silver and zinc. Its association with silver is especially noteworthy, and there was a time, not so many years ago when lead was considered mainly a by-product of silver mining to be sold for extremely low prices. Although many minerals containing lead are known, the most important by far is *galena* (lead sulphide), an easily recognized, brightly metallic mineral. Of the other lead minerals the carbonate, *cerrusite*, and the sulphate, *anglesite*, are of commercial importance, but are not so frequently found as *galena*.

It is very pleasing to the miner to find and mine ore rich enough in lead to be shipped directly to a smelter without intermediate processing; but he is ordinarily not so lucky. He is indeed fortunate to find any ore even after extensive and costly prospecting with churn drill, diamond drill, shafts, drifts, crosscuts and other development work. Sometimes an ore is phenomenally rich in lead but contains so much zinc and copper that special treatment is required. More often the miner will struggle with a low grade of lead ore, perhaps as low as 3 percent lead, and attempt to mine it at a profit. One large mining company has to mine about 3,000,000 tons of ore to recover 100,000 tons of lead. Obviously, with low grade ore, large amounts of waste rock, or gangue, must be removed before shipment to a smelter in order to reduce transportation and smelting charges. Moreover, it is necessary to remove nearly all zinc-bearing minerals in the ore so that the miner will not be penalized by the lead smelter for the zinc content, which is classed as an "impurity," because it interferes with the lead smelting operation.

CONCENTRATING THE ORE

To concentrate the lead ore it is crushed extremely fine, sometimes to particles less than 1 mm. in diameter, and treated by one of the modern processes of mineral concentration. The remarkable flotation process may be used, a method simple enough to describe but complicated in execution, and such an important and marvelous metallurgical development of the twentieth cen-



PRIMARY LEAD PRODUCTION AREAS IN THE UNITED STATES

STATE	NO.	DISTRICT	COUNTY OR COUNTIES
ARIZONA	1	HARSHAW	SANTA CRUZ
	2	WARREN (BISBEE)	COCHISE
	3	PIMA	PIMA
	4	OLD HAT	PINAL
	5	BIG BUG	YAVAPAI
CALIFORNIA	6	RESTING SPRINGS	INYO
	7	COSO	INYO
COLORADO	8	CREEDE	MINERAL
	9	ANIMAS	SAN JUAN
	10	PIONEER (RICO)	DOLORES
	11	UPPER SAN MIGUEL	SAN MIGUEL
	12	SNEFFELS	OURAY
	13	TOMICHI	GUNNISON
	14	LEADVILLE	LAKE
	15	RED CLIFF	EAGLE
IDAHO	16	WARM SPRINGS	BLAINE
	17	BAY HORSE	CUSTER
	18	COEUR D'ALENE	SHOSHONE
ILLINOIS	19	UPPER MISSISSIPPI VALLEY	NORTHERN PART OF STATE
	20	KENTUCKY AND SOUTHERN ILLINOIS	HARDEN
KANSAS	21	TRI-STATE AREA	CHEROKEE
KENTUCKY	20	KENTUCKY AND SOUTHERN ILLINOIS	CRITTENDEN
MISSOURI	21	TRI-STATE AREA	12 COUNTIES IN SOUTH- WESTERN PART OF STATE
	22	SOUTHEASTERN MISSOURI AREA	SOUTHEASTERN MISSOURI
MONTANA	23	BUTTE	SILVER BOW
	24	HEDDLESTON	LEWIS & CLARK
	25	EAGLE	SANDERS
NEVADA	26	BATTLE MOUNTAIN	LANDER
	27	PIOCHE	LINCOLN
NEW MEXICO	28	CENTRAL	GRANT
	29	MAGDALENA	SOCORRO
NEW YORK	30		ST. LAWRENCE
OKLAHOMA	21	TRI-STATE AREA	OTTAWA
UTAH	31	OPHIR	TOOELE
	32	RUSH VALLEY	TOOELE
	33	BINGHAM	SALT LAKE
	34	PARK CITY	SUMMIT, WASATCH
	35	TINTIC	JUAB, UTAH
VIRGINIA	36	AUSTINVILLE	WYTHE
WASHINGTON	37	BOSSBURG	STEVENS
	38	METALINE	PEND OREILLE
WISCONSIN	19	UPPER MISSISSIPPI VALLEY	LAFAYETTE, IOWA, GRANT

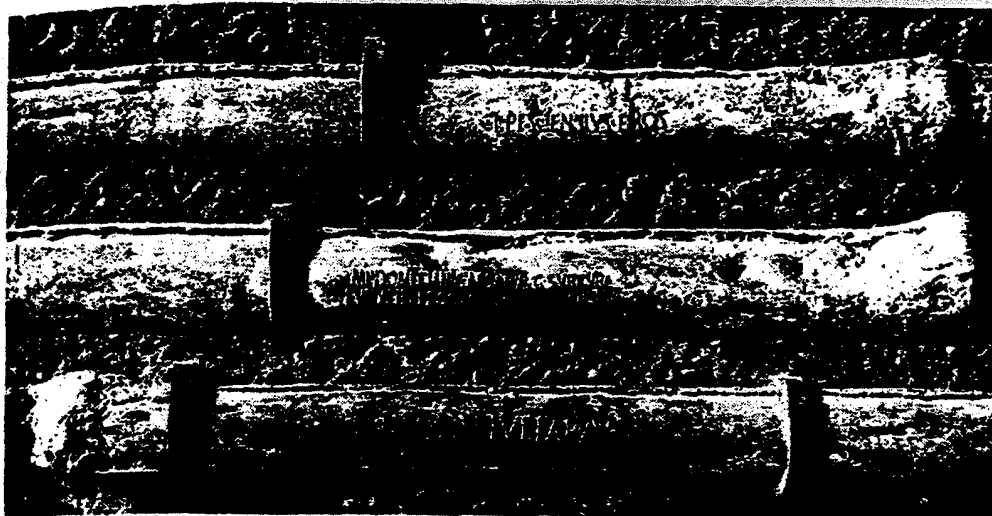
ture that it has left a deep impression upon the lead and practically all other metal mining industries. Flotation is applicable principally to the sulphide type of ore, fortunately the commonest variety, or to an oxide ore which has received a preliminary sulphiding. Briefly, the flotation process generally constitutes taking finely crushed ore diluted with, say, four times as much water, and agitating the mass violently with air in a tank to which a fraction of one percent of pine oil, with or without small amounts of other suitable chemicals, has been added. As a result of the agitation a froth containing most of the metallic constituents of the ore is formed on top of the tank while the valueless gangue matter remains unaffected at the bottom of the tank. The froth flows from the tank and is easily dried.

Flotation practice has reached such a stage of perfection that extraordinarily efficient work is being done, not only in extracting a single mineral from an ore, but also in separating the several minerals in so-called complex ores, for example, an ore consisting of an intimate mixture of lead, copper and zinc minerals. For years the treatment of many complex ores baffled metallurgists, but with selective flotation as a tool, many mineral deposits considered practically worthless a few years ago have developed into important lead mines. Furthermore, many straight lead ores formerly believed too low grade for economical treatment have suddenly become profitable possibilities, adding greatly to the world's available lead reserves.

Flotation has, to a considerable extent, supplanted earlier methods of concentration using gravitational methods of milling, that is, pulsating jigs, vibrating tables, and many other machines, but the older mechanical methods are used alone or with flotation in treating many ores for which they are particularly suited.

SMELTING THE CONCENTRATES

Lead concentrates when they leave the mill contain 40 percent and upwards of lead. The richer the lead content the better, for it reduces transportation and smelting costs. Smelting is a continuous operation generally conducted in blast furnaces but, before the concentrates can be charged into the furnace, they



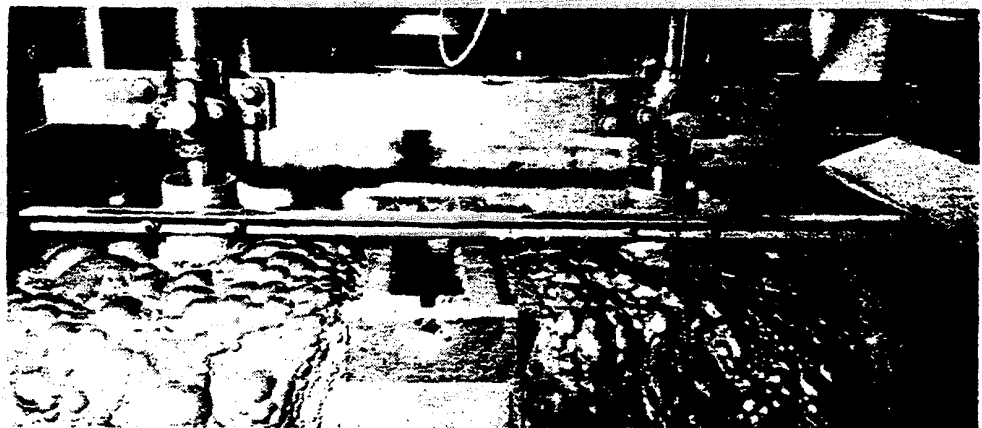
Almost perfectly preserved lead pipe used by the Romans for conducting water more than 1900 years ago.



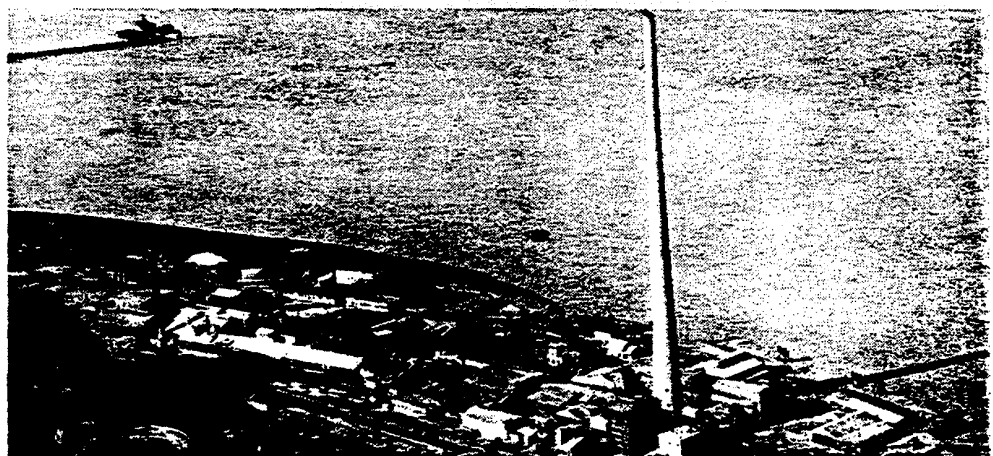
Lead covered domes of world famed St. Sophia in Istanbul. The lead roofs date from the middle of the Seventeenth Century.



Surface plant of a typical western lead mine and ore concentrating mill.



The lead-rich component of the ore is collected as a froth in flotation cells.



A lead smelter and refinery where the ore is reduced to pure metallic lead.

must be roasted to remove most of the sulphur contained in the concentrates and to agglomerate the very fine flotation product which is not a physically desirable blast furnace material. The roasted concentrate, or sinter, now in the form of lumps, is charged into the top of the heated blast furnace with limestone and other suitable fluxes and coke for fuel. A blast of air is admitted to the lower part of the furnace to aid combustion and to complete the formation of metallic oxides which are reduced to metal by the coke and carbon monoxide present. The non-metallic waste forms a slag with the fluxing materials.

The blast furnace is then tapped so that the lead flows off into kettles or molds. In this form the lead is a semi-finished product known as base bullion, containing silver and impurities. Specifically, base bullion contains small amounts of gold, silver, copper, zinc, antimony, arsenic, bismuth and other impurities which must be removed in whole or in part by refining to produce a commercial lead.

REFINING PROCESSES

The most widely used refining process is the Parkes process. By this treatment the lead is first melted and allowed to cool below the freezing point of copper, which crystallizes and is removed by skimming. It then passes to a reverberatory or softening furnace where the temperature is raised and the molten lead stirred. A blast of air oxidizes any antimony or arsenic present, both of which impurities harden lead (hence the term "softening" furnace), and these oxides are skimmed off.

A continuous softening process for the elimination of antimony and arsenic from lead bullion has been perfected which represents more than just a conversion from batch to continuous procedure. In this process, oxidation rates many times in excess of those obtainable by usual batch softening methods are realized by the continuous maintenance of the antimony content of the furnace metal within a determined optimum range of 0.01-0.05 percent antimony. The accelerated oxidation rate obtainable in continuous operations permits a marked reduction not only in the operational costs of batch methods, but also in space and equipment requirements.

After softening the lead goes to the desilverizing kettles where small quantities of zinc are added. Gold and silver are more soluble in zinc than in lead, and, consequently, any of these metals present in the lead immediately leaves it in favor of the zinc. As zinc is lighter than lead, the zinc rises to the surface and, when the temperature is lowered, solidifies, and is skimmed. This leaves only a little zinc remaining as an impurity which is oxidized and skimmed in a reverberatory furnace. A more recent development removes the zinc as a vapor by creating a vacuum over the surface of the molten lead. The zinc vapor is condensed as metal on the cool dome of the vacuum vessel and re-used. Refined lead becomes one of the purest of the commercial metals through this treatment, and is cast into pigs.

The Pattinson process, now rarely used, depends upon the fact that when lead is cooled slowly part of it will solidify and can be skimmed off while the silver will remain in the molten lead left behind. The Betts process, employed in several plants including one in the United States, is an electrolytic method advantageously used with bullion high in bismuth. The bismuth is removed and recovered, which is not the case with the Parkes process.

The Harris process of softening and dezincing by the use of molten caustic salts is used in some plants in England, Europe and Japan. The process is designed to remove impurities from molten desilverized lead by pumping it through a mixture of molten salts contained in a tank above the lead kettle. The metallic impurities react with the chemicals and are collected in the form of their oxides or oxysalts. The Harris process while sound in theory has not been universally adopted since in practice it cannot always compete economically with the Parkes or Betts process.

Some ores, such as those of southeastern Missouri, contain too little silver for profitable desilverizing. Therefore the finished pigs, while free from other impurities, are noted for their comparatively high silver and copper content and are given the designation "chemical" lead because of wide use in the chemical industries in the form of sheet and pipe. This is but one of the commercial grades of pig lead available to the consumer. These grades are described on page 70.

SECONDARY LEAD

The importance of secondary lead, which is derived from lead or lead alloy scrap cannot be underestimated. It is a significant factor in the lead market because lead is easily melted and refined and does not become contaminated by impurities during service. In 1950 in the United States, approximately 421,000 tons of lead were produced from secondary sources. This compares to a mine production figure of 430,000 tons. Over the past twenty-five years secondary lead accounted for slightly over 37 percent of the total amount of lead consumed in this country.

The chief source of secondary lead is from automobile storage batteries that have been scrapped, generally after about 2 years' service. It has been estimated that over a period of years, 80 percent of the lead used in the manufacture of storage batteries re-enters the market as secondary lead. Additional sources of secondary metal include cable sheathing, pipe and sheet, solder and lead drosses.

Secondary lead is reclaimed by fire refining methods in refineries usually devoted exclusively to the handling of secondary lead and lead alloys. A comparatively small percentage is also refined at primary refineries.

Much of the secondary lead produced is sold as lead alloy, particularly lead from reclaimed batteries and cable sheathing which contain small percentages of antimony and other metals. The bulk of the secondary lead recovered containing antimony is re-sold to battery manufacturers. Secondary lead containing tin is most often re-used in the manufacture of solder, bearing metals and other lead-tin alloys.

By applying proper refining techniques soft lead can be produced from secondary sources to meet primary lead specifications.

LEAD CONSUMPTION

The largest amount of lead used in the United States goes into the manufacture of storage batteries. Among the other top consumers of lead are cable covering, paint, construction (including chemical construction), and gasoline. The following tables show the uses of lead percentagewise from 1938 through 1950 and the amount of lead used for various purposes in 1950.

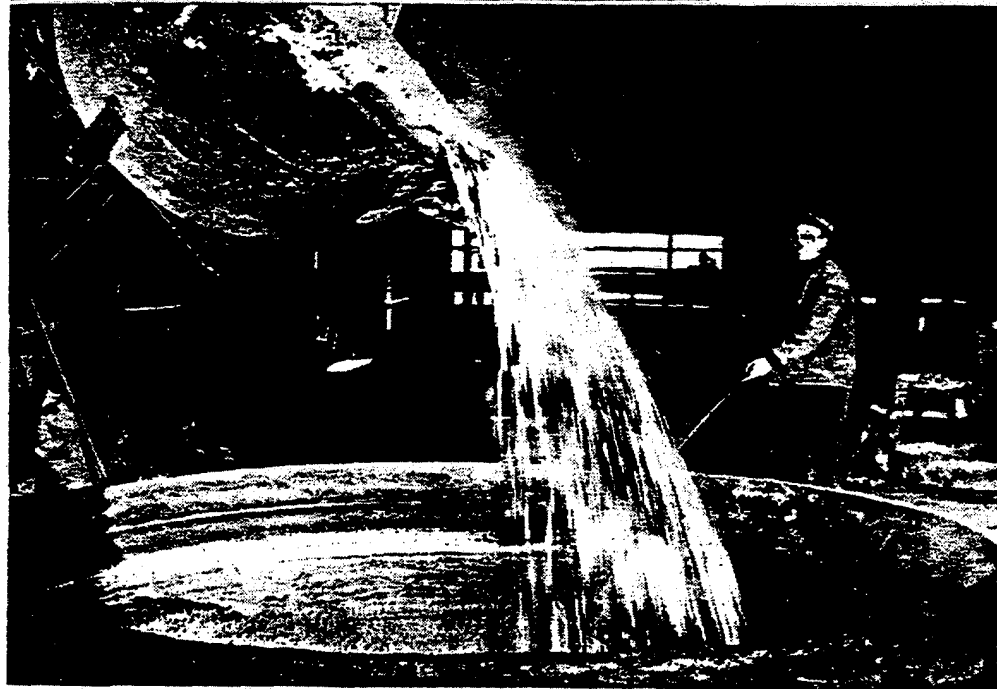
USES OF LEAD IN THE UNITED STATES BY PERCENTAGE *

Purpose	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949
White lead	13.00	11.24	8.88	8.10	7.50	4.55	5.50	4.10	5.19	4.60	3.04	2.37
Red lead and litharge...	7.87	8.58	7.59	8.48	6.80	7.18	7.84	6.82	6.59	5.60	5.22	5.60
Storage batteries	30.59	29.89	28.16	28.34	21.56	23.86	28.17	29.50	28.11	32.42	33.06	32.88
Cable covering	10.99	11.15	13.73	10.48	16.50	12.82	12.02	10.70	12.00	18.54	16.32	14.99
Building	6.59	7.50	8.81	9.05	11.00	5.64	6.42	6.80	8.43	6.66	5.89	5.55
Tetraethyl	4.73	4.50	6.81	4.74	4.88	5.48	7.82	7.59	5.10	5.68	7.42	11.72
Automobiles	1.10	1.33	1.41	1.14	0.30	0.00	0.09	0.10	0.11	0.09	0.09	—
Ammunition	5.71	6.84	7.10	6.81	8.30	16.18	5.78	4.80	3.24	3.41	3.76	2.07
Foil	4.03	3.27	3.00	4.29	0.77	1.18	1.47	1.56	0.43	0.81	0.27	0.31
Bearing metal	1.65	1.92	1.79	2.88	2.00	3.18	3.76	4.20	4.43	3.42	3.68	3.07
Solder	2.75	3.00	3.07	3.43	3.80	3.45	3.76	4.70	5.73	5.03	5.08	0.72
Typemetal	2.20	2.10	2.15	1.90	2.00	1.55	2.11	2.50	3.57	2.18	5.24	2.88
Calking	2.20	2.40	2.46	2.95	4.00	2.73	2.93	3.52	4.22	4.26	3.56	3.89
Other uses	6.50	6.98	6.48	6.91	10.59	12.61	12.83	13.61	12.76	12.71	9.67	8.50
Total tons	546,000	607,000	782,000	1,049,000	1,000,000	1,100,000	1,090,000	1,000,000	925,000	1,172,000	1,129,000	868,000

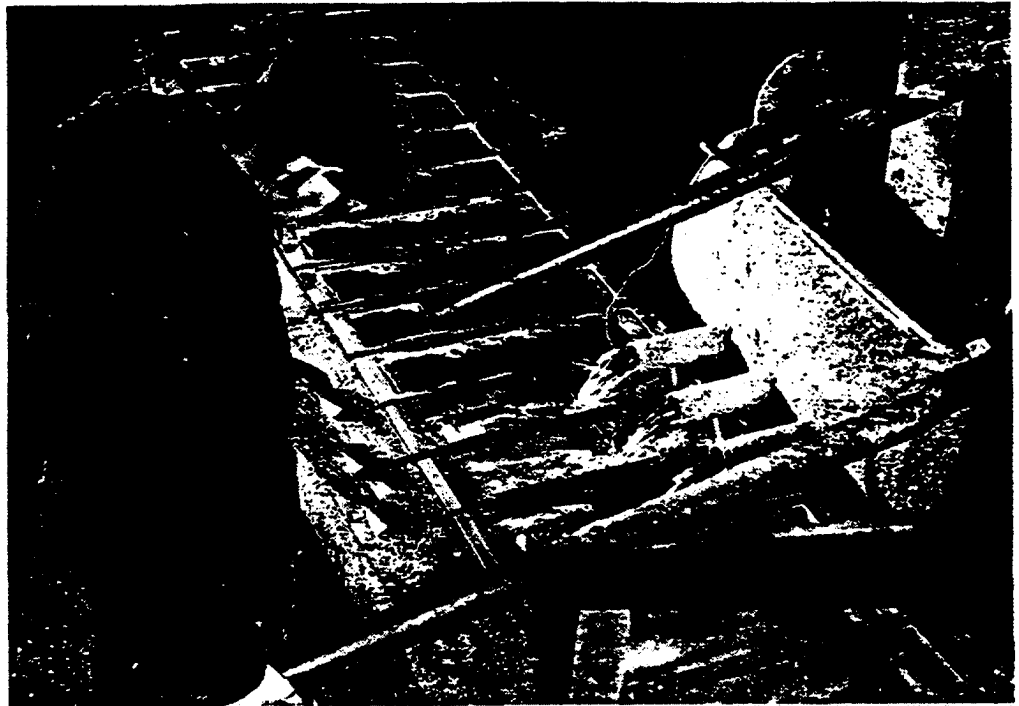
* American Bureau of Metal Statistics.



Tapping lead bullion from a lead blast furnace.



Pouring lead bullion into a kettle for fire refining.



Casting fully refined lead into pigs.



Pig lead ready to begin its service to industry.

FROM MINE TO FINISHED METAL

13

CONSUMPTION OF LEAD *

Use	Tons
Storage batteries	406,800
Cable covering	136,800
Building (including chemical construction)	61,500
Tetraethyl lead	111,100
Red lead and litharge (other than for storage batteries) ...	75,900
Solder	88,100
White lead	34,000
Calking	61,100
Bearing metal	33,100
Ammunition	32,800
Typemetal	30,900
Foil	3,300
Other uses	136,600
Total	1,212,000

* American Bureau of Metal Statistics.

CHAPTER THREE

Lead in Modern Living

TO UNDERSTAND the possibilities of lead, some knowledge of its existing uses and why it is used for these purposes is helpful. Its applications are so broad throughout industry that no review of them can hope to be complete or nearly complete. Yet this discussion will give some idea of how its properties are being put to work and what a factor it has become in our modern way of life.

We would still be cranking our automobiles and using gas lights on them were it not for the peculiar electrochemical properties of lead and its oxides utilized in storage batteries. This same kind of battery propels submarines under water, lights and air-conditions railway cars, is used in telephone communication, provides emergency power in utility plants, powers industrial trucks and mine locomotives, lights miners' lamps, and now even provides the power for pocket flashlights and hearing aids.

The corrosion resistance of lead, together with its flexibility, accounts for its broad use as sheathing for power and telephone cable, underground, under water and strung on poles, on land and on ships at sea. In this case, a seamless lead sheath is extruded around the insulated conductors which form the core.

Sulphuric acid and other corrosive chemicals are essential in the production of thousands of modern necessities and conveniences, from high explosives to rayon garments, from synthetic rubber and gasoline to fertilizers for the farm and garden. Equipment and pipe lines made of or lined with lead, which resists the fiery attack of these corrosives, make possible the economical production of many of these modern chemical wonders.

Lead's density supplies the necessary ballistic properties to small arms ammunition. Extruded as rod, the lead is cut and swaged in a single operation to the approximate size and shape

of bullet cores. For shot to be used in shot gun shells, it is poured through sieves from considerable height, forms by surface tension into round drops, and falls into vats of water. Large shot is cast.

Lead azide, a chemical compound, has become a standard detonator explosive because it is less sensitive to shock, flashes at a higher temperature, is more stable than those previously used, and can be stored at elevated temperatures for indefinite periods without deterioration. It makes possible safer, surer ammunition.

Lead takes wings in the latest high-powered aircraft in the form of counterweights in ailerons and rudders which eliminate flutter and provide ease of control through perfect balance. It is also used to balance propellers. Lead alloys often form the dies for stamping aluminum parts of these same planes.

Lead as an alloying element is found in bronzes and babbitts and, as the principal ingredient of lead-base bearing alloys, has reduced costs and removed our dependence on imported tin. These alloys are found in all kinds of vehicles on land, sea and in the air, and wherever machinery is used. Even more universal in use are the soft solders, which are alloys of lead and tin usually, but may be alloys of lead and other metals. Low melting alloys of lead are used as matrices to hold punches in intricate dies and for bending tubing. Hardening in liquid nitrogen enables certain lead alloys to be used as the die material itself for short-run sheet metal stamping.

The X-ray and gamma ray are both vitally important to medicine and are rapidly assuming equal industrial importance as a means of non-destructive testing for hidden flaws in products. The high density and atomic weight of lead make it the most efficient material economically to confine these rays to the places where they are useful and protect operators against their harmful effects. In the wartime development of the atom bomb and subsequent utilization of atomic energy, lead continues to play an indispensable rôle in protecting operating personnel by confining dangerous radiation.

Red lead paint is a standard protection for modern steel structures of all kinds, including buildings and ships, and white lead is one of the basic paint pigments used in the protection and beautification of our homes.

Tetraethyl lead in high octane gasoline has been a major factor in making possible the tremendous power of our airplane and automobile engines, while litharge is used to remove corrosive sulphur from motor fuel, thereby helping to prolong the life of these engines. Litharge, too, is an ingredient in the manufacture of both natural and synthetic rubber and in certain lubricating greases.

Broad use of lead and lead alloy coatings to prolong the life of iron and steel is a recent development. They are being used on a variety of steel products from telephone pole-line hardware to sheets for duct work. Coated steel is ideal for products that must be formed because the lead acts as a lubricant in the dies. For instance, it has been used widely in drawing steel shell cases. Lead added as an ingredient in steel is another modern development that has improved the machining properties of steel greatly, speeding production and increasing the life of tools astonishingly. Lead is also added to brass for the same reason.

In all sorts of building construction, lead has its part in the plumbing and water distribution systems. Modern plumbing and electrical installations, to both of which lead contributes so much, probably are the biggest advances in building construction of recent years, for it is not so long ago that such facilities were virtually unknown. Sheet lead is used, too, for roofing, flashing and other waterproofing on many structures, including refrigerator room linings on ships. Lead headed nails have a big field for fastening sheet steel. Lead is sometimes used for its non-sparking properties alone or combined with some of its other properties. Floors in plants where explosive substances are manufactured offer a good example. It is also used as lead mats to insulate against vibration both under building and machinery foundations, and on pipe line hangers, particularly on ships. Lead anchors are commonly used for fastening objects to concrete, stone or brick facings.

The plastics industry makes extensive use of lead. Metallic lead molds for plastics are made by several processes, including die-casting and dipping steel patterns into molten lead, the lead solidifying on the steel. Molds are stripped from the pattern, used once and remelted. Certain lead compounds are excellently suited and extensively used as heat and light stabilizers for

familiar household vinyl plastics. They prevent hardening and embrittlement and aging and discoloration on exposure to light.

Powdered metallic lead is added to grease for heavy duty machinery where it provides lubrication at heavy loads and prevents corrosion and frictional wear. Powdered lead is also used in the manufacture of bearings, heavy duty clutch facings and even as a pigment in paint.

The foregoing, as stated, is in no sense complete, but may give some idea of lead's wide range of usefulness and how many of our modern conveniences and necessities would be lacking without lead. Some of the most important applications and alloys are discussed on the following pages.

CHAPTER FOUR

Forms and Fabricating Processes

THOSE who wish to use lead not only have a choice among several grades of pure lead (see page 70) but of a variety of alloys as well. In addition, it can be obtained as pigs or ingots or special shapes, as semi-fabricated products in a variety of forms, and as completely finished items.

Pigs of lead and antimonial lead usually weigh about 100 lb. each, while ingots of lead or its alloys may have almost any desired weight and shape from the small 3- to 5-lb. cakes to be melted in portable gasoline furnaces to 100-lb. cylindrical billets to fit extrusion presses.

In semi-fabricated and fabricated form, a variety of lead and lead alloy products are available. Examples are:

- Extrudedpipe, rod, wire, ribbon, traps, bends,
wedge lead, special shapes
- Rolledsheet, foil, strip, blanks for drawing,
stamping and spinning, blanks of
various shapes
- Castsand or die-cast (gravity or pres-
sure)
- Chemical Compounds....oxides, carbonates, sulphates, chro-
mates, organic compounds, silicates,
acetate, etc.
- Othermetallic powder, wool, shot

Lead and its alloys can be fabricated by almost all commercial processes. It can, for instance, be extruded, drawn, rolled, cast, stamped, spun, and can be applied as a coating to other metals either by hot-dipping, electroplating or spraying. Thick layers of lead can be bonded to steel or other metals for greater strength. Joints may be made by soft soldering or welding.

The properties of lead and most of its alloys are quite different

from those of other metals, but this very difference makes lead peculiarly suitable for many applications where other metals would not be practical. On the other hand, it is often possible to gain some useful property of lead in cases where lead may not at first seem suitable, if these differences are clearly recognized. For instance, slight design changes or changes in manufacturing technique may make it possible to use lead with greater satisfaction in place of a metal with quite different characteristics.

In general, lead and its alloys have high resistance to corrosion, high specific gravity, are comparatively soft, have a low melting point and are easily fabricated. They have low electrical conductivity and tensile strength and a relatively high coefficient of thermal expansion. However, the properties can be varied within quite a wide range by judicious use of alloying elements. For instance, strength and hardness of ordinary lead can be multiplied many times or melting point greatly reduced by alloying.

Tools used in working lead are usually of somewhat different design from those employed with other metals. For instance, hard wood is preferred in spinning lead. Tools should not be so sharp and should be of such a design that they will not bite too strongly into the soft metal. Thus relatively dull tools have been found preferable for broaching, threading and other operations.

EXTRUDED PRODUCTS

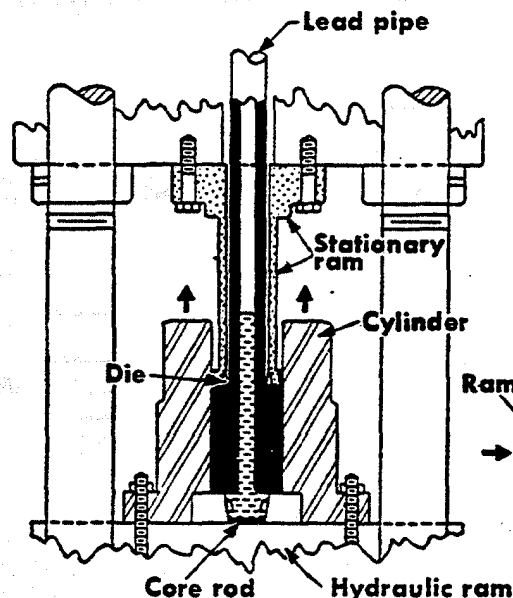
Lead and most of its alloys may readily be fabricated by the extrusion process. This process is used to make seamless lead pipe which can thus be produced in continuous pieces of considerable length. Hydraulic presses exerting pressures up to 45,000 lb. per sq. in. are employed for this purpose, the pressure depending upon the cross-section of the product extruded and the metal or alloy used.

At the top of the typical lead pipe press is a nozzle with a round hole in its center. Below this is a cylinder containing lead which has been drawn from the melting pot and allowed to solidify. As hydraulic pressure is applied, lead is forced out of the press through a die in the bottom of the nozzle. However, this would make a solid rod of lead, so means must be used to make the hole in the center of the pipe. This is accomplished by fastening a

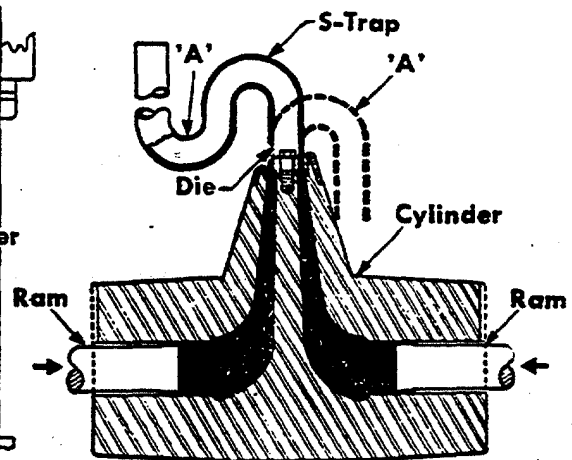
steel rod the size of the hole in the pipe to the bottom of the lead chamber in the press and allowing it to extend up into the center of the hole in the nozzle. Thus the lead is forced out through the ring between the steel rod, or mandrel, and the walls of the hole in the nozzle, forming a seamless, continuous lead pipe. For small sizes of tubing the slender mandrel is fastened by arms to the die itself, as it would not be rigid enough if it extended to the bottom of the chamber. Although the lead is separated as it flows past these arms, it is forced together again above them and forms the solid wall of the pipe.

Lead pipe, because of its corrosion resistance and flexibility, finds countless uses, the principal ones being in the chemical industries and plumbing and water distribution. Its flexibility makes fabrication of coils of various shapes for heating and cooling particularly easy. Joints may be made by welding (lead "burning"), soldering or mechanically, the choice depending upon the use to which the pipe is put. Sizes may range from fine tubing $\frac{1}{16}$ -in. inside diameter and even less to 12-in. or larger pipe, with almost any desired wall thickness. Either pure lead or alloys may be used.

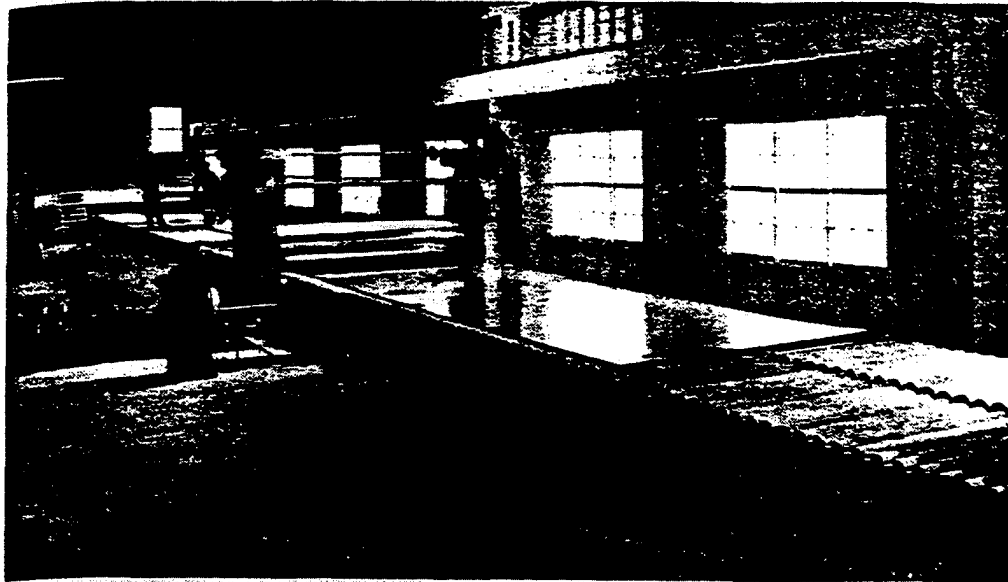
Special extrusion presses make it possible to extrude lead sheaths around cable or other cores, and still other presses to



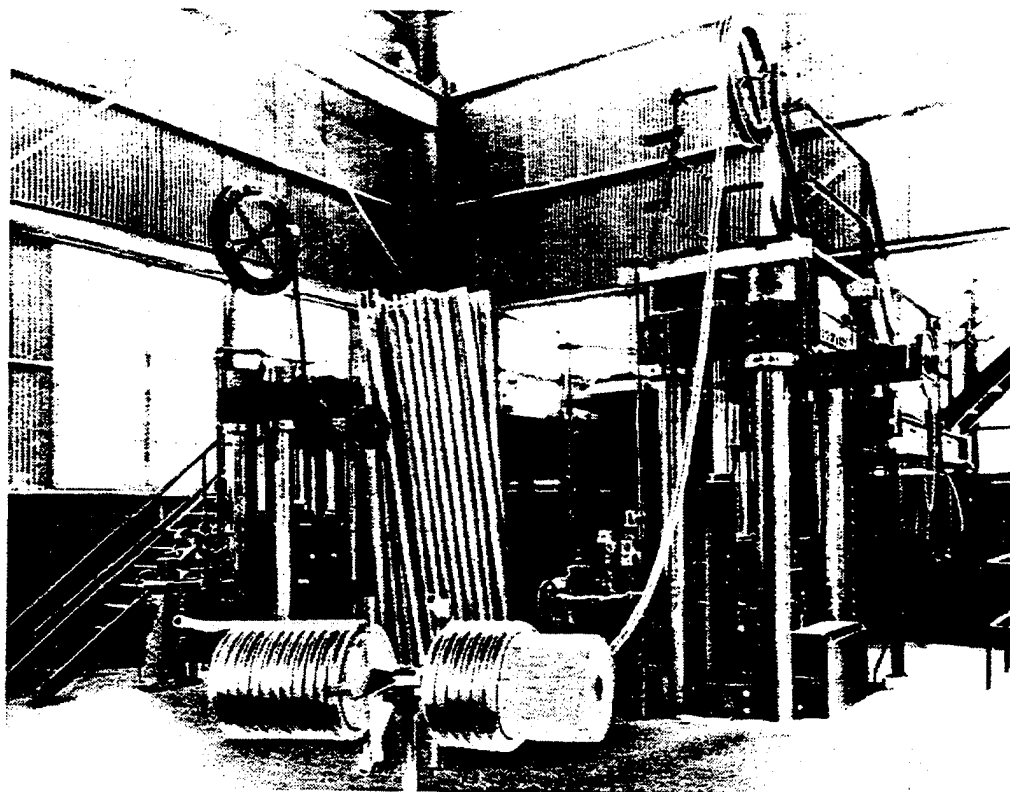
Hydraulic press for extruding lead pipe.



Hydraulic press with double ram for extruding lead traps and bends.

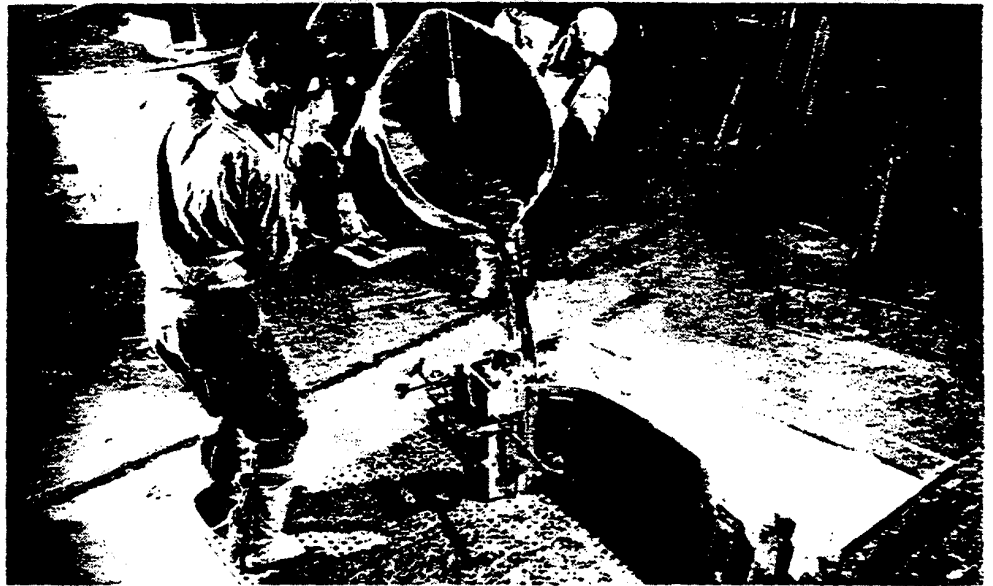


Sheet lead rolling mill and cutting table.

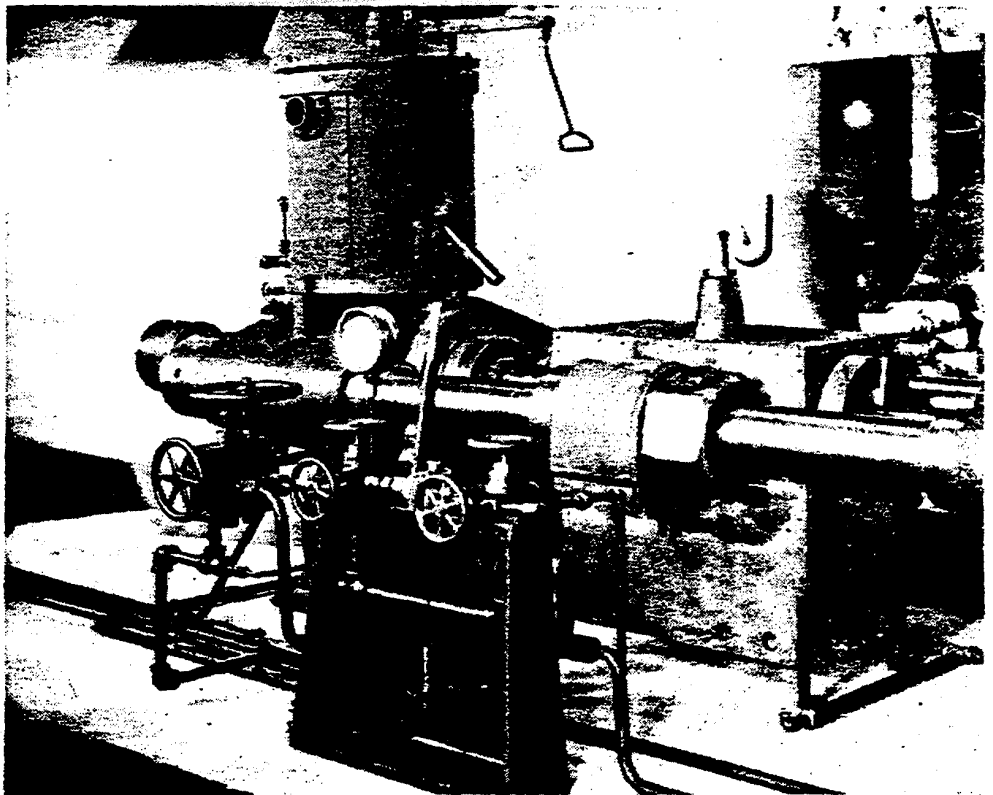


John Robertson Co.

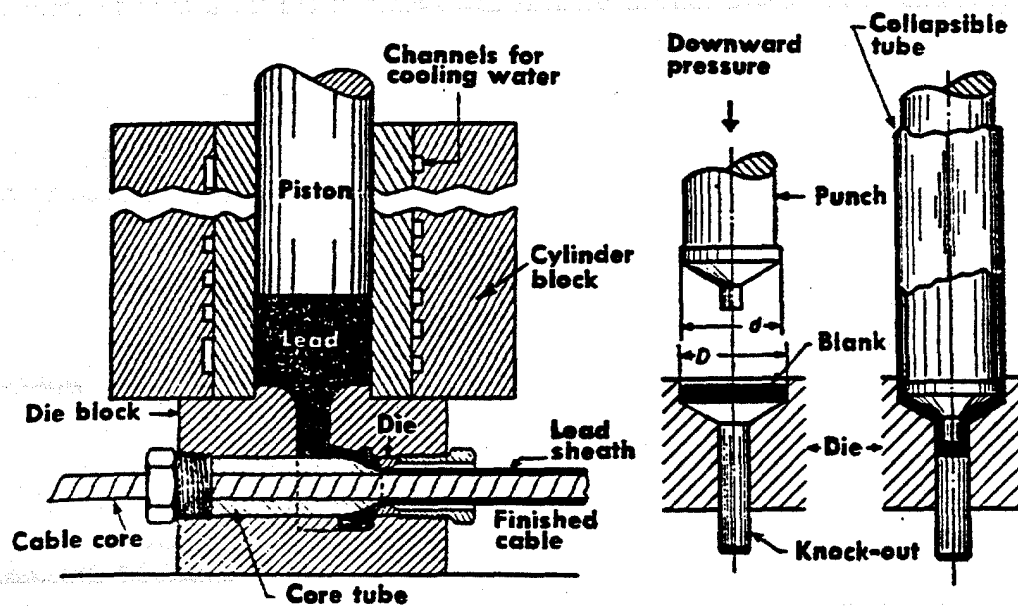
Hydraulic presses for extruding lead pipe. Large, thin wall pipes are extruded in straight lengths; smaller sizes are coiled. *Diagram on page 20.*



Because of its low melting point, lead is readily cast into practically any shape.



Double ram lead trap and bend press. Controls in the foreground independently regulate hydraulic pressure on two horizontal lead cylinders. *Diagram on page 20.*



Hydraulic press for extruding a lead sheath on electric cable.

Method of producing a collapsible tube by impact extrusion.

extrude specially shaped products such as traps and bends. Solder is extruded with or without a core of flux.

Cable presses usually have the die at the side of the cylinder instead of at the top as in a pipe press. The unsheathed cable is fed into one side of the cylinder emerging through the die on the other side. The cable itself acts as the core and the lead extrudes around it through the die to form the sheath. Similar presses are used to extrude a lead sheath around rubber hose, this sheath forming a mold during the curing process and later being stripped from the finished hose.

Such presses played one of the most dramatic production rôles of the last War. On them were produced great lengths of lead pipe, with the core of electrical conductors omitted. This pipe was then wrapped with steel wire, tape and jute just like a submarine cable and welded together into continuous armored lead pipes as much as 40 miles long which were laid under the English Channel from England to continental Europe. Through these lines was pumped a large part of the gasoline needed to keep the Allied armies on the continent moving on the land and in the air.

Trap and bend presses have two horizontal cylinders to contain the lead instead of one vertical cylinder. These cylinders are opposed to each other and feed the metal to a die at the top

between them. When equal pressure is applied to the two cylinders, the lead extrudes through the die as a straight pipe. However, if lead is fed from one cylinder at a slower rate than from the other, the pipe bends in the direction of the slow cylinder. The bend can be reversed by reversing the pressure on the cylinders.

Many other forms of lead and its alloys are extruded. As examples may be cited bullet core rod, welding rod, lead wire, comes, wedge lead, lead ribbon and lead anodes. Small counterweights of uniform cross-section are often extruded as rod or pipe and cut to length, while counterweights for airplanes and gliders are frequently extruded as strip which is cut to the exact size and weight needed.

Lead may also be extruded by the impact method, this procedure being employed for the production of collapsible tubes for tooth-paste, shaving cream, glue and many other plastic products. Discs or blanks are cut from rolled sheet lead or lead alloy and may have a coating of tin on one or both sides. In special machines, the discs are formed into tubes by a combination of extrusion and impact forces. The method has also been applied, for instance, in making condenser tubes, so that tubes of cross-section other than round, that is, oval or rectangular, are produced satisfactorily.

Special synthetic linings have been developed for lead collapsible tubes, the selection being dependent upon the material to be packaged.

By the regular extrusion method, lead or lead alloy pipe or tubing can also be produced having a completely uniform extruded tin lining, both pipe and lining extruded in a single operation.

ROLLED PRODUCTS

Among the most generally useful lead and lead alloy products are those produced by cold rolling. These may range in thickness from foil only 0.00035 in. thick to sheets 2 in. thick or more, and may be rolled to any desired thickness. Sheet lead weighs approximately 1 lb. per sq. ft. for each $\frac{1}{16}$ in. of thickness. Thus 4-lb. sheet lead, as it is termed commercially, is $\frac{1}{16}$ in. thick, 8-lb. sheet lead is $\frac{1}{8}$ in. thick. Above 16-lb. sheet, this

relationship does not hold exactly, and $\frac{1}{2}$ -in. sheet lead weighs 30 lb. per sq. ft. while 1-in. weighs 60 lb. per sq. ft. The thickness of foil, that is, weights less than about 1 lb. per sq. ft., is usually designated in thousandths or ten-thousandths of an inch.

The machinery and equipment in general use for the rolling of sheet lead consists essentially of a kettle, slab casting pan, rolling mill and roller tables, and cutting table. The slab casting pan is a heavy open top steel casting, the sides of which are tapered sufficiently to facilitate removal of the frozen slab. Slabs are normally cast 4 to 6 inches thick, the length being determined

SHEET LEAD WEIGHT AND THICKNESS

Pounds per sq. ft.	Approx. thickness in inches		Pounds per sq. ft.	Approx. thickness in inches	
	Decimal	Fraction		Decimal	Fraction
$\frac{3}{4}$	.0117	$\frac{1}{80}$	8	.1250	$\frac{1}{8}$
1	.0156	$\frac{1}{64}$	10	.1563	$\frac{5}{32}$
$1\frac{1}{2}$	.0234	$\frac{3}{128}$	12	.1875	$\frac{3}{16}$
2	.0312	$\frac{1}{32}$	14	.2188	$\frac{7}{32}$
$2\frac{1}{2}$	.0391	$\frac{5}{128}$	16	.2500	$\frac{1}{4}$
3	.0468	$\frac{3}{64}$	20	.3333	$\frac{1}{3}$
$3\frac{1}{2}$	.0547	$\frac{7}{128}$	24	.4000	$\frac{2}{5}$
4	.0625	$\frac{1}{16}$	30	.5000	$\frac{1}{2}$
5	.0781	$\frac{5}{64}$	40	.6667	$\frac{2}{3}$
6	.0937	$\frac{3}{32}$	60	1.0000	1

by the width of the mill. Large slabs sometimes weighing as much as 8 tons are usually cast in a horizontal position. Alloy lead is generally cast on end in a vertical mold often oil- or water-cooled to prevent segregation.

Rolling mills used for the production of sheet lead are of the reversible type having either a single-roll or double-roll drive. The rolls are mounted one above the other; the lower roll has a fixed elevation while the upper can be raised or lowered several inches to accommodate the thickness of full slabs. Larger mills have rolls 30 in. in diameter by 12 ft. in effective length. These rolls have a slight crown to compensate for deflection when wide sheets are rolled. The slab of lead is passed back and forth between the rolls reducing the clearance after each pass until the proper thickness is reached. It is possible to roll the sheet to obtain different thicknesses at different points in the length.

Roller tables extend about 45 ft. on either side of the main

mill rolls and are at the same elevation as the top of the lower roll. The sections adjacent to the large rolls consist of closely spaced, power driven, live rollers to move the heavy lead sheet. The remainder of the roller table consists of idle rollers.

On the cutting table the lead is mechanically trimmed and cut to size. Sheets may be produced in widths up to 10 or 11 ft. and lengths up to 40 ft. depending upon thickness, but 8 ft. wide and 20 ft. long is usually considered standard. Likewise, they are available as strips of various widths such as 12, 18 or 24 in., as for flashings. Foil usually comes in rolls with widths anything up to 24 in.

The metal used for rolled products may be lead, an alloy, or laminated. In the latter case, for instance, lead foil is produced with a thin layer of tin firmly bonded to it on one or both sides.

Although sheet lead has a multitude of applications, the most important are in the construction of corrosion resistant equipment for the chemical industries (see page 44) and for roof flashings, roofing, and other waterproofing (see page 87). Durability and flexibility are the big advantages lead has for these purposes, although appearance and non-staining are also important in the case of roofing and flashing.

Joints may be made by welding (this is a *must* for chemical installations to avoid corrosion of the joints), by soldering, or by loose-locking (this is a *must* for roofing and flashing installations to provide for expansion and contraction).

The principal use of foil is in packaging articles or products that must be protected from moisture or light or must have their moisture content preserved. It also has a number of important industrial uses as in condensers, electrotypers' foil, solder foil, and metallic packing. In X-ray work, lead foil protects the packaged film and lead sheets averaging 0.003 to 0.005 in. in thickness are used extensively as intensifying screens. Methods have been developed for making absolutely airtight joints in foil by special and extremely simple soldering techniques.

Rolled products have a number of miscellaneous uses such as blanks for making collapsible tubes, for making etched name and instruction plates for machinery and equipment, blanks for spinning, drawing or further fabrication, and for gaskets and washers.

CASTINGS

Lead and certain of its alloys are excellent metals for making a variety of castings providing high strength is not a requisite and the castings are not used at high temperatures. The casting qualities are excellent, the melting temperatures low, and corrosion resistance superb under most conditions. Certain kinds of castings have long been made of lead or its alloys, ranging from anchors for masonry, cast lead joints in cast-iron bell and spigot pipe (see page 79) and counterweights, sinkers and sounding leads to intricate printers' type (see page 127), pumps, valves and 17-ton vessels for handling corrosives and tiny scale ship, plane and tank models and practice bombs for military training purposes.

More recently it has been found advantageous to use lead for certain kinds of castings for which it had not previously been considered. This should not be taken to indicate that lead can be used indiscriminately in lieu of other metals, for the properties are often quite different. Yet advantage may frequently be taken of some of lead's desirable characteristics, such as corrosion resistance, to produce superior products if its properties, advantages and limitations are clearly recognized.

The strength of the lead alloys, while usually much higher than lead itself, is low compared with most other metals. For instance, lead base castings may run as high as one-third the strength of common zinc-base die-casting alloys. The lead alloys also lose strength quite rapidly at elevated temperatures. On the other hand, casting qualities and corrosion resistance, as mentioned, are excellent and the castings take electroplate, paint, enamel or lacquer finishes well where desired for decoration. Such finishes are not ordinarily required for protection. Furthermore, the lead alloy castings are not subject to dimensional changes with the passage of time. Lead and its alloys may be cast in almost any kind of mold, either by gravity or under pressure.

Articles that require no great strength are easily cast of lead or its alloys. Many others, where strength is a factor, can be cast of lead alloy as well as stronger metal through proper design to provide reinforcement where needed. Sometimes reinforcing

elements made of stronger metals are cast into the lead to give greater strength.

In general, the lead alloys will produce castings with tensile strengths ranging from 3,000 to 11,000 lb. per sq. in., Brinell hardness from 7 to 22, and with points of complete liquefaction from about 475 to 600 deg. F.

While lead and its alloys have been used for years, a few examples of products recently converted to lead alloy will illustrate its adaptability. Trap screws or clean-out plugs for plumbing traps, and a number of other threaded closures used under no great pressure are now made of lead alloy. Practice bombs were converted from stronger metal to lead alloy without redesigning because no great strength was required. Machinery and equipment name and instruction plates have been made of cast lead alloy as well as etched alloy sheet lead mentioned elsewhere.

Water closet floor flanges are being made of lead even though considerable strength is necessary. This conversion was accomplished by increasing the thickness of the flange about 50 percent and providing reinforcing ribs on the back. Die-cast lead alloy working parts and nozzles for fire extinguishers are examples of lead castings used for reasons of corrosion resistance, as are valves and pumps used in chemical installations. Battery connectors with steel inserts are examples of lead castings with internal reinforcement.

The best casting temperature for typical lead base die castings is about 600 deg. F. Minimum wall thickness for large die castings is about 0.05 in. and for small die castings about 0.035 in. The variation from drawing dimensions is ± 0.001 in. and the maximum number of threads is 32 threads per in. Draft for both cores and sidewalls is 0.001 in. per side per in. while minimum diameter of holes is 0.05 in. depending on depth.

Tables listing properties of some of the lead base casting alloys will be found on pages 198 and 202.

CHAPTER FIVE

Lead Storage Batteries

THE lead storage battery is so much a part of our everyday lives that seldom are we aware of our dependence upon it. Everyone knows battery power starts the motor of an automobile, but most of us do not know about the hundreds of ways battery power is used by electric utilities, transportation and communication companies and almost every type of industry. This wide use of lead storage batteries is not accidental, but a natural result of the important assistance which lead storage batteries gave the pioneers of the electrical industry in developing machinery and equipment for the generation, distribution and use of electricity. Storage batteries became such an integral part of all of the many electrified services now so essential to modern living that storage battery power serves us every day in many unsuspected ways.

Lead storage batteries constitute the most dependable apparatus by which energy can be conveniently stored for future use. They can be charged with enough energy to lift their own weight well over 32,000 ft., or more than six miles, and they possess the unique ability of being able to deliver large amounts of energy quickly in a short period of time, or small amounts of energy over long periods of time. A good example of this highly important operating characteristic is the battery used to energize the electrical system of an automobile. Press the starter button and the battery instantly supplies large amounts of starting energy for the few seconds this high power is required, or turn on the parking light switch and the battery supplies the insignificant amount of energy required for as long as necessary. It is this simple operating characteristic inherent in lead storage batteries which enables them to provide a reliable and economical solution to an extremely wide variety of electrical problems.

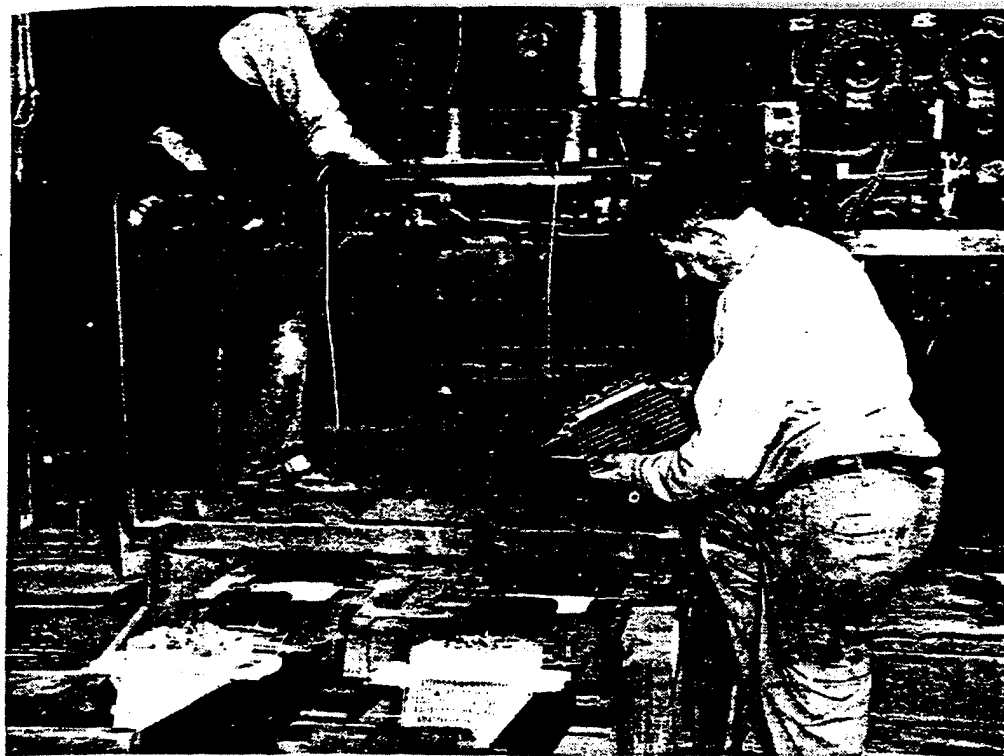
Flexibility of operation is another useful characteristic of storage batteries. Cells of these batteries can be combined to meet the specific voltage requirements of any electrical system whether it is a few volts or a thousand volts. Such batteries can be designed to deliver high current at low voltage or low current at high voltage. They range in capacity from a few amperes to the many thousands of amperes needed to propel a giant submarine underwater.

Lead storage batteries, or "accumulators" as they were once called, occupy an interesting place in the development and growth of the electrical industry. From the time Volta discovered the galvanic battery, or pile, in 1800, scientists experimented with many types of batteries made from different kinds of metals. These early storage batteries were crude. None of them were commercially successful, but they were useful in the laboratories and helped in the discovery of many working principles of the great mystery—electricity.

It was not until 1859 that Gaston Planté began a series of experiments which proved that battery electrodes, or plates, made from two different forms of lead were superior to electrodes made with other metals. Batteries made with lead plates had many more satisfactory electrical and operating characteristics than any other type of energy accumulator and they lasted longer. The Planté battery was the first lead-acid type of storage battery.

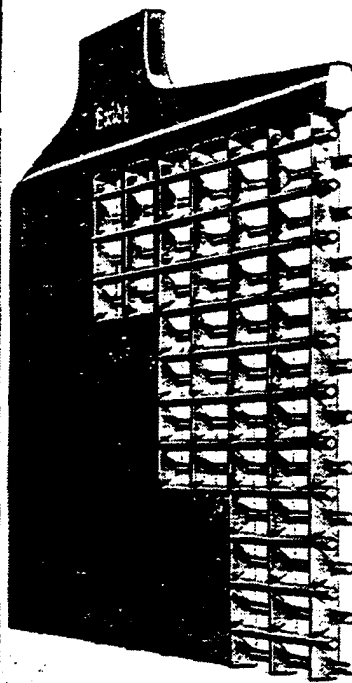
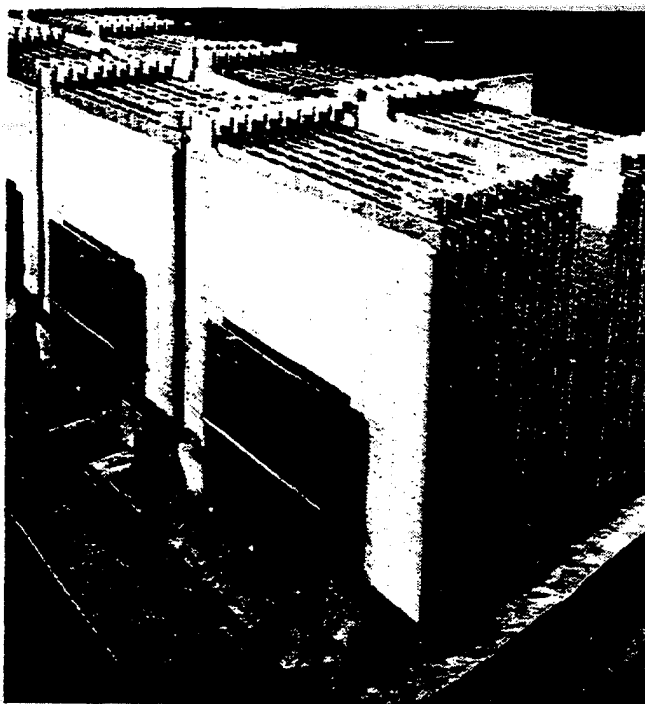
The first commercial use of storage batteries was for telegraphy in 1879. However, none of the early types of storage batteries were of much practical use outside laboratories until the commercial development of the dynamo put the possible usefulness of lead storage batteries on an entirely new and different basis. It created an urgent need for a reliable means of storing energy which would enable managers of the early lighting plants to overcome many of the operating difficulties which plagued them.

At the same time the dynamo became commercially useful, a method of pasting perforated plates with lead oxides was invented. This new battery discovery increased the storage capacity of lead batteries. Since they could be formed in a few days with relatively cheap power from a dynamo, this type of battery seemed to be an answer to the pioneer electrician's prayers.



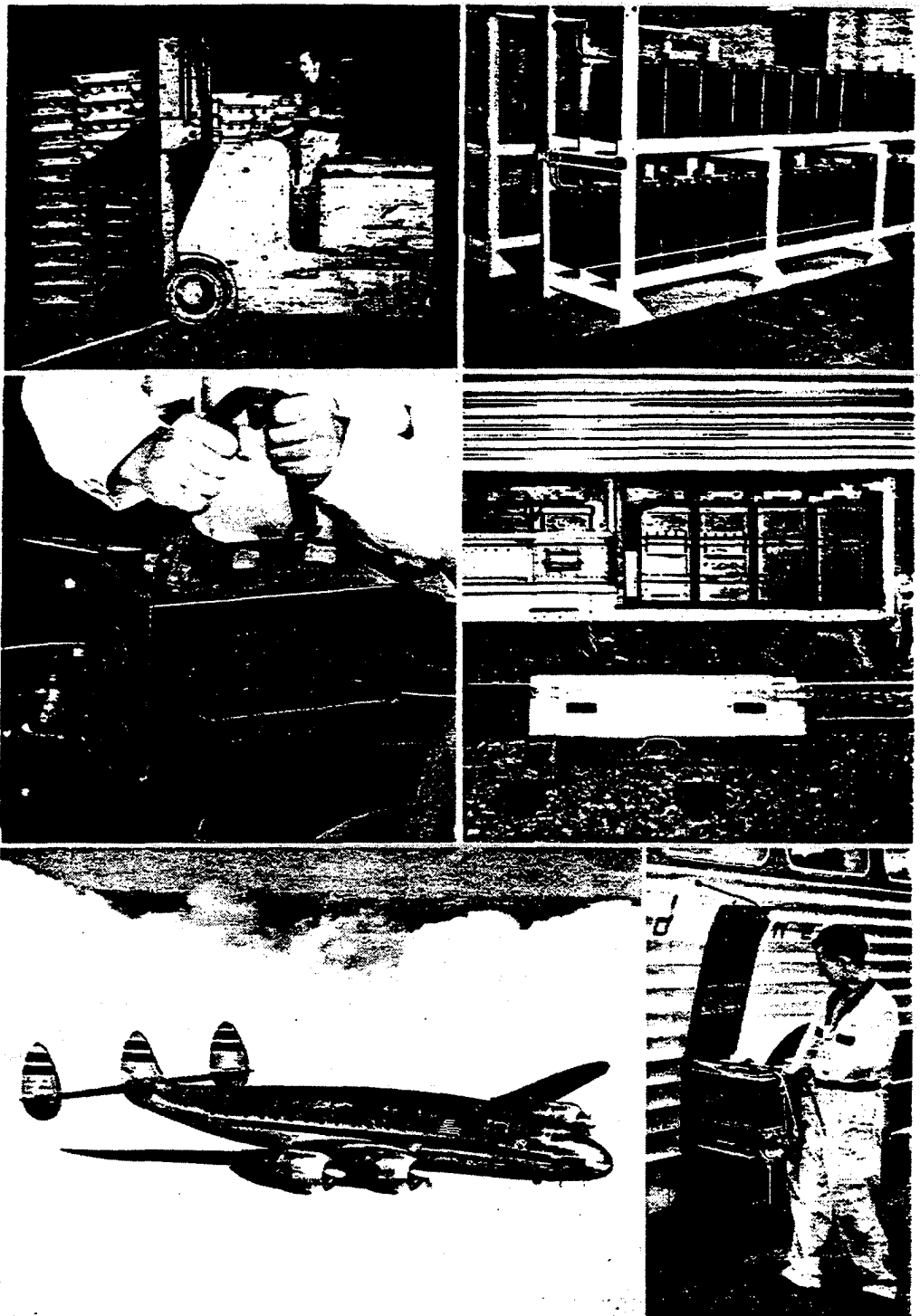
The Electric Storage Battery Co.

An automatic grid casting machine for making automotive battery plates.



The Electric Storage Battery Co.

Left. Submarine battery plates assembled as elements for cells. *Right.* Partially pasted section of a lead-acid storage battery grid.



The Electric Storage Battery Co.

Typical applications of storage batteries. Heavy duty batteries provide power for industrial trucks. Standby batteries are ready to supply current for emergency lighting or communications. Practically all forms of transportation—automobiles, trains, planes and buses—depend on storage batteries to supply their electrical needs such as starting, ignition, lighting, air conditioning.

This new battery development occurred in 1881, the year before Thomas Edison opened the world's first electric lighting central station on Pearl Street in New York City. In 1882, the Pennsylvania Railroad experimented with the new kind of lead battery as a substitute for kerosene in the lighting of passenger cars. These batteries also were used in 1882, to light a few incandescent lamps on the trans-Atlantic steamship "Labrador."

It was not until 1885 that storage batteries were first used for central station operations. At this stage in the development of the electric industry mechanical failures were frequent, due to sudden fluctuations of the load on generating machines. It was at this point that the ability of lead storage batteries to quickly deliver large amounts of energy for short periods of time was first suggested as a remedy for these troubles. A few years later, storage batteries used for this purpose enabled many pioneer electric light and power companies to put their service on a continuous 24-hour-a-day basis.

In the early 1890's, many additional uses were found for storage battery power. These were trolley car operation, 1890; railroad signaling and propulsion power for electric carriages, 1891; the operation of telephone exchanges, police and fire alarm signal systems, electro-plating, welding, elevators, 1892; Edison's Kinetoscope (forerunner of moving pictures), 1893; electric locomotives, surgical knives, mine locomotives, 1894; wireless (Professor Preece), 1896; Holland's submarine, 1897; automobile lighting and ignition, and the cranking of stationary Otto engines, 1900 and Marconi wireless, 1901. The first distress signal sent by wireless in 1909 was battery-powered; battery-started automobiles first appeared in 1911 and, in 1912, batteries started airplane motors.

HOW THE BATTERY OPERATES

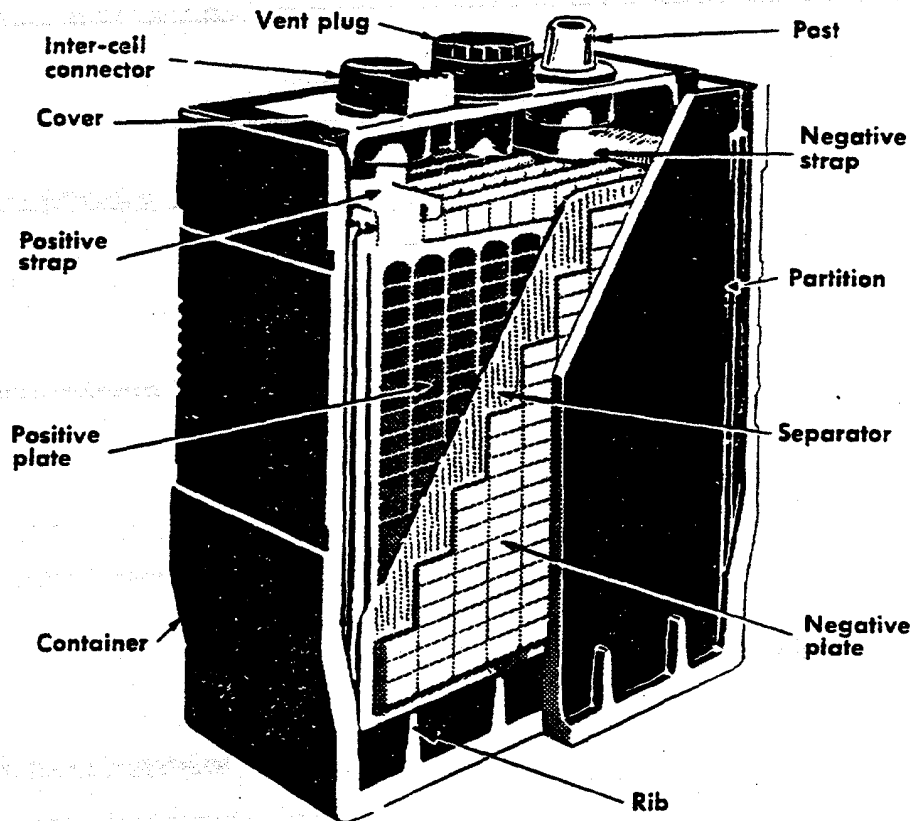
The simplest form of a storage battery is two plates of different (dissimilar) metals immersed in an electrolyte. When connected to an electric circuit, pressure (voltage) is created by the plates. The electric pressure of each lead battery cell is approximately 2 volts. Incidentally, the addition of plates to a cell only increases its capacity (amperes or ampere hours), the pressure, 2 volts, remains the same.

The plates of lead acid storage batteries are prepared from perforated grids cast from an alloy of lead containing between 7 and 12 percent antimony, about 0.25 percent tin, and small amounts of arsenic and copper. The presence of antimony gives additional hardness and corrosion resisting characteristics. The presence of tin gives better casting qualities. The interstices in the negative grid are pasted with litharge, or a mixture of litharge and finely divided metallic lead made into a paste with water and sulphuric acid. The positive plate usually contains litharge and finely divided metallic lead and in some cases up to 25 percent red lead. The mixture of litharge and metallic lead is sometimes referred to as "black oxide." After the plates have been pasted, dried, and the cell assembled, sulphuric acid is added. The plates are then "formed" by passing an electrical current through them to convert the positive plate into lead peroxide and the negative plate into finely divided sponge lead. Formation usually requires from 24 to 48 hours. What takes place is shown by changes in chemical composition indicated in the table below. The material of the positive plate is oxidized from lead oxide to lead peroxide. The material of the negative plate is reduced from lead oxide to metallic lead.

Negative plate		Positive plate			
Initial composition, percent	Final formed composition, percent	Initial composition, percent	Final formed composition, percent		
PbO	90	3	PbO ₂	20	86-78
PbSO ₄	10	2-5	PbO	55	7
Pb	—	95-92	PbSO ₄	25	7-15

For maximum capacity on discharge it is essential that both plates be quite porous to permit an extended reaction between the sulphuric acid and the active material of the plates. This porosity is determined by the original characteristics of the raw materials, such as the fineness of the oxide employed, and by the densities of the paste mixtures utilized in preparing the plates.

On discharge, both the finely divided sponge lead constituting the negative plate and the lead peroxide constituting the positive plate react with the sulphuric acid electrolyte and are converted to lead sulphate. During such discharge an oxidation-reduction takes place opposite to that occurring during charge and current



Construction of a typical lead-acid battery cell.

flows in the opposite direction. The sulphuric acid concentration is depleted during charge and the state of charge can be measured by the specific gravity of the sulphuric acid.

Batteries of the lead-acid type can be discharged at very high rates. The only limit is the ability of motors and wires in the electrical circuit to handle the current. It is this operating characteristic that makes storage batteries an ideal source of power for many heavy-duty services, such as providing power to crank the engines of giant diesel-electric locomotives or supplying motive power for the operation of electric industrial trucks, mine locomotives or submarines. Whether a lead battery is discharged quickly at high rates or intermittently at high (peak) or low rates, makes no difference in its life.

Charging the battery is just the reverse. The lead sulphate is converted to lead peroxide and sponge lead and sulphuric acid is regenerated, increasing the concentration of the electrolyte. During the early part of a charge, large amounts of direct cur-

rent can be utilized. This is why it is permissible, with proper control equipment, for a local serviceman to give an automobile battery a so-called "fast charge," which, however, is never a full charge.

Battery capacity is rated according to the current (amperes) it can deliver for a certain length of time or the product of amperes and hours. For example, an automobile battery may deliver 4 amperes for 20 hours—thus, it is an 80 ampere hour battery on the 20-hour basis.

About 60 to 70 percent of the total weight of most storage batteries is lead and about 52 percent of this is antimonial lead, lead oxides comprising the balance. They consume more lead than any other use of this remarkably versatile metal.

WHERE BATTERIES ARE USED

The largest numerical use of lead storage batteries is to furnish power for starting, lighting, ignition, radio and accessory equipment on automobiles, trucks, buses and motor coaches. On farm tractors and heavy construction equipment, they are used for starting, lighting and ignition. On airplanes they provide power for engine starting, cabin, landing and navigation lights, radio, radar and other navigation instruments. Aviation batteries are of a special design which will not spill their acid even when the plane is flying upside down.

Typical automobile batteries are three cell 6 volt types, although six cell 12 volt batteries are also used for motor coaches. Automobile batteries are rated as to capacity at the 20-hour rate at 80 degrees Fahrenheit and 300 ampere rate at zero degree Fahrenheit, due to the dual service they must perform of providing small currents for a long time for lighting and larger currents for a short time for starting. Capacities commonly used in passenger cars range from 80 to 150 ampere hours at the 20-hour rate.

The containers of automobile batteries are either made of hard rubber or a bituminous composition material. Wood is customarily used for separators, although porous rubber is often substituted, or glass fiber mats are used in conjunction with the wood.

Electric utility companies are large users of storage batteries for the operation of switchgear to supply emergency lighting in central and substations. Formerly, in the D. C. districts of large cities, immense storage batteries were used to take over the entire load of business areas during emergencies. It has been estimated that the emergency discharge rate of one of these standby batteries for six minutes was 2,125,000 amperes at 125 volts. However, batteries of this type are gradually being eliminated as utilities change their systems from D. C. to A. C.

Today there are a number of conditions that disrupt service (storms, fires and accidents) over which utility companies have no control. In places such as hospital operating rooms, crowded theatres, school auditoriums, large stores or other places of public assembly where interruptions of electric lighting might be dangerous to life or property, storage batteries are used to provide emergency lighting. In numerous and varied industrial activities, batteries provide emergency power to assure the uninterrupted operation of important processes or process control equipment.

In the field of electrical communications, storage batteries are used to assure the continuous operation of telephone, telegraph, telephoto, teletype, radio, radio-telephone, television and municipal fire and police alarm equipment. Motion picture companies use batteries to assure the highest quality of sound recording.

In central telephone stations, storage batteries are essential to the operation of the transmitting, signaling and relay circuits. In an emergency, they carry the entire load. They are generally eleven-cell batteries with a second similar battery used with the first for toll or long distance calls. These batteries have capacities up to 13,000 ampere hours, which are doubled when the two are used in parallel. Similar batteries of 120 volts are used for telegraph operation.

All forms of transportation use storage batteries. The railroads use them to crank the engines of diesel-electric locomotives and to operate their control circuits. Storage batteries provide power for passenger car lighting and air conditioning. They are relied upon to safeguard the operations of vitally important railroad signals, switches and communication systems.

Aboard fishing vessels, work boats, river boats, freighters, ocean liners and yachts, storage batteries provide power for light-

ing, ship-to-shore telephones, radar, sounding equipment, inter-ship communication systems, fire alarm systems and the operation of numerous other auxiliary apparatus. On submarines they supply all these services in addition to providing for propulsion when noiseless operation and a non-oxygen consuming power source is paramount.

In the mechanization of metal and coal mines, lead storage batteries provide the motive power for shuttle cars and electric locomotives. They are also used to power tramming locomotives used in tunneling operations. In this connection, storage batteries have been used in building the Holland, Cascade and New York-to-Brooklyn tunnels, New York City subways, and the water supply systems of Los Angeles, Detroit, Baltimore and New York. Storage battery haulage locomotives have also helped in building such well-known projects as Boulder Dam, the Golden Gate Bridge, and the George Washington Bridge over the Hudson River.

Supplying motive power for the operation of electric materials handling trucks is probably the most outstanding way storage batteries are used by almost every kind of industry. These battery-powered trucks are highly efficient tools which enable one man to handle more material in less time and with greater safety than could be handled manually by a gang of men.

The first electric industrial truck was used by the Pennsylvania Railroad in 1906. Today more than 60,000 are in operation in this country. It is estimated that 90 percent of those installed in the past twenty years are still operating. The lead storage batteries which power them have a life ranging from five to ten years, depending upon the type of work and the kind of care given them. With two sets of batteries, one charging while the other is in use, an electric truck can operate 24 hours a day.

Battery-electric industrial trucks are rarely out of service for unscheduled repairs. Thus, their utility value is high and their operating and maintenance costs are low. Today these battery-powered materials handling trucks are providing industry with its most effective way of cutting production costs.

Another industrial use of storage batteries for motive power work is the operation of storage battery diesel locomotives for switching and intra-plant haulage in large mills. The locomotive

can run for several hours on batteries alone and, by using both batteries and diesel engine, can exert greater power for starting heavy loads than any other kind of locomotive having a self-contained power unit.

Farmers and others not served by power companies have greatly benefited from the development of isolated electric current generating plants. These plants consist primarily of a small gasoline engine, a generator and storage batteries. The battery stores up energy generated intermittently by engine and generator, and in turn supplies current on the farm, when needed, in a steady even flow. As these batteries are usually discharged intermittently over several days, they are given a 72-hour capacity rating as well as the customary 8-hour rating. The 8-hour rating is about 70 percent of the 72-hour rating.

Lead storage batteries have recently been developed for spot welding which supplies current as high as 38,000 amperes. Another recent development is a tiny lead-acid storage battery no bigger than a pack of cigarettes. It is so small that it is filled with a hypodermic needle, yet has as many as 18 cells.

U. S. Government services use large quantities of storage batteries in a great many military, as well as peacetime, activities.

Among the latest important uses of lead storage battery power is in the field of atomic research, and they continue to be widely used in scientific, college and industrial laboratories for conducting experiments which will produce the new electrical services and products for tomorrow.

CHAPTER SIX

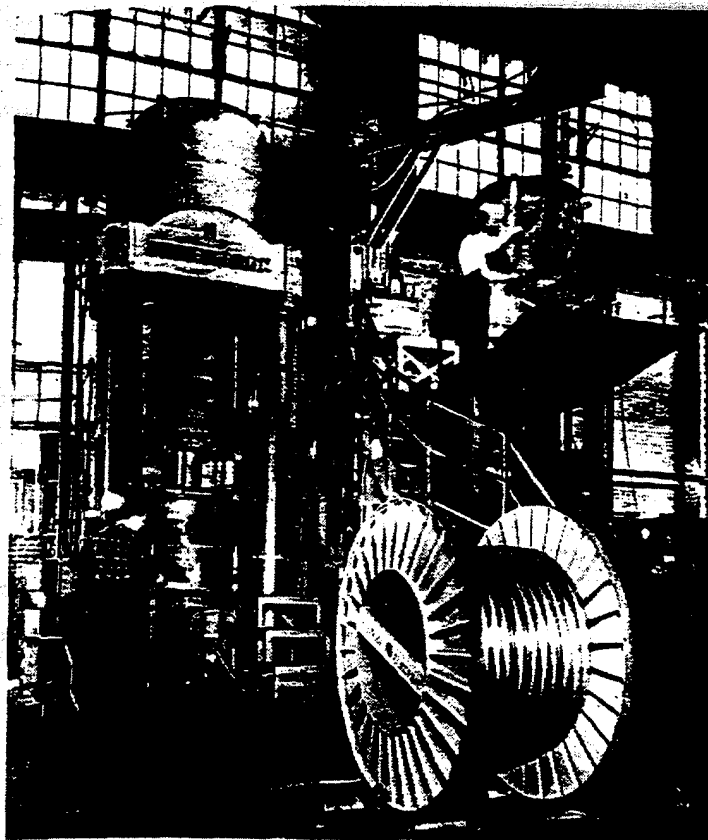
Lead Covered Cable

LIKE storage batteries, lead covered cable exemplifies the importance of lead to modern living. Both uses are electrical in this electrical age, and both require huge tonnages of lead to place them among the largest consumers of the metal. As much as 200,000 tons of lead have been used in a year to cover cable, and the cable thus covered has been estimated at some 30,000 miles annually.

Lead is used in the construction of two general types of electrical cables, i.e., cable for communication over telephone and telegraph lines and cable for the transmission and distribution of electric power from public utility generating stations. A characteristic feature of both the telephone business and industries selling electric power is the fact that the nature of their business requires engineering planning to provide for future developments many years ahead. In the formulation of such plans, consideration is given not only to the continued expansion of demand as shown by past records, but also to the effects of the slow steady increase in the number of families and business concerns in the country and of the continuing improvement in the standard of living upon telephone usage and electrical output and its distribution.

Lead covered cables are used both in overhead and underground line construction, but the modern trend is, in spite of higher first cost, to place electrical cables underground where they will be undisturbed and out of the way. This is particularly true in congested cities where overhead construction is unsightly and inadequate to meet the service requirements.

All types of underground and overhead power and communication cables having hygroscopic material such as paper for insulation must be protected from moisture to insure the successful



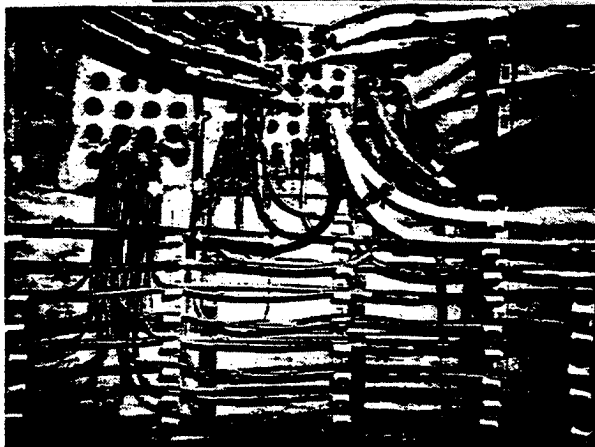
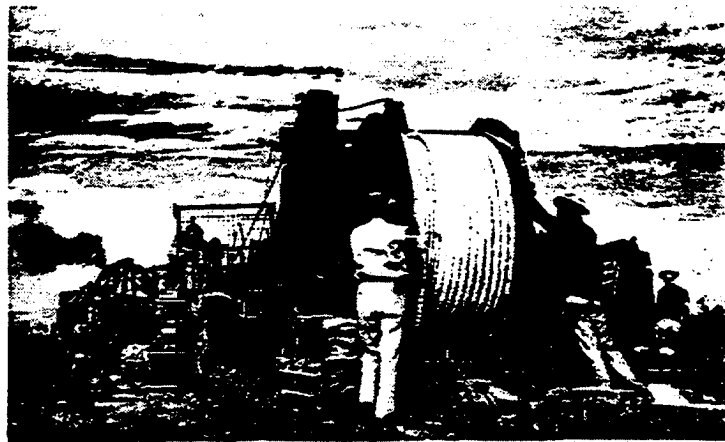
A lead cable sheathing press, cable reel and melting kettle. *Diagram on page 21.*

Western Electric Co.

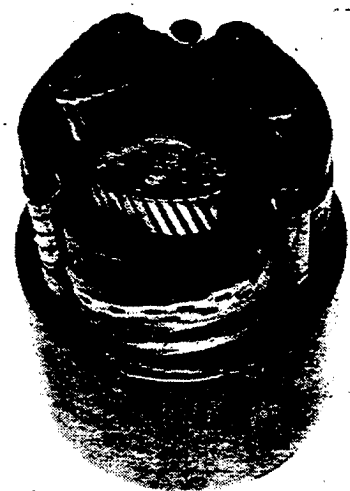


Western Electric Co.

Left. A fanned out view of typical lead sheathed 2121-pair telephone cable, about 2½ in. in diameter. *Right.* Similar view of lead sheathed six coaxial cable used in the nation-wide television and communications network, about 2 in. in diameter.



Top. A cable train burying lead sheathed coaxial cable for cross-country communication. *Left.* Inside a manhole, showing the variety of lead sheathed power cable carried in conduits beneath city streets. *Right.* Overhead 23,000-volt lead sheathed power cable and terminating pot head.



General Cable Co.

(A)

(B)

(C)

- (A) Low voltage, lead sheathed, varnished cambric insulated cable.
- (B) Arsenical lead alloy sheathed, paper insulated, oil-filled 138,000-volt cable.
- (C) Lead sheathed, paper insulated, nitrogen gas-filled 27,000-volt cable.

operation of the cable. Lead was recognized early as having desirable properties for use as a protective cable sheath and has been used successfully many years for that purpose. It is impervious to moisture and provides good protection from mechanical injury to the insulation. It protects effectively against all kinds of weather and oxidation. Its low melting point permits it to be applied in a semi-liquid condition without damage to the insulation and its pliability allows it to be used without destroying the flexibility of the cable as required for reeling, unreeling and ease of installation. Also its comparative chemical inertness results in high resistance to corrosion and long life when exposed to the acids and salts encountered in soil water.

Ideas which seem grotesque to us now permeated the minds of the first lead covered cable makers. For example, one cable was constructed of twenty bare wires, each drawn into small glass tubes and then pulled through a lead sheath and a mixture of oil and rosin added under pressure. When the lead pipe was bent, the glass broke but the wires were said to have been kept apart by the resulting glass compound.

Pure lead was used to make the first cable sheathing and is still principally employed for power cables. Early telephone cable was manufactured with a relatively soft or loose core and in order to maintain the circular cross-section of the surrounding lead sheath, about 3 percent of tin was alloyed with the lead to stiffen it and prevent its distortion under pressure of successive windings when coiled upon the reel at the factory or when bent during installation. In 1907, experimental research was undertaken to discover an alloy which would satisfactorily replace expensive tin. After much experimentation with lead alloys containing antimony, tin, copper, nickel and bismuth, an alloy was developed about five years later containing 1 percent antimony which has been used extensively for telephone cable ever since. Power cable, having a more compact core, does not require the additional stiffness imparted by antimony except where the cable is used in overhead construction or subjected to vibration, where the characteristics of a lead alloy of tin or antimony are desirable.

Lead-calcium alloy containing 0.03 to 0.04 percent calcium has been used to some limited extent for cable sheathing with satisfactory results. In England, alloys of 98.25 percent lead, 1.50

percent tin and 0.25 percent cadmium, or 99.25 lead, 0.50 antimony and 0.25 cadmium have been developed for the same purpose.

A newer arsenical lead cable sheathing alloy containing small percentages of bismuth, arsenic and tin has been perfected. Its chief advantages are increased tensile and bursting strengths and a higher annealing temperature. The latter improvement is particularly significant because wiped joints may be made on this sheath without unduly softening or lessening its tensile or bursting strengths adjacent to the joints. The alloy is composed of 0.1 to 0.2 percent arsenic, 0.07 to 0.2 percent bismuth, 0.05 to 0.25 percent tin and the balance lead.

Where lead covered cables are used for submarine purposes or for direct earth burial a metallic armor is normally applied over the sheath for protection against mechanical injury. For submarine cable this armor usually consists of an asphalt impregnated jute bedding directly over the lead followed by a serving of galvanized steel wire armor with a layer of asphalt impregnated jute yarn over the armor. Where cable is for direct earth burial, flat steel tapes and 0.010 in. lead tapes are used in place of steel wire for the metallic armor. Other types of protective coverings or modifications of the above are sometimes used for special service conditions.

MANUFACTURE OF LEAD COVERED CABLE

In the early days the core of wires was pulled into a lead sheath which had already been made, but it was soon found possible to extrude the sheath directly around the core. The principle is the same as that used in the manufacture of lead pipe, except that the fixed mandrel or core which makes the hole in the pipe is replaced by a hollow mandrel through which the cable core passes, moving with the lead. Molten lead is placed in the chamber of a hydraulic press and cooled under pressure to the proper temperature for extrusion. When pressure is applied, the lead is extruded through the die and carries the cable along with it. A drawing of a cable press is shown on page 22. As the filling of the lead chamber and cooling requires considerable time, the tendency has been toward presses with larger lead

containers, which has increased the speed of the operation. The pressure on the lead is about 54,000 lb. per sq. in. Constant study of temperatures, speed of extrusion and contour of the extrusion chamber has led to marked refinements in the quality of the product.

One of the problems in telephone cable production has been to carry as many messages as possible in as small a space as possible. Present telephone cable consists of a maximum 2,121 pairs of 26 A.W. gauge wire enclosed in a $2\frac{3}{8}$ in. inside and $2\frac{5}{8}$ in. outside diameter sheath. This is the size of sheath which has been found desirable in duct work and the problem has been to increase the number of wires that the sheath may hold. The progress that has been made is shown by the fact that the number of pairs of wires has increased from 50 in 1888 to 2,121 in 1939. As these wires are first covered with paper insulation either in the form of a wrapping of paper or of paper pulp applied directly to the wire, improvement in both paper and pulp and in the insulating machines to apply these has made it possible to use less insulation, thus economizing on space. The insulated wires are twisted into pairs which are stranded into groups of suitable sizes and then stranded into a compact core.

Development of coaxial cable, which has a solid conductor at the center surrounded by a copper tube separated from the conductor by insulating discs at about 1-in. intervals, permits transmission of the same number of messages as formerly but on a much smaller and less expensive cable. A lead sheath of course protects coaxial cable just like other cables. This is a comparatively recent development, an experimental installation between New York and Philadelphia having been installed in 1936, and the first commercial installation between Minneapolis and Stevens Point, Wis., completed in 1940. Now something on the order of 6,000 miles of this cable are in service, including the transcontinental line from the eastern seaboard to Los Angeles.

TELEPHONE AND TELEVISION CABLE

The first long distance lead sheathed toll cables in the United States were placed in service in 1906 between New York and

Philadelphia and between Chicago and Milwaukee. Each was about 93 miles long. In 1913, an underground toll cable was completed between Boston, New York, Philadelphia and Washington, a distance of 453 miles. In 1925, the New York-Chicago line was completed and a year later extended to St. Louis. Since that time, toll cable lines have been extended to span the continent and conversations between all principal cities in the United States are carried over toll cable lines.

One of the newer developments is gas filled telephone cable. In 1928, about 50 miles of aerial toll cable between Philadelphia and Reading, Pennsylvania, had been filled with nitrogen gas under pressure and the cable divided into sections by means of gas-tight dams. The purpose of this was to provide a means of monitoring the physical condition of the cable sheath. Should the cable sheath be injured, the gas pressure drops in that particular section, sounding an alarm which locates the trouble approximately and allows "trouble shooters" to make repairs before any serious damage occurs. This was one of several pioneer installations of gas pressure maintenance systems in a program which developed to the point where the greater portion of the toll cable plant is now under pressure.

To protect this warning system, it is common practice to test wiped joints in cable sleeves with soap solution to insure that there will be no pressure leak in gas filled areas due to porosity of the wiping solder. A unique sealing method which assures the tightness of such joints has been developed by Bell Telephone Laboratories, Inc. The method consists of applying a supplementary layer of a lower melting solder over the surface of the wiped joint. By taking advantage of the residual heat in the joint immediately after wiping, the sealing solder is melted and the joint permanently sealed without requiring extra heat. The special solder used for sealing by this method is the lowest melting (eutectic) alloy of lead, bismuth and tin, which contains 32 percent lead, 52½ percent bismuth and 15½ percent tin. The alloy melts completely at 95° C. In operation the sealing solder in the form of a thin stick is touched to the wiped joint as soon as the latter has solidified. The sealing alloy melts readily and is wiped around the joint with a finishing cloth. The same technique can

be used to seal old joints providing the joint is well cleaned and then heated from 150° to 170° C.

The contrast between the capacity of the familiar telephone pole containing several crossarms and the modern toll cable line is particularly striking. A typical open wire line carrying four fully equipped ten-pin crossarms, or 20 pairs, has provided what is known as 20 physical telephone circuits and 10 phantom circuits, a total of 30 voice frequency talking circuits. The introduction of carrier frequencies on open wire lines has increased the number of available talking circuits to 262 for the same wire and crossarm installation. A further increase in the number of talking circuits has been provided by the use of coaxial cable. With eight coaxial tubes in a single cable as many as 3,600 one-way telephone channels or a lesser number of telephone and television channels are possible.

POWER CABLE

Cables used for the transmission and distribution of electric power are furnished in many types and sizes. Unlike telephone cable using a large number of small wires with thin insulation, power cables usually have only one, two or three conductors, with heavier insulating walls. The conductor sizes normally range from 14 A.W. gauge to 750,000 circ. mil in multi-conductor cables and up to 4,000,000 circ. mil in single conductor cables. The thickness of insulation on the individual conductors depends on the voltage rating of the cable, with the heavier walls used at the higher voltages. The thickness of the lead sheath increases with the cable diameter and covers a normal thickness range of from $\frac{3}{8}$ in. to $1\frac{1}{4}$ in.

The three general types of insulation used in the manufacture of power cable are paper, varnished cambric and rubber or synthetic material. Varnished cambric and rubber are used only for the low and intermediate voltages, while paper is used over the full voltage range up to 220,000 v. The first 220,000-v. cable was placed in operation in France in 1936. This was a single conductor, paper-insulated, oil-filled, lead-covered type. Many of the principal cities in the United States have cables operating in the high voltage range from 66,000 to 138,000 v.

Because of the extrusion method used for applying the lead sheath along with other manufacturing facilities such as stranding, insulating and cabling, it is possible to manufacture cable in long lengths as often required for submarine installations. Where cable is to be pulled in underground ducts, it is usually supplied in specified lengths corresponding to the distance between manholes. The individual lengths are spliced together to form the complete circuit. In splicing lead covered cable a lead sleeve, used to seal the splice, is wiped with solder to the cable sheath at each side of the splice forming the well-known plumber's joint.

In some places where severe corrosive conditions are encountered or where scoring of the sheath is inevitable, neoprene or polyethylene jacketed cables are being used. These are regular lead sheathed cables to which a jacket of neoprene or polyethylene about $\frac{1}{4}$ in. thick is applied by extrusion.

One of the most dramatic developments of World War II was the installation of a series of 3-in. inside diameter lead pipe lines under the English Channel from the British Isles to the European mainland. Through these lines were pumped the huge quantities of gasoline and oil needed to keep the Allied armies moving. These pipe lines were constructed exactly like submarine cable except that the conductor and insulation core were omitted. Thousands of tons of lead have also been used for sheaths on Signal Corps cable and for communication and power cables on shipboard.

CHAPTER SEVEN

Lead in Modern Chemical Construction

LEAD and some of its alloys are extensively employed in the construction of equipment for the production, transportation, storage and use of many corrosive chemicals. Details regarding many of the chemicals with which lead is used and some corrosion rates are given on pages 51 to 69.

COMPOSITION

It is important in selecting lead for corrosion resistant equipment to decide upon the correct grade or alloy for the purpose. If unalloyed lead is used, it is generally one of the A.S.T.M. grades known as chemical lead, acid lead, or copper lead. Although these grades are somewhat stronger than others, there are installations where still greater strength or fatigue resistance are needed. In such cases an alloy may be used. The alloys also may have better corrosion resistance under some operating conditions.

One of the most common lead alloys thus employed is antimonial lead containing up to 12 percent—usually about 4 to 6 percent—antimony, but since this alloy loses strength rapidly at elevated temperatures, its principal use is with temperatures only up to 250 deg. F. Tellurium-lead, an alloy of lead with about 0.05 percent tellurium, has found recognition in the last few years because of higher resistance to fatigue failure. This alloy work-hardens and in corrosion resistance is comparable to chemical lead. A proprietary lead alloy has been developed especially for use in contact with chromium plating baths. Like the lead sulphate film which forms on contact with sulphuric acid, the purpose of this alloy is to promote the formation of an adherent protective film of chromates which will inhibit corrosion by chromic acid. An alloy of lead with about 7 percent tin has also

been used successfully in chromium plating operations, and a 1 percent silver alloy is used for insoluble anodes in electrolytic zinc refining and plating.

METHODS OF JOINING

Joints in lead used for corrosion resistant equipment are made by fusion welding, a method of joining that is commonly known by the somewhat misleading term of lead "burning" (see page 72). This method is used so that no metal other than lead will be exposed to corrosive attack. Likewise, it is necessary to see that the lead exposed to attack is uniform in composition in order that all exposed metal may resist attack uniformly. Therefore, if metal has to be added through the use of a filler or welding rod in making joints, the rod should have the same composition as the lead being joined. Thus, chemical lead should be joined by the use of a chemical lead welding rod, 6 percent antimonial lead by the use of a 6 percent antimonial lead welding rod, and so on. Oxygen and hydrogen are the most generally preferred gases for lead welding, but others, such as oxygen and acetylene, and oxygen and city gas, are also used.

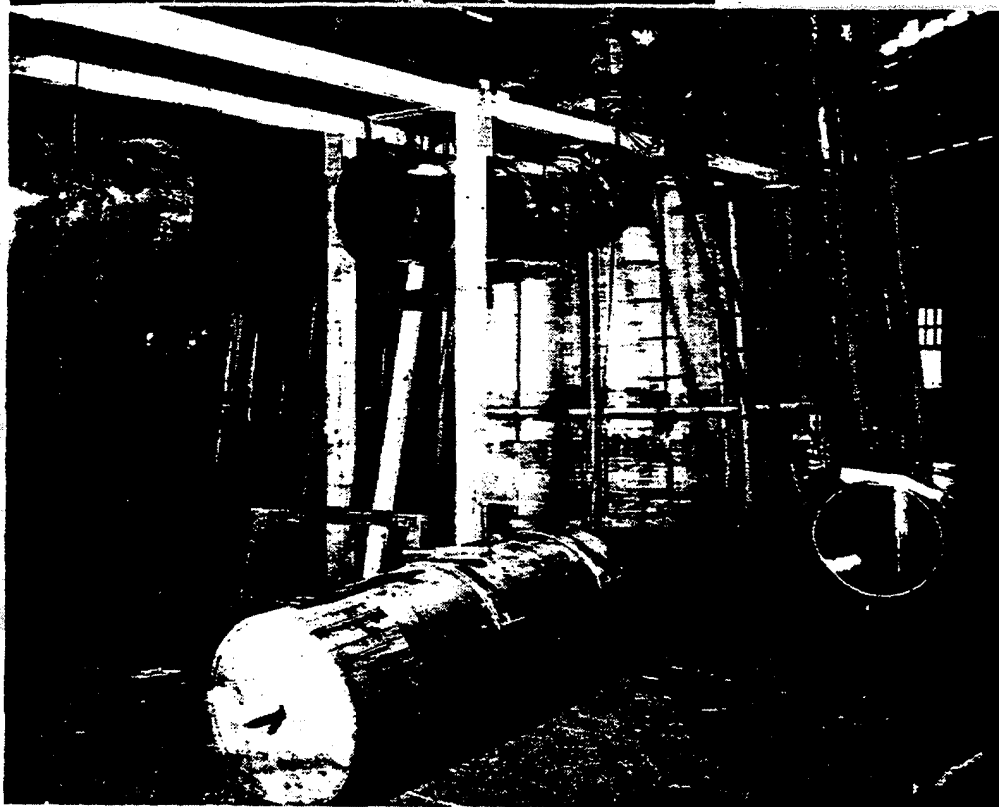
METHODS OF CONSTRUCTION

Because of its low strength, lead is usually supported by some other stronger material, such as steel, wood or concrete. Occasionally chemical equipment is made of cast lead alloy, but then the walls are unusually thick to gain the necessary strength; valves, pumps and fittings are also frequently made of cast lead alloy. Sometimes the supporting structure may be merely a framework of steel, but more often the entire outer shell is made of strong material with a lead lining applied to it in various ways. Small tanks may simply have the sheet lead lining hung in them by turning the lead over the upper edge.

Thickness of sheet lead linings depends largely on the degree of corrosive attack. Rarely is sheet lead lighter than 8-lb. ($\frac{1}{8}$ in. thick) used in chemical equipment. Frequently different thicknesses are used for different parts of equipment, tank bottoms often being lined with heavier lead than sides because of greater wear. For example, the upper part of a vertical tank might be



Welding a vertical lap seam on the lead strap covers of a steel strapped lead lined foamite tank.



Cup welding the sections of a sheet lead gas conduit on a Mills-Packard sulphuric acid chamber. Note strap hanger method of supporting conduit.



Sheet lead cage construction. Note unlined steel framework at upper right, helical lead pipe cooling coils and lead lined steel pipe and valves at lower left.

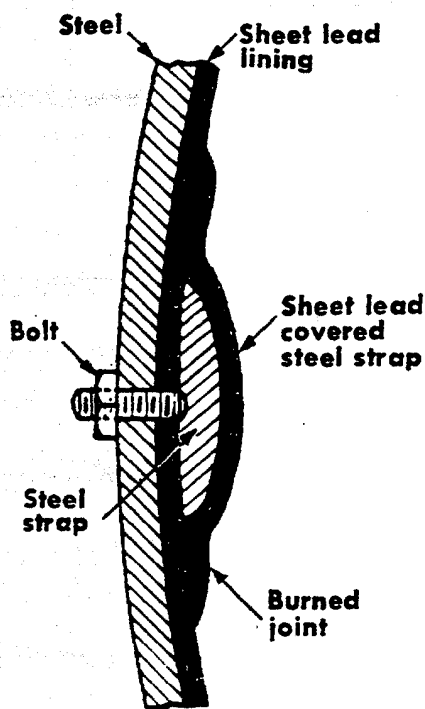


Interior of a completely bonded lead lined steel reaction vessel.

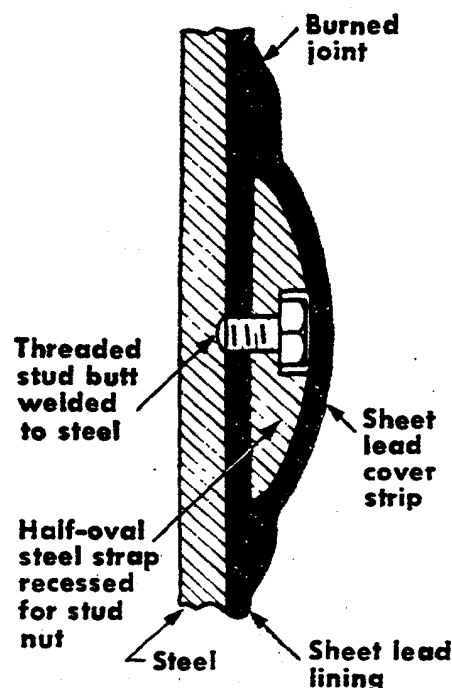
$\frac{1}{4}$ -in. lead, the lower part $\frac{3}{8}$ -in., and the bottom $\frac{1}{2}$ -in. lead. Abrasion may also be a factor in determining the correct thickness.

For better support, the lining is often held by 2-in. half-oval steel flats fastened at frequent intervals inside the lead and through it to the outer steel shell. These straps are covered with strips of lead welded to the lead lining on either side. Vertical straps are usually about 18 in. apart and no more than 24 in. Horizontal strapping in lieu of vertical strapping is seldom used, particularly when under-hand welding is involved. Occasionally in tanks more than 10 feet deep one or two horizontal straps are used in conjunction with the usual vertical strapping to help support the weight of lead.

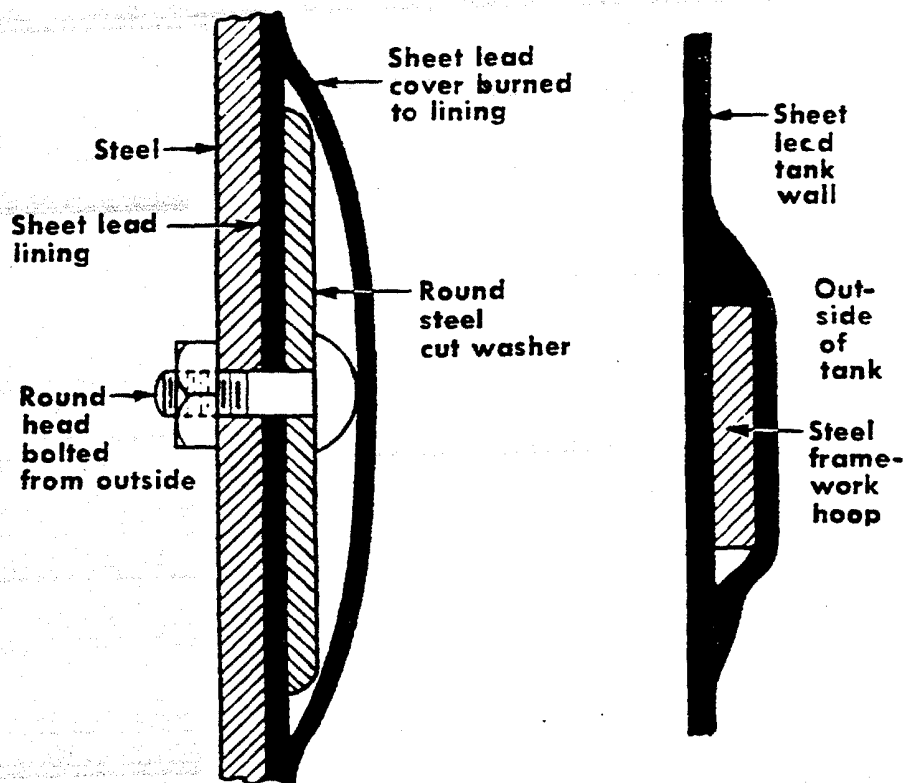
Automatic stud welding eliminates drilling of the steel shell and positioning of the lead sheet, generally resulting in time and cost savings on the installation of strapped linings. A threaded stud can be butt-welded by means of a special gun directly to the inside of the shell, either through precut holes in the lead or between two lead sheets where they butt together. Half-oval steel strapping is slipped over the threaded stud and bolted down on top of the lead.



Bolted strap.



Welded stud fastened strap.



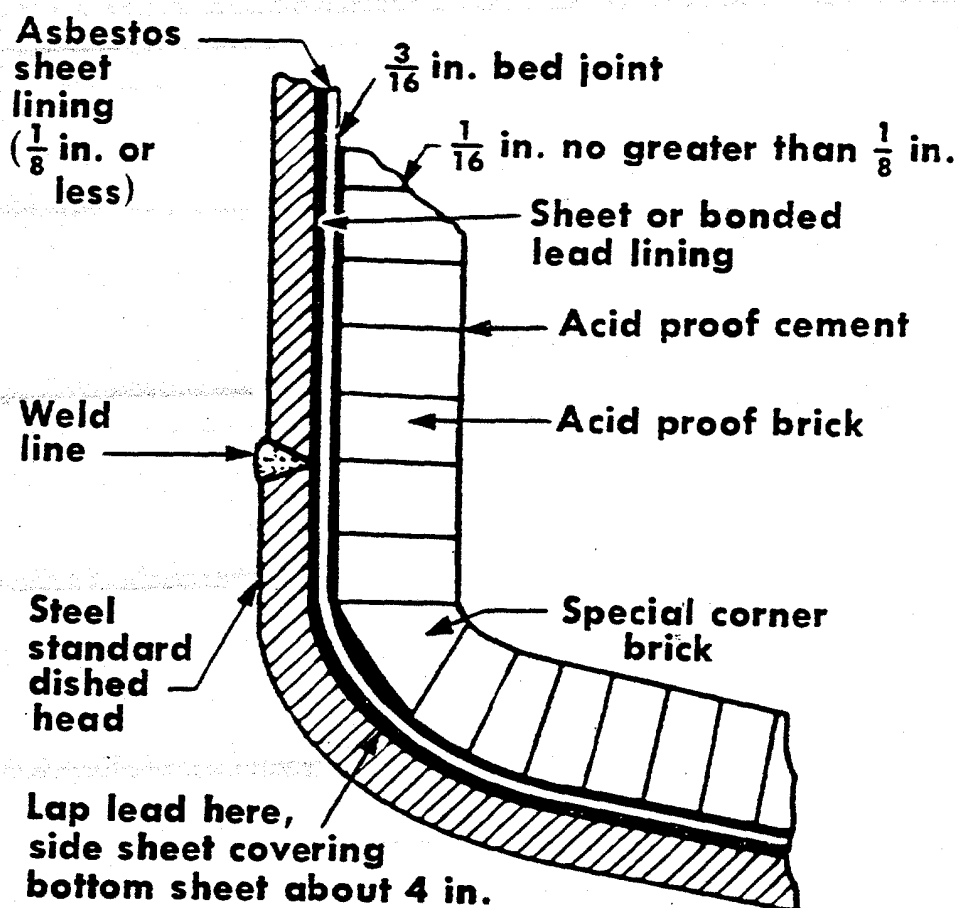
Button type fastening.

Cage construction.

Occasionally it is advantageous to use a large steel cut washer and a roundhead bolt to fasten sheet lead to a steel or wooden shell. The bolt and washer are covered with a lead cap which is burned to the lining. This tends to distribute the load over a large area and aids considerably in minimizing fatigue. The bolts used in this manner are evenly spaced over the entire lining at about 18-in. centers.

Combine the corrosion resistance of lead with the strength of steel and, in effect, you have what has been achieved with bonded lead lining. Bonded lead is simply a thick layer of lead bonded to a steel plate so as to form a homogeneous metallic structure. The thickness of the layer, depending upon the ultimate use, ranges from $\frac{1}{8}$ in. to $\frac{3}{4}$ in. Bonded lead lined vessels are especially recommended for use where heat transfer is important, where rapid temperature fluctuations, high temperatures (up to 450° F.), vibration or repeated shock are encountered or when the vessel operates under vacuum.

Brick and lead linings—a steel shell lined first with lead and then a layer or two of acid-proof brick set in suitable cement—provide another approach to corrosion problems in chemical construction. Brick and lead lined vessels are recommended where high temperature (above 450° F.), vacuum, pressure, abrasion or erosion must be contended with. Brick linings alone are always considered permeable, due to the porosity of the brick and the inability of the bricklayer to secure a continuous cement film between and in back of the brick. The lead lining acts as an impervious barrier between the shell and the brick so that any corrosive seepage is retained by the lead thus preventing damage to the steel shell.



Brick lining with impervious lead interliner.

LEAD PIPE IN CHEMICAL EQUIPMENT

Horizontal runs of lead or lead alloy pipe are generally continuously supported in steel or wooden troughs, or in specially constructed sheet metal shells. Vertical runs are supported at frequent intervals, say every 18 in. Long runs are provided with expansion bends if they operate at high or fluctuating temperatures. When greatest strength is essential, lead-lined steel pipe may be used. The inside of the steel pipe is coated with a bonding agent such as solder and extruded lead pipe inserted. The lead is expanded under steam pressure against the heated steel and is thus "sweated" to the steel pipe.

Lead or lead alloy pipe may be joined by welding or by welded flanges and bolts. Lead flanges are usually backed by loose steel flanges. Flanged joints are generally used for lead-lined steel pipe.

Heating or cooling coils made of lead pipe are important items in many pieces of chemical apparatus. Usually they are helical in shape but may take other forms. Lead spacers are welded at intervals, generally not more than 18 in. apart, around the coil between the turns for support. Where greater strength is needed, the coils may be made of copper tube completely covered with lead. Also flat coils for the ends and bottoms of tanks are used.

Thickness of lead pipe depends on several factors including corrosive attack, abrasion and the pressure to be handled. For instance, if wall thickness is calculated in the usual manner to accommodate a given pressure, additional wall thickness is allowed to compensate for loss through corrosion or abrasion. Pipe $1\frac{1}{2}$ in. in diameter with $\frac{1}{2}$ -in. walls is commonly used with steam pressures up to 45 lb. per sq. in. The formula generally used to calculate wall thickness is given on page 192.

To the wall thickness thus calculated must be added allowances for corrosion and abrasion. The velocity at which a corrosive solution flows across the surface of lead is also a factor in rate of corrosion, but no definite relationship has been established between the two. If the pipe is not used under pressure, then corrosion or abrasion is the principal factor, and the lightest weight of pipe generally selected under such conditions is the class known as "B" or "M" weight in sizes up to 2 in., and $\frac{1}{4}$ -in.

wall in larger sizes. Standard weights of lead pipe are designated by the actual inside diameter and by a letter showing the wall thickness or weight per running foot (see page 76).

HEATING COIL FORMULA

For Calculating Length of Lead Pipe Needed for Heating Solutions—Time 1 Hour

$$\text{Mean temperature difference deg. F.} = \frac{(T - T_1) - (T - T_2)}{2.3 \log_{10} \frac{(T - T_1)}{(T - T_2)}}$$

where T = Temperature of steam or heating medium in deg. F.

T_1 = Initial temperature of solution in deg. F.

T_2 = Final temperature of solution in deg. F.

$$\text{Length of pipe required} = \frac{V \times W \times (T_2 - T_1) \times Sp \times 12}{H \times M \times D \times 3.1416}$$

where V = Volume of solution in gallons

W = Weight of solution in lbs. per gal.

T_2 = Temperature to which solution is to be heated in deg. F.

T_1 = Initial temperature of solution in deg. F.

Sp = Specific heat of solution

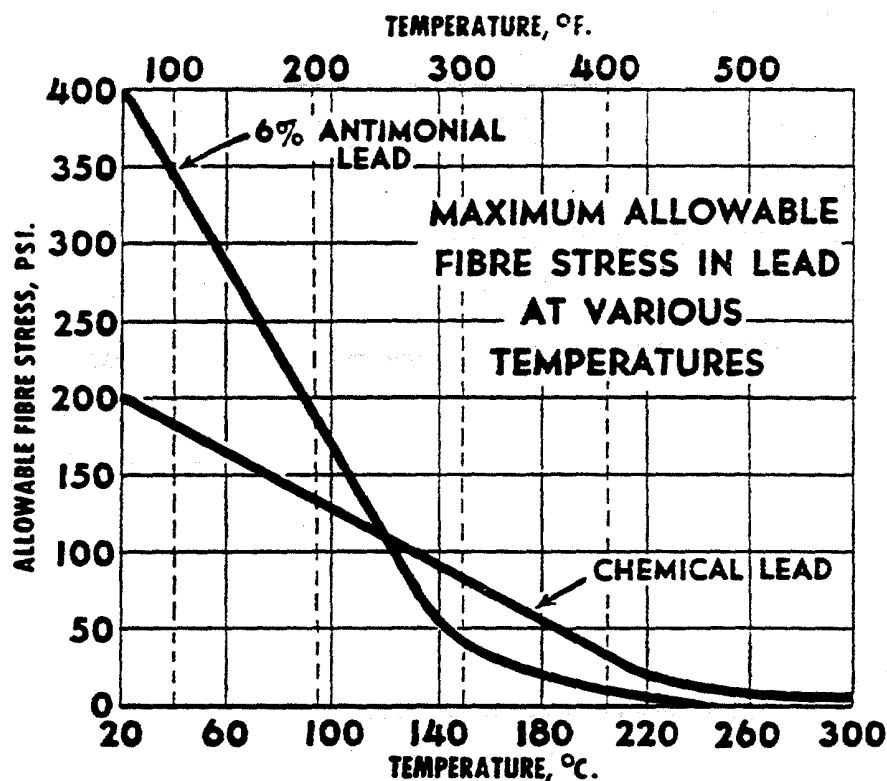
H = Heat transfer in B.t.u./sq. ft./deg. F./hr. = 150

M = Mean temperature difference deg. F.

D = Outside diameter of lead pipe in inches.

NOTE.— H varies with the thermal conductivity of the solution, the density of the solution and the amount of stirring. As a general figure $H=150$ when convection currents function well or there is mild stirring. For a more thorough consideration of heat transfer problems, engineering books on the subject should be consulted.

The graph which follows may be used to estimate the safe working pressures of chemical lead or 6 percent antimonial lead pipe at various temperatures and equivalent steam gauge pressures. On page 192 is a table of values upon which this graph is based along with formulas for calculating the proper pipe sizes under specific conditions of temperature and pressure. The curve of safe working pressure limits for tellurium lead can be assumed to follow that of chemical lead.



Safe working pressures for lead pipe.

The following table is an approximate guide to the length of lead pipe needed in heating coils to heat solutions in open tanks under certain conditions:

APPROXIMATE FEET OF LEAD PIPE TO HEAT 100 GAL. IN 2 HR.

Temperature of solution, deg. F.	Steam pressure			
	10 lb. per sq. in.		30 lb. per sq. in.	
	$\frac{3}{4}$ in. I. D. Feet	1 in. I. D. Feet	$\frac{3}{4}$ in. I. D. Feet	1 in. I. D. Feet
100	3	2.5	2.5	2
110	4	3.25	3	2.5
120	5	4	4	3.25
130	6	5	5	4.25
140	7.75	6	5.75	4.75
150	9.5	7.75	7	5.5
160	11.75	9.25	8.25	6.5
170	14.5	11.75	10	8
180	17.5	14	11.75	9.25
190	21.25	17	14	11.25
200	23.25	20.25	16.5	13

CHAPTER EIGHT

Corrosion Resistance of Lead and Lead Alloys

BEHIND many of the most important uses of lead lies its remarkable resistance to corrosion by a wide variety of chemicals. It is used for protection against weather and soil, for conveying water and protection against moisture, and for handling corrosive chemicals, including what is probably the most important of all industrial chemicals, sulphuric acid.

Lead usually relies for its high resistance to corrosion upon a thin protective coating that forms on its surface. For instance, when the coating which forms on lead in contact with corrosives is one of the highly insoluble lead salts such as the sulphate, carbonate or phosphate, resistance to corrosion is high. On the other hand, if the soluble nitrate forms, little protection is afforded the lead, and it may corrode further. Likewise, if insoluble protective coatings are removed mechanically, as by abrasion or erosion, corrosion resistance is reduced.

Lead generally has good resistance to neutral solutions where lead carbonate and possibly oxide are corrosion products, and fair resistance to alkaline solutions in which these are soluble. Experience has shown that lead is commercially resistant to chromic, sulphuric, sulphurous and phosphoric acids; that it is subject to corrosion at somewhat higher rates by hydrochloric and hydrofluoric acids; and that it is susceptible to being strongly corroded by acetic, formic and nitric acids. Also, nitrate salt solutions are moderately corrosive whereas carbonate solutions are not.

CORROSION RATE INTERPRETATION

It is important in discussing corrosion that a uniform system of designation be used, such as mils or inches penetration per month or year, or milligrams per square decimeter per day. But either of these systems can be somewhat misleading insofar as

the common tendency is to judge best performance on the basis of the lowest corrosion rate. This is especially true in the case of lead in chemical equipment which for mechanical reasons is used in thicknesses generally of $\frac{3}{16}$ in. or greater. Such thicknesses are of a distinct advantage from a corrosion viewpoint. Other corrosion resistant materials are normally used in much lesser thicknesses. Thus for equal uniform corrosion rates, lead would far outlast such other materials because of this difference in thickness.

Designating corrosion rate according to weight loss as milligrams per square decimeter per day instead of volume loss as inches penetration per year is also misleading in the case of lead since lead has the highest density of any commonly used corrosion resistant material. This means that what might appear to be an excessive corrosion rate expressed in weight loss of lead could actually be a very nominal rate of corrosion in terms of volume loss.

When comparisons are being made between various corrosion resistant materials an appreciation of the above will lend much to the proper interpretation of corrosion rate data.

CORROSION RATE CONVERSION DATA

$$\text{ipy} = \text{Mdd} \times 0.00144 \div \text{density}$$

where:

ipy=inches penetration per year

Mdd=milligrams per square decimeter per day

density=grams per cubic centimeter of metal in question.

Metal	Density (gm/cm ³)
Lead	11.35
4% Antimonial lead.....	11.03
6% " "	10.88
8% " "	10.74
10% " "	10.59
12% " "	10.52

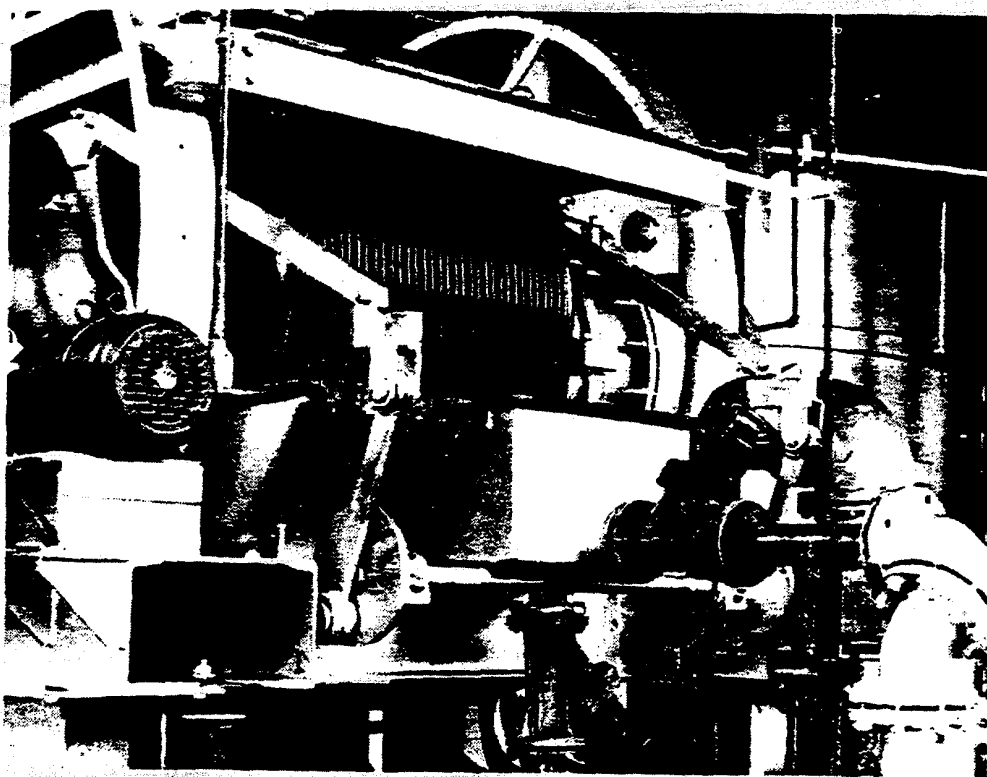
$$\text{Mils penetration per year} = \frac{\text{ipy}}{1000}$$

FATIGUE AND STRESS CORROSION

Since lead has a relatively high linear coefficient of thermal expansion (29×10^{-6} per deg. C, 17 to 100 deg. C, or approximately three times that of steel) it undergoes considerable movement

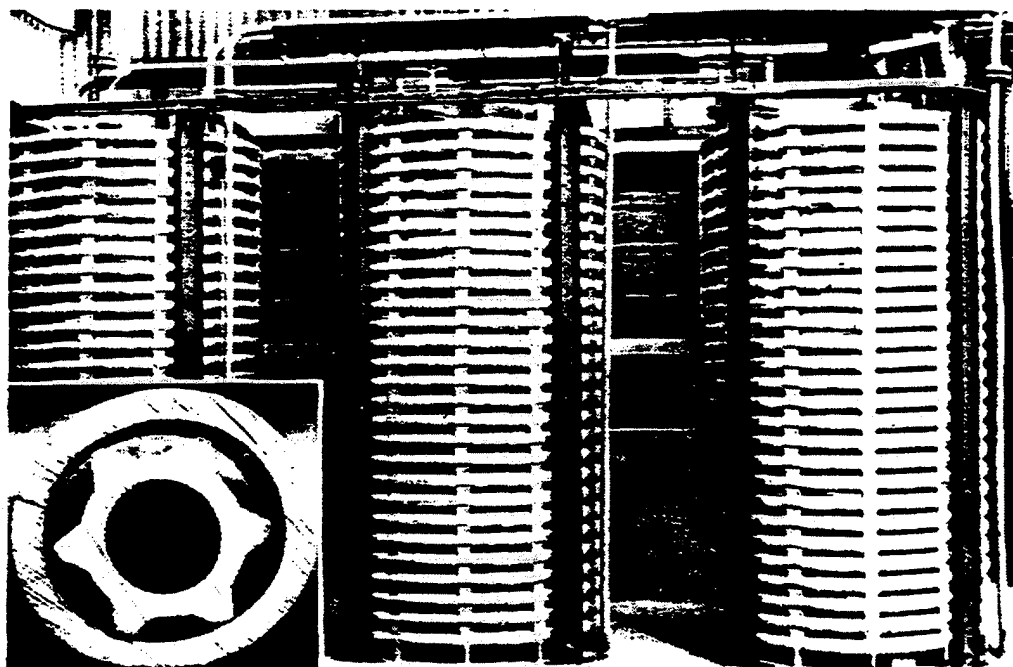


Mills-Packard chambers for making sulphuric acid. They are constructed entirely of sheet lead supported in a steel frame and cooled externally by water flowing down the sloping sides.

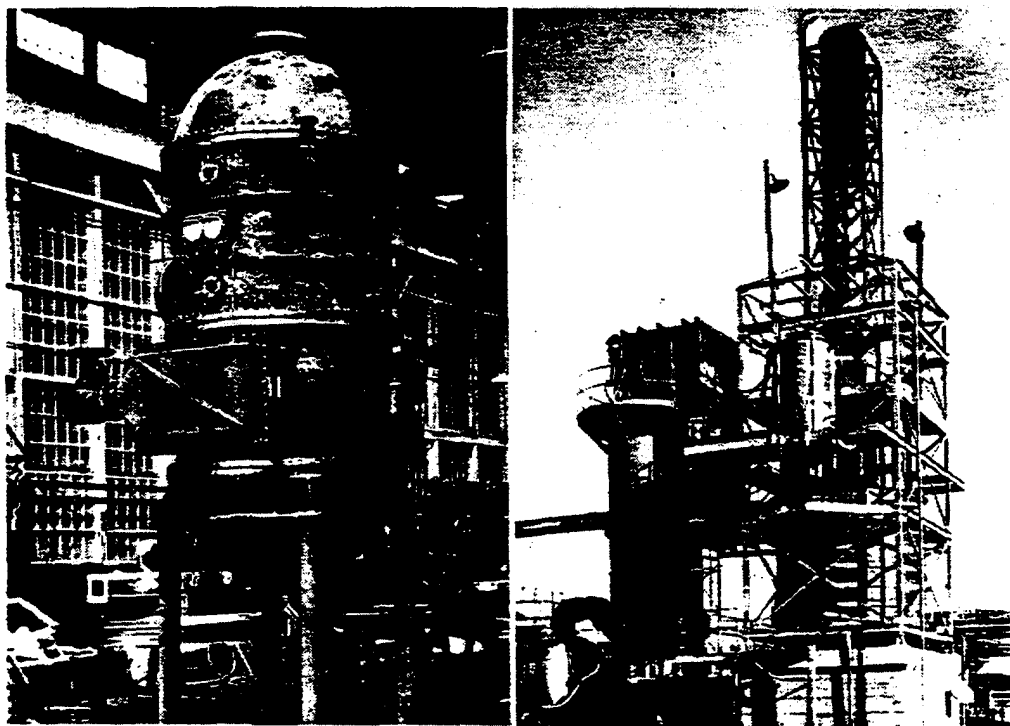


Svenson Evaporator Co.

Lead lined vacuum filter, piping and valves for handling sodium sulphate and viscose rayon spinning bath slurries.



Lead heat exchanger coils for hot dimethylaniline sulphate. *Inset.* Cross-section of coil. Area of space between the pipes equals inside area of the finned pipe.



Struthers-Wells Co.

Left. Seventeen-ton evaporator made entirely of cast 8 percent antimonial lead and used for concentrating titanium sulphate solution. *Right.* Lead and brick lined sulphuric acid sludge concentrator and sheet lead electrostatic acid mist precipitator.

when subjected to severe cyclic temperature changes. It is this differential in expansion rates which largely accounts for the occasional cracking of lead due to buckling. Adequate and proper strapping serves practically to eliminate or minimize this effect. Other factors which occasionally contribute to fatigue conditions include vibration such as that transmitted by nearby machinery, stirring equipment, etc. and strain induced as a rule by inadequate support of hanging sheet lead.

Fracturing caused by repeated bending is hastened by simultaneous exposure to corrosive conditions, thus resulting in a form of stress corrosion. The normal fatigue fracture of lead is intercrystalline and in a corrosive environment fresh crystal surfaces of metallic lead are being constantly exposed until the full depth of the metal is penetrated. Thus, indication of stress corrosion in lead is evidenced by more or less severe intercrystalline etching, sometimes to the point of fracture if the stress conditions are not removed or modified. Cracks from fatigue failures in lead pipe are often transverse and usually at the outside of a bend.

There are two approaches toward the elimination of difficulties brought about by the above conditions:

1. Remove the source of stress.
 - a. This may be done by insulating the equipment from vibration or,
 - b. Spreading out the heating-cooling cycle or,
 - c. Lowering the peak temperature if possible.
2. If the source cannot be removed, counteract the effect by,
 - a. Providing adequate strapping to relieve stress caused by hanging or,
 - b. Use a homogeneously-bonded lead lining to counteract severe cyclic temperature changes or,
 - c. Protect the lead mechanically and thermally with a brick lining or,
 - d. Use thicker lead to reduce fibre stress.

Fatigue characteristics may vary with different alloys of lead. Chemical lead alloyed with 0.04 to 0.05 percent tellurium is amenable to work-hardening, an effect which normally takes place during the sheet rolling operation. The property of work-hardening coupled with the fact that the presence of tellurium in chemi-

cal lead acts as a grain growth inhibitor, raises the fatigue resistance of tellurium lead above that of unalloyed chemical lead.

GALVANIC CORROSION

Corrosion associated with the current of a galvanic cell made up of dissimilar electrodes is defined as galvanic corrosion. This is also known as "couple action." Galvanic corrosion is generally understood to consist of the sum total corrosion, which comprises the normal corrosion that would occur on a metal exposed alone plus the additional amount due to contact with the more noble metal. Since all metals are electrically conductive, the possibility of galvanic corrosion taking place when two or more dissimilar metals come in contact in the same electrolytic medium is almost always present. However, in most chemical installations using lead in a corrosive electrolyte, galvanic corrosion usually is of little consequence and is ordinarily ignored. The film which forms on lead as a result of ordinary chemical reaction, in most instances, acts as an electrical insulator. This is especially true in sulfuric acid exposure, lead sulfate being practically non-conductive.

ATMOSPHERIC AND SEA WATER EXPOSURE

This table is reproduced from a paper of the Institute of Metals, London, by J. Newton Friend, head of the Department of Chemistry, The Technical College, Birmingham, England, entitled, "The Relative Corrodibilities of Ferrous and Non-Ferrous Metals and Alloys." It summarizes the results of his study. The specimens used were cylindrical bars 2 ft. long and $1\frac{1}{2}$ in. in diameter. They were exposed to the city air of Birmingham, an industrial center, for seven years on the roof of the Birmingham Technical College. Similar tests were also carried on at Weston-super-mare, where the samples were exposed to sea water. The relative percentage losses shown in the last two columns of figures reveal that antimonial lead and soft lead stand first and third respectively in the atmospheric corrosion tests and fourth and fifth in the sea-water tests, being exceeded only by tin and nickel, much more expensive metals.

SUMMARY OF RESULTS OF EXAMINATION OF THE BARS EXPOSED TO CITY AIR BIRMINGHAM FOR SEVEN YEARS, 1922-1929

No.	Metal	Com- position,* percent	Surface condition prior to exposure	Original weight, gm.	Loss in weight, gm.	Loss as percent of original weight	Relative per- centage losses†	Relative percent losses in sea tests at Weston‡	Remarks
20	Copper, "arsenic free"	As 0.01	Polished	3526.4	8.1	0.230	58	—	Green stain coat; tenacious Metal surface condition
1	" ordinary	As 0.10	"	3536.9	6.5	0.184	47	73	
21	" arsenical	As 0.25	"	3535.6	5.9	0.167	42	—	
19	" "	As 0.43	"	3481.2	7.7	0.221	56	—	
2	" "	As 0.45	"	3502.0	6.3	0.180	46	68	
3	Nickel-copper	Ni 1.75	"	3508.0	6.6	0.188	48	61	
4	Nergandin brass	—	"	3373.5	13.3	0.394	100	100	Closely adher- underneath Metal surface condition White deposit coating; ten- herent
5	Naval brass	—	"	3305.5	11.4	0.345	88	112	
6	Muntz metal	—	"	3314.1	12.4	0.374	95	57	
7	Screw metal	Pb 1.37	"	3311.2	11.7	0.353	90	29	
8	Aluminum	Si 0.25 Fe 0.32	"	1057.7	1.2	0.113	29	89	
9	Lead, soft	Pb 99.06	"	4394.3	3.8	0.086	22	13	Perfect
10	" antimonial	Sb 1.6	"	4375.7	0.5	0.011	3	10	"
11	Nickel	—	"	3552.5	10.8	0.473	120	9	Greenish under- layer. Inclepe
12	Tin, English common ingot	Sn 99.2	As cast	2793.3	2.8	0.100	25	1	Closely adher- posit under l
13	" high-grade, pure..	Sn 99.75	"	2855.5	2.0	0.070	18	2	
14	Zinc	Zn 99.82	Polished	2819.4	15.2	0.539	137	94	Small pinhole
15	Wrought iron (mean of 11-12 bars)	—	As rolled, with scale	c. 3000	207.2	0.71	1703	100	Surfaces rou- slightly pitted
16	Mild steel (mean of 7 bars)	—	As rolled, with scale	c. 3000	308.5	10.28	2609	112	" "
18	Stainless steel (mean of 3 bars)	Cr 12-13	Polished	c. 3000	3.0	0.10	25	49	Excellent con-

* For full analyses, see *J. Inst. Metals*, 1928, 39, 115, Table I.

† Taking nergandin brass as standard since it lost the same percentage amount in weight as the wrought irons taken in the sea-action tests at Weston.

‡ Calculated from data in Table III., *J. Inst. Metals*, 1928, 39, 122.

LEAD IN MODERN INDUSTRY

CORROSION IN SALT WATER SOLUTION

(200 days at 8.5 deg. C.)

Loss in wgt., percent	NaCl con- centration, percent	Loss in wgt., percent	NaCl con- centration, percent
0.00	0.0834	1.0	0.6982
0.25	0.2331	1.5	0.567
0.50	0.2626	3.0	0.243
0.75	0.4003	6.0	0.127

Corrosion rate increases up to about 1 percent solution concentration, and then decreases.

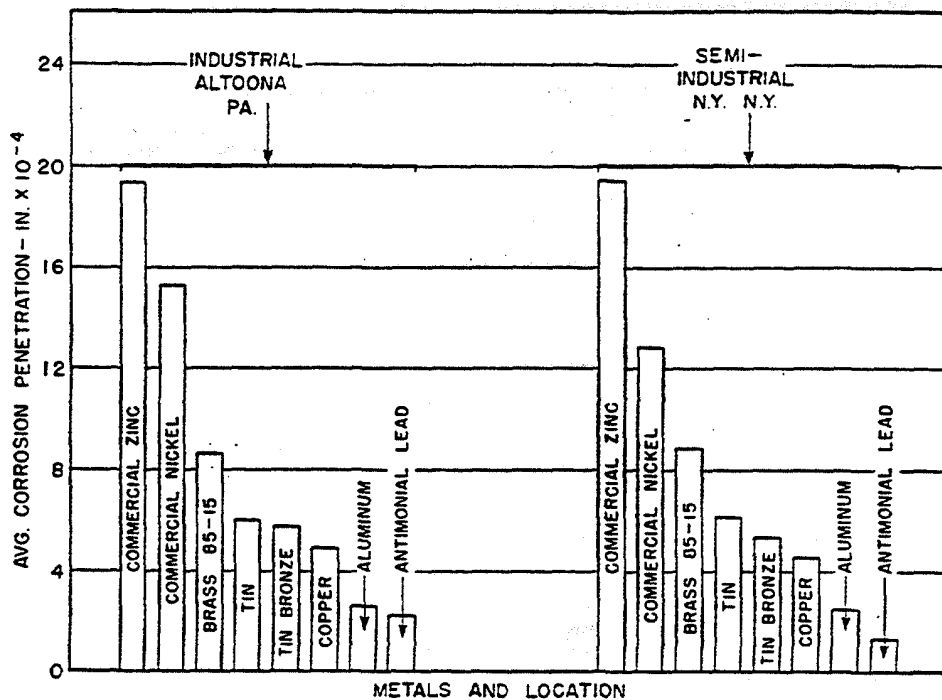
Sea water has a salt concentration of 2.7 percent resulting in a corrosion rate of about 0.25 percent.

ATMOSPHERIC CORROSION

Location	Exposure, years	Average penetration, inches	
		Chemical lead	1% Antimonial lead
Altoona, Pa.	9.25	0.000267	0.000214
New York, N. Y.	9.38	0.000167	0.000113
Sandy Hook, N. J.	9.45	0.000200*	0.000190*
Key West, Fla.	9.32	0.000216	0.000205
La Jolla, Cal.	9.14	0.000162	0.000236
State College, Pa.	9.27	0.000188	0.000129
Phoenix, Ariz.	9.10	0.000094	0.000109

* Samples lost—values estimated.

The above data is based on the 1944 report of A.S.T.M. Committee B-3.



Atmospheric corrosion tests. Ten-year period. ASTM-Proc. 1944.
Antimonial lead 1%.

From the foregoing, it is obvious that the losses are of such small magnitude over even a ten-year period as to be negligible and of no practical importance. Therefore, the chief value of the A.S.T.M. exposure studies with respect to lead is to indicate that the use of lead exposed to atmospheric corrosion is practical under all conditions of exposure and that atmospheric corrosion has little or no effect on lead.

SOIL CORROSION

Soil	Years buried	Loss. oz. per sq. ft. per yr.
Muck	2.11	0.51
Sand	2.07	0.36
Clay	2.10	0.16

NOTE.—Above figures approximate as rate varies in different localities and with different conditions.

Rate of corrosion in soils decreases in the following order:

(1) muck, (2) cinders, (3) sand, (4) clay

SOIL, WASTE AND VENT EXPOSURE

In a recent test of various materials used in plumbing soil, waste and vent lines conducted under accelerated conditions in Fort Worth, Texas, lead pipe proved to be outstanding. It was shown to have a relative life expectancy of more than six times that of any of the other materials tested.*

After exposure for one year in a moist atmosphere containing hydrogen sulphide from sewage disposal sludge, the lead pipe showed a uniform penetration of only 0.000259 in. All of the materials tested were either customarily used or suggested for use in soil, waste and vent lines.

In addition, lead was the only material not effected by pitting whereas all of the others were pitted in varying degrees. In one case, the pits penetrated completely through the pipe wall.

Results of this test prove that the use of lead as a soil, waste or vent material is definitely to be recommended for safety and long life in a plumbing installation.

* The results of the test were described in a paper presented at the 1949 Annual Convention of the American Society of Sanitary Engineering and published in the 1949 Yearbook.

CHEMICAL CORROSION RESISTANCE

The data given here are indicative of the performance of lead in contact with various corrosive chemicals. Since operating conditions vary widely, it is usually wise to use actual exposure tests under operating conditions whenever possible to forecast performance. However, the performance of lead is so well known when exposed to many chemicals, such as sulphuric acid, with which it has been employed so extensively for a long time, that such tests are not always necessary.

Among the many variables determining the suitability of lead, or any other material for that matter, may be temperature, concentration, grade of lead or type of alloy, rate of flow, presence of oxygen, degree of abrasion and presence of impurities.

CORROSION DATA

Metal	Solution and concentration, percent		Temperature, deg. C.	Rate of corrosion, in. penetration per mo.
Lead	2.4	H ₂ SO ₄	25	0.000165
	5		25	0.000024
	50		20	0.00001
			100	0.0002
Hard lead	1	H ₂ SO ₄	20	0.00002
			100	0.00006
	10		20	0.00006
			100	0.00003
	50		20	0.00001
			100	0.0002
	95		20	0.0001
			100	0.0041
Lead	20	H ₂ SO ₄	25	0.0001
	18		25	0.0032
	15		25	0.0179
	10		25	0.0489
	5		25	0.0856
	2		25	0.1326
Lead	42	pure phosphoric acid	15	0.00165
	76	pure	15	0.00469
	42	impure	15	< 0.00001
	10	pure	80	0.00035-0.00748
	25	pure	80	0.00417-0.01480
	50	pure	80	0.00602-0.01197

CORROSION RESISTANCE OF LEAD AND LEAD ALLOYS 59

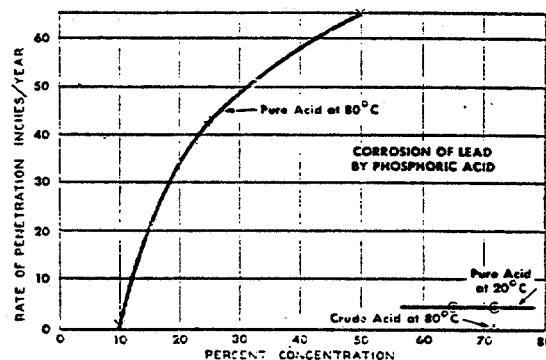
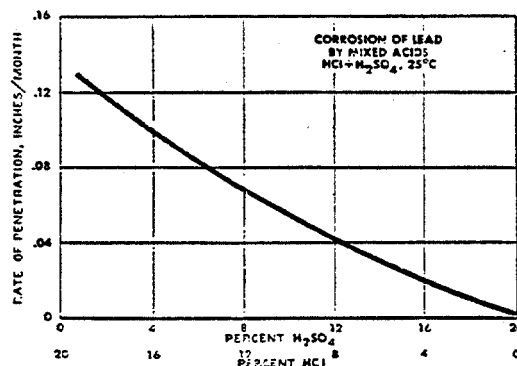
CORROSION DATA—Continued

Metal	Solution and concentration, percent		Temperature, deg. C.	Rate of corrosion, in. penetration per mo.
	dilute	concentrated		
Lead		dilute crude phosphoric acid	80	0.00001-0.00008
		concentrated crude	80	0.00002
	8.3 H ₂ SO ₄	1.7 NaCl	20	0.0016
			100	0.0234
	16.7	3.3	20	0.0002
			100	0.0265
	31	17	20	0.0081
			100	0.0369
	33.3	6.7	20	0.0007
			100	0.0148
	50	10	20	0.0010
			100	0.0034
	1	HCl	25	0.001
			100	0.003
Lead	5		25	0.0015
			100	0.0045
	10		25	0.001
			100	0.013
	20		25	0.007
			100	0.120
Hard lead	1	HCl	20	0.0001
			100	0.0001
	5		20	0.0001
			100	0.0006
	10		20	0.0002
			100	0.0006
	35		20	0.0010
			100	0.0024
Lead	5	NaOH	20	0.0011
			100	0.0035
	25		20	0.0004
			40	0.0002
			60	0.0005
			80	0.0007
			100	0.0014
	35		20	0.0003
			100	0.0005
Lead	Alum 38° Bé		100	0.00174
	100 antimony trichloride		100	0.0049
	20 comm. (95) sodium hydrosulphite		25	0.00007

CORROSION DATA—Continued

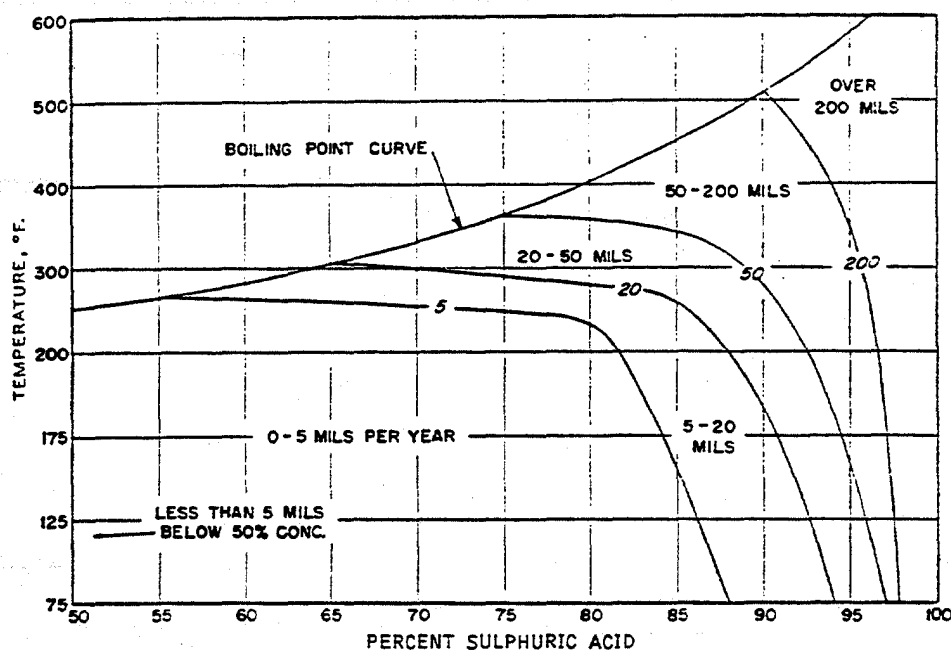
Metal	Solution and concentration, percent	Temperature, deg. C.	Rate of corrosion, in. penetration per mo.
Lead	4 acetic acid	Room	0.00177
	3		0.00175
	2		0.00183
	1		0.00162
	0.5		0.00162
	5		0.0024
	10		0.0015
	20		0.0023
	40		0.0018
	60		0.0023
Lead	Glacial 98	25	0.007
		50	0.020
Lead	5 sodium sulphide	25	0.002
		100	0.001
	10	25	0.001
		100	0.001
	15	25	0.001
		100	0.001
	20	25	0.001
		100	0.001
	25	25	0.001
		100	0.001

The foregoing data on chemical corrosion rates of lead are largely from "Laboratory Corrosion Tests" by Calcott and Whetzel, and "Corrosion Resistance of Metals and Alloys" by MacKay and Worthington.

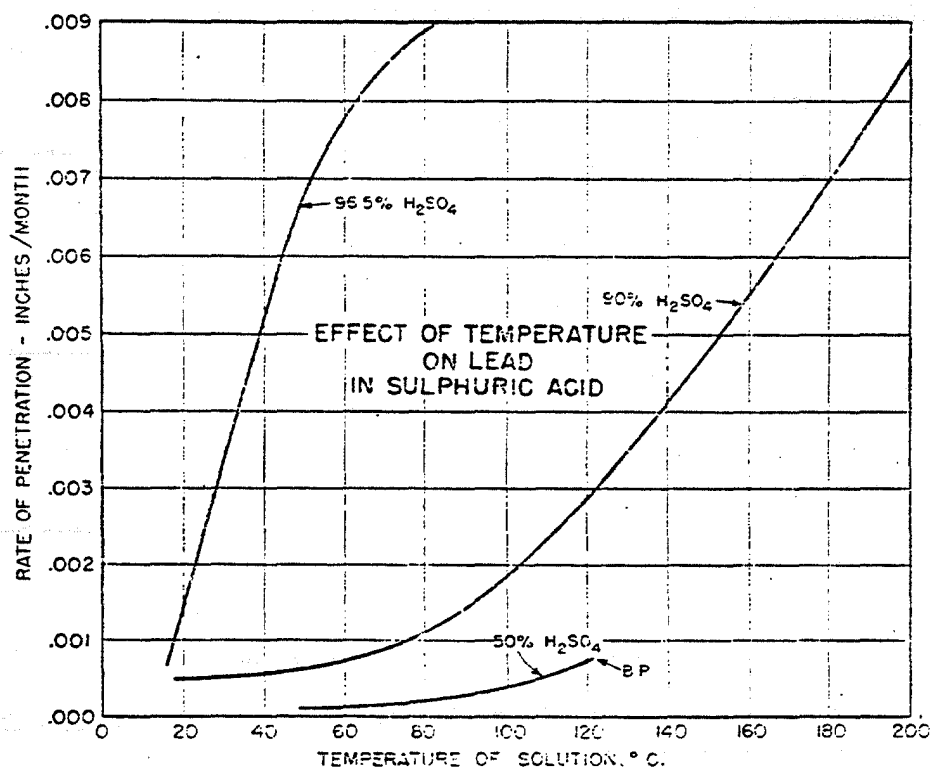


Corrosion of lead by mixed acids and by phosphoric acid.

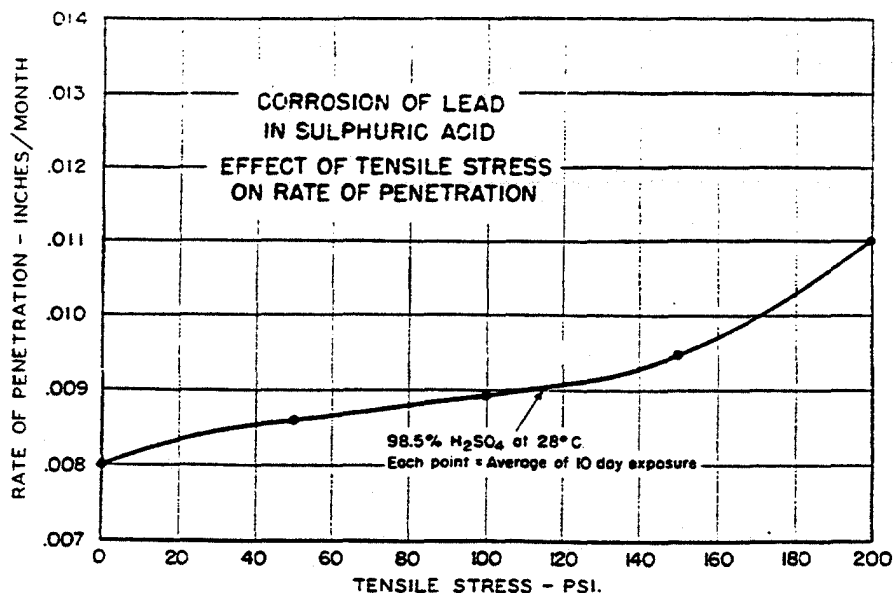
CORROSION RESISTANCE OF LEAD AND LEAD ALLOYS 61



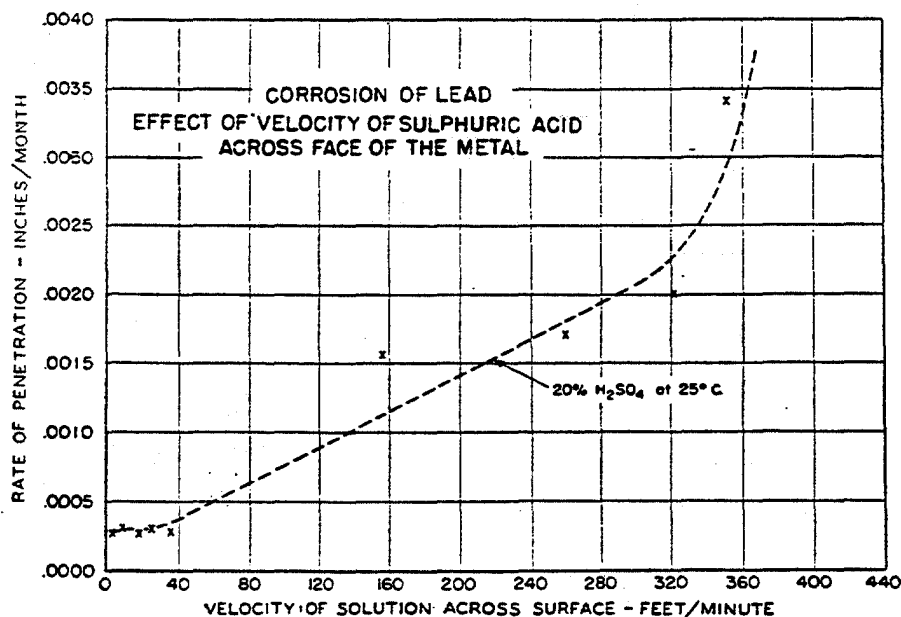
Corrosion of lead by sulphuric acid as a function of temperature. Concentrations below 50% are not shown because resistance of lead is very good even at temperatures including boiling. *Ind. & Eng. Chem.*, Sept., 1951.



Effect of temperature on lead in sulphuric acid.



"Results show a rapid increase in the rate of attack when the stress exceeds 100. Measurements made under other conditions suggest that the curves obtained will be of similar shape, but of course, possessing different ordinates, according to the severity of the corrosive conditions. The effect of the applied stress upon the coating of lead sulphate is to allow the acid to penetrate through the cracks to the metal below." "Some Observations on Corrosion of Lead," *Metal Industry*, June 16, 1933.



Increased velocity of liquid in contact with lead increases the rate of corrosion because: 1. Protective coating of $PbSO_4$ cut off and exposes fresh metal surface to acid; 2. Protective coating of hydrogen stripped from surface, de-polarizing the metal; 3. Mechanical erosion of metal by cutting action of impurities or scale in the acid solution. Effect of 350 ft. per min. is equivalent to the rate of corrosion of 95% H_2SO_4 at 50° C. Calcott, *AIChE Trans.* Vol. XV.

Some common chemicals and the behavior of lead toward them are discussed here.

ACETIC ACID

Moderately corrosive to lead but corrosion is greatly accelerated by high velocities and temperatures. Acetic anhydride and glacial acetic acid are handled in lead.

ACETONE

Lead may be used satisfactorily.

ACETOPHENONE

Lead equipment used in manufacture.

ACETYLENE

Has little effect on lead.

ADIPIC ACID

Lead lined digester used in manufacture.

ALCOHOL, ETHYL

Does not affect lead.

ALCOHOL, METHYL

Does not affect lead.

ALUMINUM CHLORIDE

Lead is used to some extent in condensers.

ALUMINUM SULPHATE OR ALUM

Lead used satisfactorily in manufacture and handling of liquid alum.

AMMONIA

Lead is unaffected by the dry gas, and by the liquid.

AMMONIUM AZIDE

Does not affect lead.

AMMONIUM BIFLUORIDE

Lead used satisfactorily.

AMMONIUM CHLORIDE

Lead may be used at ordinary temperatures with concentrations up to 10 percent.

AMMONIUM FLUORIDE

Solutions at room temperature and free of ammonia satisfactorily handled in lead.

AMMONIUM FLUOSILICATE

Lead is used occasionally for valves and fittings.

AMMONIUM HYDROXIDE

Lead satisfactory with liquid or gas at practically all temperatures and concentrations.

AMMONIUM PHOSPHATE

Lead may be used satisfactorily.

AMMONIUM SULPHATE

Lead may be used freely.

ANTIMONY CHLORIDE

Lead is somewhat corroded, but is used with comparative economy for chlorinating the trichloride to the pentachloride.

ARSENIC ACID

Lead salt forms on contact but lead pipe known to last 10 to 15 years if salts cleaned out periodically.

BARIUM SULPHIDE

Lead tanks are used in handling solutions prior to precipitation of barium sulphide.

BENZOL

Has little or no effect on lead if pure.

BENZYL CHLORIDE

Lead may be used satisfactorily.

BENZYLPHENOL

Manufactured in lead lined vessels at temperatures up to 40° C.

BORIC ACID

Lead is used satisfactorily.

BRINE

(See Sodium Chloride)

BROMINE

Lead may be used when cold and acid free.

CADMIUM SULPHATE

Lead is widely used for lining plating tanks.

CALCIUM ACID PHOSPHATE

Lead can be used in a wide range of concentrations and temperatures.

CALCIUM BISULPHITE

Lead can be used in a wide range of concentrations and temperatures.

CALCIUM CARBONATE

Found in natural waters and forms a good protective coating on lead. Added to water to reduce plumbo-solvency.

CALCIUM HYDROXIDE

Presence in "green" cement corrodes lead in presence of moisture and oxygen. However, added to soft waters reduces plumbo-solvency.

CARBONATES, SOLUBLE

Act as a protection to lead by formation of lead carbonate coating.

CARBON DIOXIDE

Acts as a protection to lead in natural waters unless present in excess, when it increases solubility. Lead is used in acid-carbonate systems of generating CO₂.

CARBON TETRACHLORIDE

Lead is used at ordinary temperatures.

CASTOR OIL IN ACID

Lead is used for piping and valves.

CHLORINATED HYDROCARBONS

Action on lead varies from slight to severe depending upon breakdown to HCl and presence of organic acids.

CHLORINATED POLYVINYL CHLORIDE

Lead used throughout manufacture.

CHLORINATION PROCESSES

Lead is slowly corroded at temperatures usually used, but has satisfactory life compared with other common metals, and greater economy.

CHLORINE

Dry does not affect lead and lead may be used with moist chlorine up to about 110 deg. C. with slight corrosion. Amounts of chlorine used in water treatment do not affect lead.

CHLOROBROMOMETHANE

When dry (less than 0.02 percent H_2O) practically non-corrosive to lead.

CHROMIC ACID

Since chromates form a good protective coating on lead, lead may be used with fairly high concentrations of this acid. High lead alloys are widely used in chromium plating.

CINDERS

Lead embedded in cinders should be protected.

COAL TAR

Lead used in refining and recovery of many by-products.

CONCRETE, CEMENT OR MORTAR

When "green," free lime present attacks lead. Aging to carbonate lime or applying asphalt coating on lead recommended to prevent such corrosion.

COPPER SULPHATE

Lead is used for anodes and tank linings in electroplating.

DIBUTYL THIODIGLYCOLATE

Part of manufacturing process conducted in lead lined vessels.

DIHYDROXYDIPHENYL SULPHONE

Lead cooling coils and bonded lead lined pressure vessel used in manufacture.

ELECTROGALVANIZING

Lead equipment finds good usage.

ETHER

Little or no effect on lead. Used in its manufacture.

FATTY ACIDS

Lead may be used but it will react slowly in presence of oxygen.

FERRIC CHLORIDE

Lead not recommended.

FERRIC SULPHATE

Lead stands up well over a wide range of concentrations and temperatures.

FERRIC AMMONIUM SULPHATE

Lead stands up well over a wide range of concentrations and temperatures.

FERROUS CHLORIDE

Lead is recommended.

FERROUS SULPHATE

Lead used for tank linings and coils in production and use.

FLUOROLUBES

Addition polymers of trifluorovinyl chloride used as lubricants. Shipped in lead lined pails to prevent contamination and discoloration.

FORMALDEHYDE (Formic Acid)

Action on lead similar to that of acetic acid.

HEXACHLORBUTADIENE

Highly corrosive to all metals except lead. Lead used throughout manufacture at temperatures up to 205° C.

HEXACHLORETHANE

Lead lined equipment used for chlorination vessel and crystallizing basins up to 60 percent concentration and 136° C.

HYDROCHLORIC ACID

Use of lead is not generally recommended but it has been used with some corrosion in concentrations up to 30 percent at normal temperatures and 20 percent at 100 deg. C. Antimonial lead shows better resistance than ordinary lead.

HYDROCYANIC ACID

Lead used in manufacture.

HYDROFLUORIC ACID

Lead is commonly used and has fair resistance to cold acid up to 60 percent concentration.

HYDROGEN CHLORIDE (Anhydrous Hydrochloric Acid)

Little effect on lead.

HYDROGEN PEROXIDE

Not likely alone to affect lead, but accelerates acid corrosion. Lead is an active decomposition catalyst causing peroxide to decompose into water.

KOCH ACID REDUCTION MASS

Lead may be used safely.

MAGNESIUM CHLORIDE

Corrodes lead as it does other metals, though lead pumps are used with it.

MAGNESIUM SULPHATE

Lead stands up well over a wide range of concentrations and temperatures.

MALACHITE GREEN MOTHER LIQUOR

No appreciable effect on lead at 80 deg. C.

MERCURIC SULPHATE

Highly oxidizing, but lead in general has good resistance to most acid sulphate conditions.

MIXED ACIDS

Mixtures of sulphuric and nitric acids can be used with lead at ordinary temperatures if water present is less than 30 percent.

NAPHTHALENE

Lead may be used.

NICKEL SULPHATE AND NICKEL PLATING SOLUTIONS

Plating tanks are commonly lined with lead. Lead heating coils commonly used.

NITRATION MIXTURE OF H-ACID

Lead is used with rather high corrosion.

NITRIC ACID

Lead is not generally recommended with this acid, but is used with little corrosion when concentrations are in the range of 52 to 70 percent by weight at normal temperature.

NITRO-BENZOL AND NITROCHLOR-BENZOL

Corrosive to lead.

NITROCELLULOSE

Lead widely used, as in all rayon manufacturing processes.

NITROGLYCERIN

Lead used to handle spent acid.

NITROSYL-SULPHURIC ACID

Action on lead is least at specific gravity of about 1.5 to 1.6. Close control thus minimizes corrosion.

ORGANIC ACIDS

In general, accelerate the corrosion of lead, but their presence in solutions does not always preclude the use of lead.

OXALIC-SULPHURIC ACIDS

Lead satisfactory with oxalic acid containing 1 percent free H_2SO_4 in all concentrations from 5 to 50 percent and all temperatures from cold to boiling.

OXYGEN

Dry gas merely tarnishes lead. In presence of water, initial attack is usually followed by formation of protective coating formed by salts such as carbonates, sulphates and silicates in the water. In absence of these salts, deaeration may be employed to remove oxygen because of its action on all metals.

OXY-L ACID

Lead is corroded to some extent but is about the only economical metal that can be used with satisfaction.

PENTACHLORETHANE

Lead used in manufacture and storage at temperatures up to 80° C.

PHENOL

Lead can be used satisfactorily.

PHOSPHATES

Generally form protective films on lead.

PHOSPHORIC ACID

Lead may be used with concentrations up to 80 percent below 200 deg. F. Impure acid has even less effect on lead and can be used up to 85 percent concentration.

PHOSPHORUS OXYCHLORIDE

Storage tanks constructed of lead or bonded lead. Lead piping, coils and receivers also used. Shipped in lead carboys, lead lined drums or lead lined tank trucks.

PHOTOGRAPHIC SOLUTIONS

Lead is satisfactory generally.

POTASSIUM METABISULPHITE

Preferred material of construction is lead and lead lined steel. Evaporated in lead lined tanks at 160° F.

POTASSIUM PERMANGANATE

Attacks lead.

PYRIDINE

Does not affect lead.

SILICATES

Form protecting coatings on lead and thus can be recommended for treating natural waters if necessary.

SODIUM BIFLUORIDE

Successfully handled in lead.

SODIUM BISULPHATE

Can be handled in lead even when highly concentrated.

SODIUM BISULPHITE

Lead may be used with a wide range of concentrations and temperatures.

SODIUM CARBONATE

Dilute solutions do not affect lead; in natural waters forms protective coating on lead.

SODIUM CHLORIDE

Lead satisfactory for dilute solutions at ordinary temperatures. Sea water or brine are commonly handled in lead or antimonial lead.

SODIUM CHLORITE

Lead may be used with low concentrations at room temperature.

SODIUM HYDROSULPHITE

Lead can be used satisfactorily.

SODIUM HYDROXIDE

Lead can be used with concentrations up to 30 percent and temperatures to 25 deg. C. With concentrations up to 10 percent temperatures may reach 90 deg. C.

SODIUM HYPOSULPHITE

Lead can be used satisfactorily.

SODIUM HYPOCHLORITE

Attacks lead.

SODIUM SULPHATE

Lead can be used satisfactorily with solutions up to 10 percent concentration boiling.

SODIUM SULPHIDE

Lead can be used satisfactorily with these solutions at temperatures up to 100 deg. C.

SODIUM SULPHITE

Lead can be used with solutions up to 20 percent concentration at 25 deg. C.

SULPHATES AND SULPHITES

Generally form protective coatings on lead.

SULPHUR CHLORIDE

Has little effect on lead.

SULPHUR DIOXIDE

Has little effect on lead when dry and can be used moist up to about 200 deg. C.

SULPHUR TRIOXIDE

Can be used satisfactorily with lead.

SULPHURIC ACID

Lead is the standard material for handling this acid. It can be used with concentrations up to 96 percent at room temperature and 85 percent up to 220 deg. C. It is sometimes used satisfactorily even up to 250 deg. C.

SULPHUROUS ACID

Lead is satisfactory up to about 220 deg. C.

TANNIC ACID

Somewhat similar to acetic acid.

TARTARIC ACID

Lead covered copper tubes and cast hard lead used in evaporators.

TETRACHLORETHANE

Bonded lead reaction tower and other lead lined equipment used in manufacture.

CORROSION RESISTANCE OF LEAD AND LEAD ALLOYS 69

THIONYL CHLORIDE

Lead is used satisfactorily up to 220 deg. C. and sometimes higher.

TITANIUM SULPHATE

These solutions can be handled satisfactorily in lead.

TITANIUM TETRACHLORIDE

Lead gaskets used in pipe flanges.

UREA

Lead lined autoclave and stills used in manufacture at temperatures up to 190° C.

VICTORIA GREEN MOTHER LIQUOR

Lead may be used satisfactorily up to 80 deg. C.

WATER, DISTILLED

No effect in the absence of dissolved CO₂ or O₂.

WATER, NATURAL

Usually no effect on lead because of protective coating formed from dissolved salts. Very soft waters or those of peaty origin may react with lead slightly, as they do other metals, but such action can be prevented by treatment of the waters with lime or sodium silicate.

WOOD

Most wood has little or no corrosive effect on lead. A few instances of corrosion by wood containing organic acids, such as green oak, have been reported. Wood to be lined with lead should be inspected for presence of borers.

ZINC CHLORIDE

Lead can be used satisfactorily.

ZINC HYDROSULPHITE

Manufactured in lead lined tanks using lead cooling coils.

ZINC SULPHATE

Lead preferred when solution is acid.

CHAPTER NINE

Composition of Commercial Pig Lead

THE following are the chemical requirements for the various grades of commercial pig lead included in the American Society for Testing Materials Specification, Serial Designation B29:

	Corroding lead	Chemical lead	Acid lead	Copper lead	Common desilverized lead A	Common desilverized lead B	Soft unde- silverized lead
Silver, max., percent....	0.0015	0.020	0.002	0.020	0.002	0.002	0.002
Silver, min., percent....	—	0.002	—	—	—	—	—
Copper, max., percent...	0.0015	0.080	0.080	0.080	0.0025	0.0025	0.04
Copper, min., percent...	—	0.040	0.040	0.040	—	—	—
Silver and copper together, max., percent	0.0025	—	—	—	—	—	—
Arsenic, max., percent...	0.0015	—	—	—	—	—	—
Antimony and tin to- gether, max., percent.	0.0095	—	—	—	—	—	—
Arsenic, antimony and tin together, max., per- cent	—	0.002	0.002	0.015	0.015	0.015	0.015
Zinc, max., percent.....	0.0015	0.001	0.001	0.002	0.002	0.002	0.002
Iron, max., percent.....	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Bismuth, max., percent..	0.05	0.005	0.025	0.10	0.15	0.25	0.005
Lead (by difference), min., percent	99.94	99.90	99.90	99.85	99.85	99.73	99.93

Corroding lead is a designation that has been used for many years in the trade to describe lead which has been refined to a high degree of purity.

Chemical lead has been used for many years in the trade to describe the undesilverized lead produced from Southeastern Missouri ores.

Acid lead is made by adding copper to fully refined lead.

Copper lead is made by adding copper to fully refined lead.

Common desilverized leads A and B are designations that are used to describe fully refined desilverized lead.

Soft undesilverized lead is used in the trade to describe the type of lead produced from ores of the Joplin, Mo., district.

CHAPTER TEN

The Soldering and Welding of Lead

SOLDERING and welding are the two most common methods of joining lead. Both are effectively applied to this metal and when done properly result in joints stronger than the metal itself.

SOLDERING

Only mild, non-corrosive fluxes are needed in soldering lead, a distinct advantage. After the metal at the joint has been mechanically cleaned by scraping, wire brushing or use of a scratch cloth, salt-free mutton tallow or rosin is applied as flux. Rosin may be dissolved in alcohol for use as a liquid. Lead does not have to be pre-tinned before soldering except in particularly difficult soldering operations. Preparation of the lead by thorough cleaning and close fitting is essential to successful results. The lead surfaces in contact should be cleaned and fluxed as well as the lead on the outside so that the solder will sweat between the layers of lead.

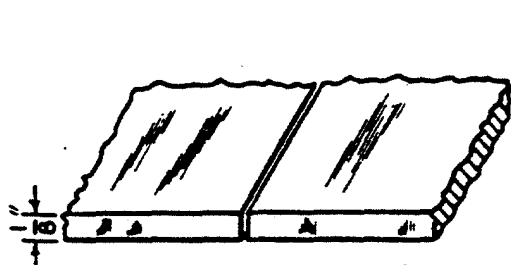
Soldering coppers or "irons" should be cleaned and well tinned. Coppers weighing about 2 lb. each (4 lb. per pair) are satisfactory for most lead work except the heaviest lead for which heavier coppers are used. Because of the low melting point of lead, coppers should not be too hot.

For general soldering of lead using a soldering copper, 50-50 solder is most popular. For wiping, however, solder containing about 37 to 40 percent tin, balance lead, with or without a small percentage of antimony, is employed. Tin content as low as 32.5 percent has been used for this purpose where the joints will not be under pressure but such low tin content is not recommended as a rule. The high melting point solders, such as lead-silver solder, cannot be used successfully with lead as the melting point is too close to that of lead itself.

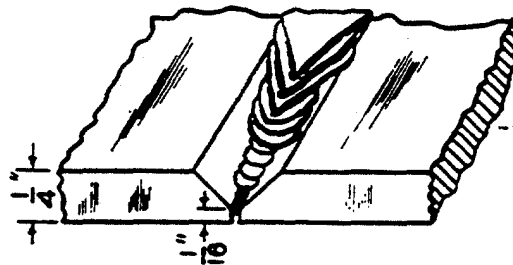
On page 40 a special sealing solder for use on wiped solder joints is described. This was developed especially for effecting gas-tight seals on lead sheathed cable splices.

WELDING

Lead welding, often called lead "burning," truly fuses the parts together without addition of any different metal, although additional lead is frequently added in building up the joint. A torch is used to fuse the metal. Since little heat is required to fuse lead, only the smallest tips should be used on the torch. The smallest sizes of tips are suitable for ordinary weights of lead, say up to 10-lb. sheet lead, and the next larger two or three sizes for heavier lead. Smaller tips are used for vertical and overhead work than for flat work.

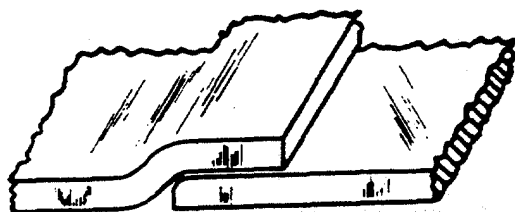


Butt joint for sheet lead $\frac{1}{2}$ in. thick or less.

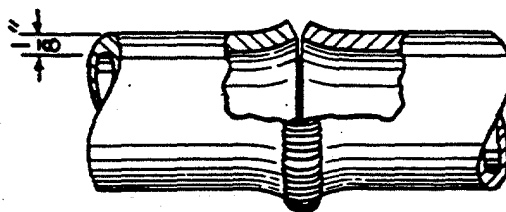


Butt joint for sheet lead over $\frac{1}{2}$ in. thick.

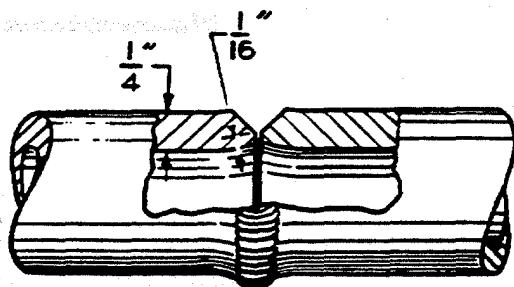
Two gases are usually employed to produce the flame. Oxygen and hydrogen are most popular, with oxygen and acetylene or other hydrocarbon gases also being used. Oxygen and city gas is sometimes employed for shop work such as storage battery welding. For light weights of lead when joints are made on the flat, flames using a single gas, such as propane, are satisfactory. Flames should be neutral for welding lead. An oxidizing flame can be easily recognized by formation of a brown oxide on the surface of the molten metal.



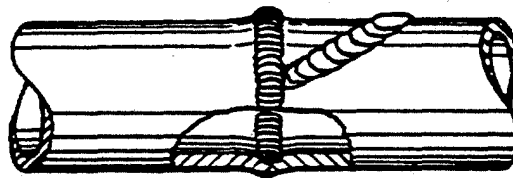
Lap joint in sheet lead.



Butt joint for pipe with $\frac{1}{2}$ in. wall thickness or less.



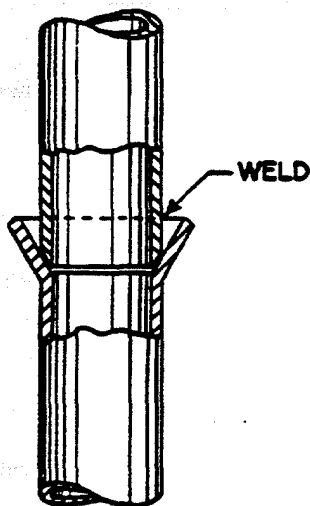
Butt joint for pipe over $\frac{1}{2}$ in. wall thickness.



Technique for welding pipe in the horizontal fixed position.

For welding, lead is prepared much the same as for soldering, being scrupulously clean, but no flux is employed. Lap joints are preferred except in very heavy lead. Lead welding rod used as a filler in the joints should have the same composition as the lead being joined and should be from $\frac{1}{8}$ to $\frac{3}{8}$ in. in diameter, depending upon the thickness of lead. Welding rod is not ordinarily used for vertical lap joints.

On butt joints, a rough rule of thumb for rod consumption for a single pass is 1 ft. of rod to 1 ft. of joint where $\frac{1}{4}$ -in. rod and 8-lb. lead are employed. There is slightly over 4 ft. per pound of $\frac{1}{4}$ -in. rod.



Cup joint for pipe in vertical fixed position.

All of the lead welding drawings shown in this chapter appear in Chapter 36 of the *Welding Handbook*, 3rd Ed., Amer. Welding Soc.

Manipulation of the torch and the kind of flame used depend on the type of joint being welded and the position of welding. In general, a semi-circular or V-shaped motion is used. The molten lead is controlled and flowed with the flame, thus accounting for the circular or herringbone appearance of the joint. Each semi-

circle or Vee is made in one continuous operation, the flame being flicked away from the work at its completion.

The speed of welding butt joints in the flat position is not much different from the speed of gas welding steel. Speeds of 30 ft. per hr. are common with 6-lb. sheet lead. Granjon's formula for determining welding speed is:

$$V = \frac{1.92 \text{ to } 3.85}{T}$$

T = lead thickness, in.

V = welding speed, ft./hr.

The principal precaution to take in lead welding is to avoid burning through or reducing the thickness of the lead.

CHAPTER ELEVEN

Lead in Modern Plumbing

LEAD WATER SERVICE PIPE

LEAD has probably a longer record of satisfactory performance than any other water service pipe material. As a consequence, it is used extensively for that purpose today, and many of America's greatest cities use it exclusively.

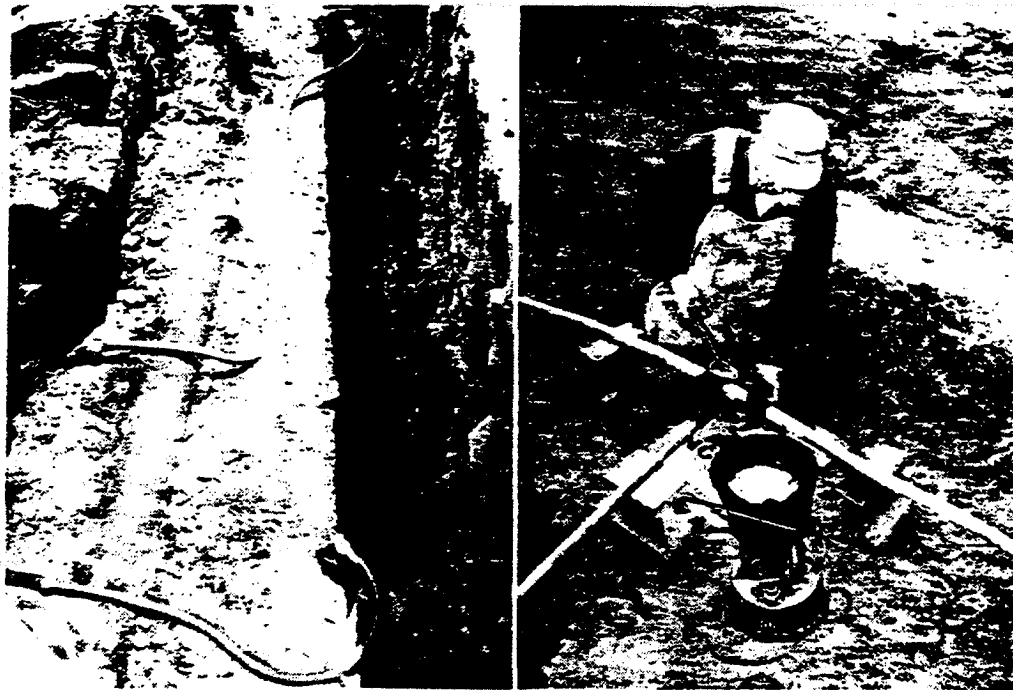
The flexibility of lead pipe allows adjustment to ground settlement without damage and minimizes the number of necessary joints. The well known resistance of lead to corrosion and the thick walls of the pipe result in exceptionally long life. Water flowing through lead pipe does not become discolored and the pipe does not clog with corrosion product.

The first essential is to select pipe of proper quality and weight for the pressure to be handled. Pipe should meet one of the recognized national standards which have been adopted to control the quality of lead pipe for plumbing and water distribution and of lead traps and bends. Federal Specification WW-P-325 covers pipe, bends and traps, while Commercial Standards CS95-41 and CS96-41 promulgated by the National Bureau of Standards cover lead pipe and lead traps and bends respectively. The Lead Industries Association also has standards on these products and licenses manufacturers to use its *Seal of Approval* on products meeting these standards as a protection to the purchaser against inferior quality. All of the standards mentioned here are substantially the same in their requirements, the principal differences being in the form of the standards and the degree of detail into which they enter.

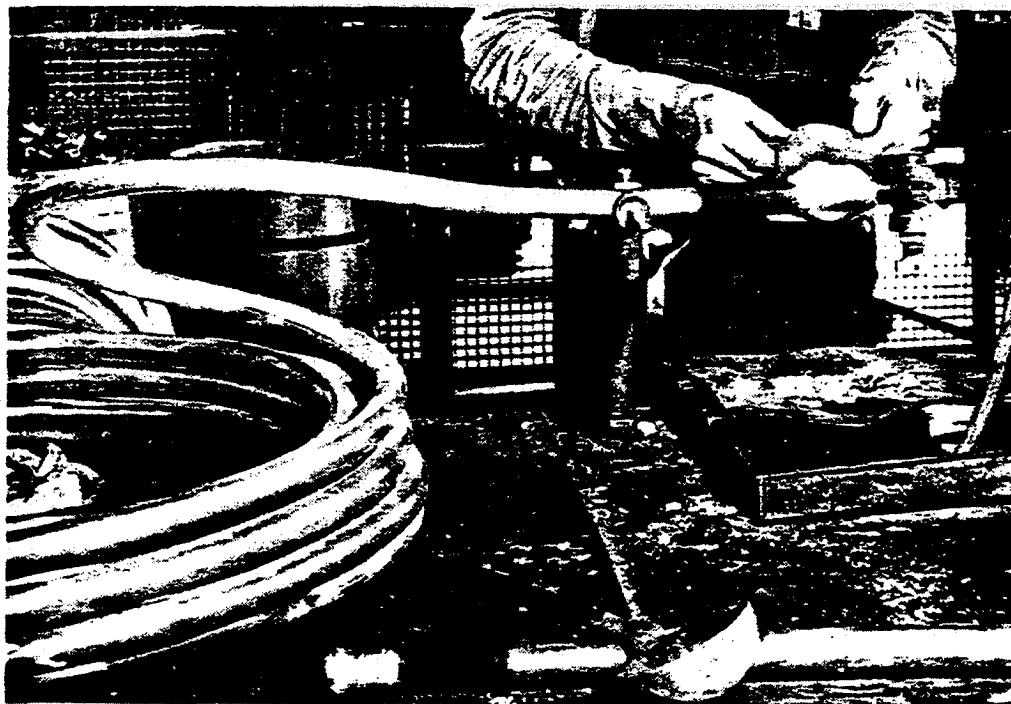
The following dimensions and weights of lead pipe for plumbing and water distribution are from Federal Specification WW-P-325:

LEAD IN MODERN INDUSTRY

Class	Commercial designation		Size (nominal inside diameter) (inches)	Wall thick- ness (inches)	Outside diameter (inches)	Minimum outside circum- ference (inches)	Nominal weight per foot (inches)
	East	West					
100 (Maximum working pres- sure 100 lb. per sq. in.)	AAA	XXS	$\frac{3}{8}$	0.256	0.888	$2\frac{5}{8}$	2.50
			$\frac{1}{2}$	.256	1.012	$3\frac{1}{8}$	3.00
			$\frac{5}{8}$	.256	1.137	$3\frac{7}{8}$	3.50
			$\frac{3}{4}$	.293	1.336	$4\frac{1}{8}$	4.75
			1	.298	1.596	$4\frac{7}{8}$	6.00
			$1\frac{1}{4}$	.320	1.889	$5\frac{1}{8}$	7.75
			$1\frac{1}{2}$	.386	2.272	7	11.25
			2	.504	3.008	$9\frac{1}{8}$	19.50
75 (Maximum working pres- sure 75 lb. per sq. in.)	AA	XS	$\frac{3}{8}$	0.175	0.725	$2\frac{1}{8}$	1.50
			$\frac{1}{2}$	.188	.876	$2\frac{5}{8}$	2.00
			$\frac{5}{8}$	.228	1.082	$3\frac{1}{4}$	3.00
			$\frac{3}{4}$	.231	1.212	$3\frac{1}{2}$	3.50
			1	.246	1.492	$4\frac{1}{8}$	4.75
			$1\frac{1}{4}$	.258	1.765	$5\frac{3}{8}$	6.00
			$1\frac{1}{2}$	.288	2.076	$6\frac{3}{8}$	8.00
			2	.376	2.751	$8\frac{1}{2}$	13.75
50 (Maximum working pres- sure 50 lb. per sq. in.)	A	S	$\frac{3}{8}$	0.143	0.661	$2\frac{1}{8}$	1.25
			$\frac{1}{2}$	.149	.798	$2\frac{3}{8}$	1.50
			$\frac{5}{8}$	.197	1.019	$3\frac{1}{8}$	2.50
			$\frac{3}{4}$	.203	1.156	$3\frac{1}{2}$	3.00
			1	.214	1.428	$4\frac{1}{8}$	4.00
			$1\frac{1}{4}$	.210	1.670	$5\frac{1}{8}$	4.75
			$1\frac{1}{2}$	.242	1.984	$6\frac{1}{8}$	6.50
			2	.252	2.503	$7\frac{1}{4}$	8.75
B (Soil and waste pipe)	B	M	$1\frac{1}{4}$	0.171	1.592	$4\frac{7}{8}$	3.75
			$1\frac{1}{2}$	.191	1.882	$5\frac{3}{8}$	5.00
			2	.205	2.410	$7\frac{7}{8}$	7.00
			$2\frac{1}{2}$	.250	3.00	$9\frac{5}{8}$	10.62
			3	.250	3.50	$10\frac{3}{8}$	12.50
			4	.250	4.50	14	16.38
			5	.250	5.50	$17\frac{1}{2}$	20.25
			6	.250	6.50	$20\frac{1}{4}$	24.12
C (Soil and waste pipe)	C	L	$1\frac{1}{4}$	0.139	1.528	$4\frac{1}{2}$	3.00
			$1\frac{1}{2}$	.165	1.830	$5\frac{5}{8}$	4.25
			2	.177	2.354	$7\frac{1}{4}$	6.00
D (Soil and waste pipe)	D	XL	$1\frac{1}{4}$	0.118	1.486	$4\frac{1}{2}$	2.50
			$1\frac{1}{2}$	.138	1.776	$5\frac{7}{8}$	3.50
			2	.142	2.284	$7\frac{1}{8}$	4.75
			$2\frac{1}{2}$	.125	2.75	$8\frac{1}{2}$	5.00
			3	.125	3.25	$10\frac{1}{8}$	6.00
			4	.125	4.25	$13\frac{3}{8}$	8.00
			5	.125	5.25	$16\frac{3}{8}$	10.00
			6	.125	6.25	$19\frac{1}{2}$	11.75



Left. Extension of a lead service pipe to a new and larger water main. Note "gooseneck" at the connection to the main. *Right.* Wiping a "tee" branch in a lead water service line in the field.



Wiping a curb stop to a long lead water service line in the shop.

Calking a lead closet bend into the cast iron stack fitting.



Pouring and calking the lead joints in a large cast iron water main.

All service pipes should be laid with goosenecks to allow for settlement. These are simple to provide in lead pipe because they can be bent integrally into the pipe without making an extra joint. In long services, say 100 ft. or more, a second small gooseneck may be provided where they enter the foundation wall. Gooseneck sizes should vary with the diameter and wall thickness of the pipe. The following table gives approximate gooseneck sizes:

LENGTH OF GOOSENECK AND LENGTH OF 100 LBS. OF PIPE

CLASS 50 (A or S Weight)

For Pressures up to 50 Pounds Per Square Inch

Inside diameter (inches)	Length of pipe in gooseneck (feet)	Width across gooseneck (feet)	Number of feet in 100 pounds
$\frac{3}{4}$	2	$1\frac{1}{4}$	33.3
1	2	$1\frac{1}{4}$	25.0
$1\frac{1}{4}$	$2\frac{1}{2}$	$1\frac{1}{2}$	21.0
$1\frac{1}{2}$	3	$1\frac{3}{8}$	15.5
2	4	$2\frac{1}{2}$	11.3

CLASS 75 (AA or XS Weight)

For Pressures up to 75 Pounds Per Square Inch

$\frac{3}{4}$	2	$1\frac{1}{4}$	28.5
1	2	$1\frac{1}{4}$	21.0
$1\frac{1}{4}$	$2\frac{1}{2}$	$1\frac{1}{2}$	16.6
$1\frac{1}{2}$	3	$1\frac{3}{8}$	12.5
2	4	$2\frac{1}{2}$	7.2

CLASS 100 (AAA or XS Weight)

For Pressures up to 100 Pounds Per Square Inch

$\frac{3}{4}$	2	$1\frac{1}{4}$	21.0
1	2	$1\frac{1}{4}$	16.6
$1\frac{1}{4}$	$2\frac{1}{2}$	$1\frac{1}{2}$	12.9
$1\frac{1}{2}$	3	$1\frac{3}{8}$	8.8
2	4	$2\frac{1}{2}$	5.1

The reason for using larger goosenecks with larger and thicker-walled pipe is to prevent thinning the pipe wall on the outside of the bend and distortion of the pipe's cross-section.

It helps to insure a proper gooseneck if the corporation cock has a tail-piece bent at a 45-degree angle. Then the pipe has to start off in that direction and be bent around to its ultimate

direction, at least forming part of the gooseneck. The gooseneck should, however, have a reverse bend to form a question mark. The gooseneck should preferably lie in a horizontal position to the right when facing the main.

Sometimes tappings are taken off the top of the main. This should be avoided, if possible, but when it is done, the gooseneck should be formed in the same way. Blocking, however, should be placed between the top of the main and section of gooseneck above it just beyond the joint. In case of settlement, this will relieve strain on the joint and tapping and will allow it to be taken up in the gooseneck. On long services or those in particularly bad ground, the pipe may be left slightly wavy to take up settlement all along the line. Both these waves and regular goosenecks should lie almost horizontally to prevent trapping of water in the pipe if drained.

SAFE WORKING PRESSURE OF LEAD SERVICE PIPE

Class of lead pipe	Application	Maximum working pressure, pounds per square inch	Nominal inside diameter (inches)	Commercial designation	
				East	West
100	Service and supply	100	$\frac{3}{4}$ to 2, inclusive	AAA	XXS
75	Service and supply	75	$\frac{3}{4}$ to 2, inclusive	AA	XS
50	Service and supply	50	$\frac{3}{4}$ to 2, inclusive	A	S

If the bottom of the trench contains rocks or stones that might damage the lead, fine soil or sand should be filled in the trench bottom before laying the pipe. Similarly it is wise to backfill for at least 6 in. with soil or sand free from rocks so that the pipe is protected all around. Where electrolysis is known to exist or where the soil contains much free lime or where the pipe passes through cinder fill, the pipe should be wrapped or laid in a trough filled with pitch. Protection should also be afforded lead pipe where it is bedded in "green" cement.

A cast-iron sleeve should be provided where lead passes through the foundation wall, the joint being made water-tight by calking with lead wool.

In the installation of lead service pipe, joints have been successfully made by wiping, welding, cupping and soldering, and by means of compression-type couplings. It is usually possible to make up the wiped, welded or soldered joints on the bench in the

shop. This is a great time and money saver and insures the best kind of joint because working conditions are ideal.

CALKING LEAD

Lead is used for calking joints in cast-iron water mains, sewer and soil pipe. It has the great advantages of durability and flexibility, the latter permitting the pipe line to adjust itself to ground or building movement without damage to the joint and without putting strain on the pipe itself. Repairs to lead joints can usually be made by simple calking without shutting off the water.

Procedure is much the same for making joints in both pressure and soil pipe except that in pressure pipe the oakum comes to about 2 in. from the end of the hub, leaving a space at least 2 in. deep for the lead, while in soil pipe, the lead space is only 1 in. deep. The following table gives the amounts of lead and oakum required for various sizes of water and gas pipe:

CALKING LEAD AND OAKUM REQUIREMENTS FOR
CAST IRON PIPE

Size of pipe	Approximate pounds of lead per joint 2 in. thick		Approximate pounds of hemp per joint	
	Water	Gas	Water	Gas
3	6.00	—	.18	—
4	7.50	8.14	.21	.23
6	10.25	11.31	.31	.34
8	13.25	14.56	.44	.49
10	16.00	17.67	.53	.59
12	19.00	20.85	.61	.67
14	22.00	—	.81	—
16	30.00	27.20	.94	1.03
18	33.80	—	1.00	—
20	37.00	41.28	1.25	1.39
24	44.00	49.07	1.50	1.67
30	54.25	60.06	2.06	2.28
36	64.75	71.57	3.00	3.32
42	75.25	83.13	3.62	4.00
48	85.50	102.63	4.37	5.20
54	97.60	—	6.25	—
60	108.30	—	8.25	—
72	746.00	—	12.50	—
84	170.00	—	15.00	—

From Cast Iron Pipe Research Association Handbook.
Clamping rings are usually used in connection with lead joints in gas mains.

For soil pipe it is usually estimated that 12 oz. of lead per joint are required for each inch of pipe diameter. Thus a joint in 4-in. soil pipe requires about 3 lb. of lead.

Pipes should be carefully aligned and braced after the first two or three turns of oakum have been calked. Final calking of the oakum should be done with a wide yarning tool to leave an even foundation for the lead. Asbestos joint runners with the clamp at the top are used around the bell opening for pouring joints in horizontal pipe. The clamp forms a gate for pouring. The complete joint should be made with one pouring. The hub should be dry and clean before pouring the lead.

Joints should not be calked until cool. Then both inside and outside calking irons should be used all around the joint on soil pipe, keeping the inside iron always against the spigot and the outside iron always against the inside of the bell. For joints in water mains, a series of calking irons should be used because the lead space is larger than in soil pipe. Enough irons should be used so that when the joint is completed the entire surface of the lead will have been calked. Large pipe thus requires use of more calking irons than small pipe.

Pneumatic hammers may be used advantageously for calking. While particularly suitable for large pipe, they have also been used successfully for water mains as small as 3 or 4 in. in diameter. Maximum air pressure at the compressor varies with the size of pipe. For example 65 lb. per sq. in. has been found suitable for 12-in. pipe and 50 lb. per sq. in. for 4-in. pipe, using a light portable hammer and not more than 150 ft. of hose.

If moisture should get into a joint before pouring, some kerosene poured in will prevent the molten lead from "exploding" when it hits the moisture.

It pays to use calking lead of high quality as it results in lower dross losses, easier calking, and fewer imperfect or "missed" joints. Use of lead meeting the requirements established by the American Water Works Association's Standard Specifications for Laying Cast Iron Pipe, Commercial Standard CS94-41 of the National Bureau of Standards, or the Standard of the Lead Industries Association assures proper quality. All of these standards are essentially the same in substance and are as follows:

COMPOSITION OF CALKING LEAD

Lead for calking purposes shall contain not less than 99.73 percent of lead.

Maximum allowable impurities:

	Percent
Arsenic, antimony, and tin together.....	0.015
Copper	.08
Zinc	.002
Iron	.002
Bismuth	.25
Silver	.02

Calking lead of such quality is readily identified by the Lead Industries' Seal of Approval stamped or cast on it along with the manufacturer's name or identification mark which also must appear on it.

Lead wool may be used instead of poured lead and should be of the same quality. It has the advantage of requiring no melting and may thus be used where fire is a hazard. Since the joint is made cold, lead wool may also be used under water or in damp locations.

Yarning is the same as for a poured joint but the lead wool is calked in one or two turns at a time. If more than one length of lead wool is needed for a joint, the ends of the two lengths should be thinned down and loosely rolled together to prevent forming a lump or projection in the joint.

LEAD IN THE PLUMBING SYSTEM

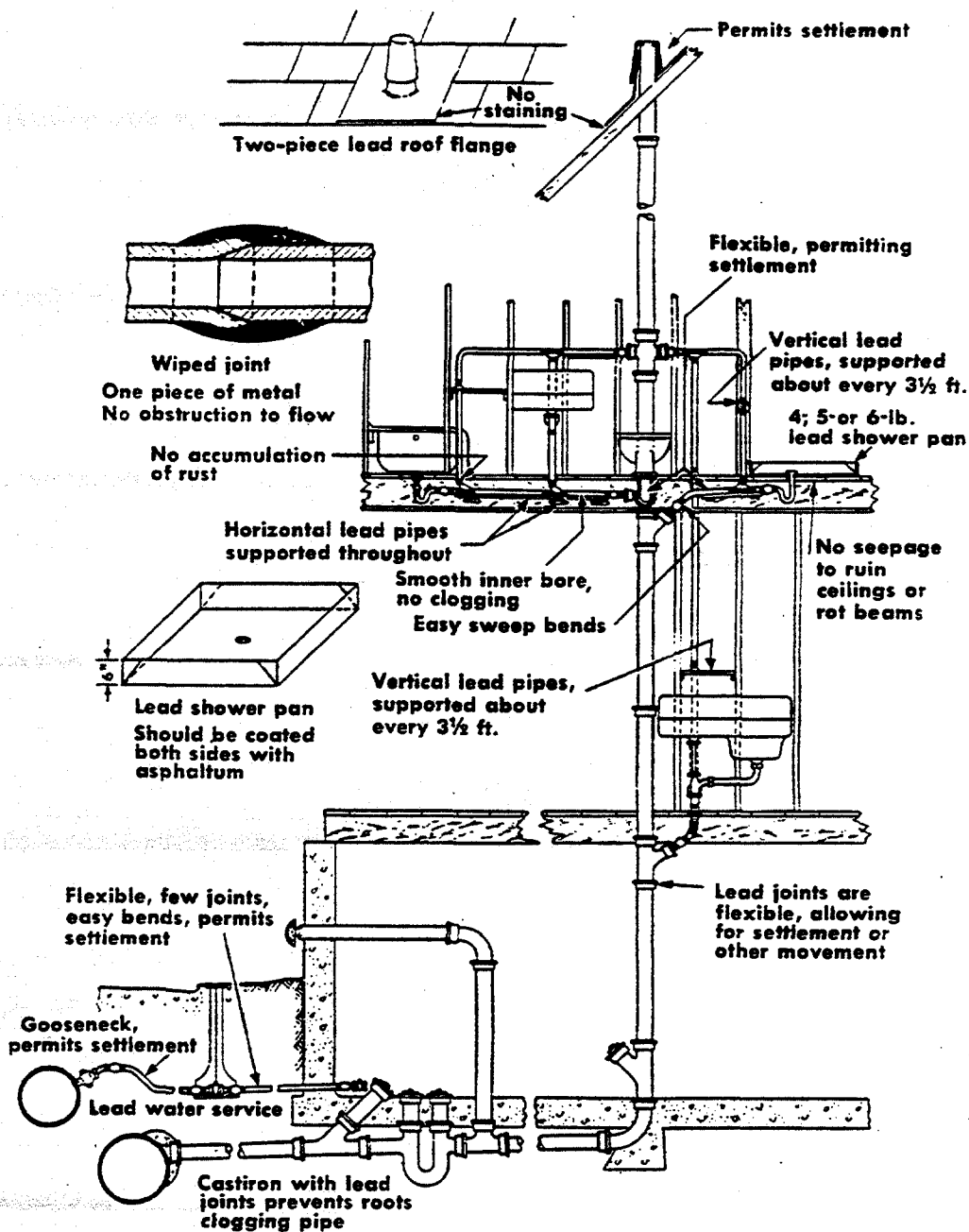
Lead serves a multitude of purposes in the plumbing drainage and venting system. It is extremely durable when exposed to the polluted water and air in those systems, being little affected by the hydrogen sulfide, ammonia and other corrosive substances found in them. It is flexible, permitting movement and settlement without damage to pipes, joints or fixtures. It requires no multitude of bulky fittings to assemble it, and joints are wiped or welded, bonding the pipe together into integral continuous lengths without danger of leaky joints and offering a smooth inner bore at the joints which does not obstruct flow or tend to clog. In fact the smooth inner bore of lead pipe and fittings offer minimum resistance to flow and corrosion product does not form to reduce the diameter and clog. Because lead pipe is flexible, easy sweep

bends, promoting good flow of water and air, may be used. It consumes little space and reduces the necessity of cutting and weakening joists, beams and studs.

The drawing on the next page shows the purposes for which lead is most widely used in plumbing and emphasizes some of the methods to follow in its installation to get best results. As in all things, proper quality and weight of material must be used. Lead pipe should not be lighter in weight than the class known as D or XL, as shown in such recognized standards as Federal Specification WW-P-325, Commercial Standard CS95-41 of the National Bureau of Standards, or the Lead Industries Association Standards (see page 76). Traps and bends should have walls 0.125 in. thick in accordance with Federal Specification WW-P-325, CS96-41 and the Lead Industries Association Standards. Such material, if of proper weight and quality, may be easily identified by the Lead Industries' Seal of Approval stamped on it.

Proper support and easy sweep bends are shown in the drawing. Where pipes change direction to run alongside a structural member, sufficient space should be left between the pipe and structural member to allow the pipe to expand without jamming up against the structure. Branches should be made at a 45 deg. angle in the direction of flow. This promotes both better flow and allows expansion to be taken up in the bend. Where pipe or fittings pass through concrete floors, they should be protected by sheet metal sleeves, and lead imbedded in or in contact with cement should be coated in the usual way with asphaltum or wrapped with tar paper to protect it from possible attack by the seepage water of "green" concrete.

In addition to the lead pipe, traps, bends and calking lead so commonly used in the plumbing system, lead has a number of other plumbing applications. Lead vent pipe flashings have several advantages. Extremely durable, lead flashings have a pleasing color and do not cause discoloration and staining of adjacent materials. They should weigh at least 3 lb. per sq. ft. Cast hard lead floor flanges make an excellent means of setting water closets and connecting to lead bends or stubs. They do not require tinning before soldering or welding to the lead bend or stub, but, since they have a somewhat lower melting point than soft lead, care must be exercised in soldering or welding not to overheat.



Typical residence lead and soil plumbing installation.

LEAD TRAP AND BEND STANDARDS

HALF S OR P TRAPS

Nominal inside diameter (inches)	Weight per running foot (pounds)	Short traps				Long traps			
		Dimen- sions		Total weight		Dimen- sions		Total weight	
		Inlet (inches)	Outlet (inches)	(Pounds)	(Ounces)	Inlet (inches)	Outlet (inches)	(Pounds)	(Ounces)
1½	2½	4½	7	4	0	4½	14	5	9
1½	3½	4½	7	4	15	4½	14	6	12
2	4½	4½	8	7	2	4½	14	9	3

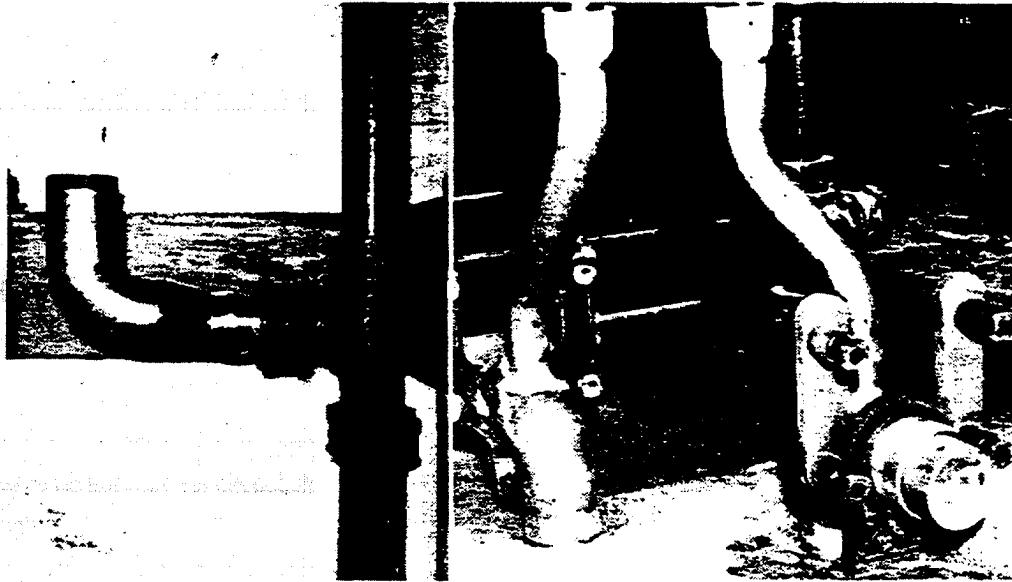
DRUM TRAPS

Trap sizes (inches)	Thickness of cap and flange (inches)	Length of thread and ring (inches)	
4 x 8 4 x 9 4 x 10	¾	⅞	Screw cap and ring thread 3-inch straight pipe thread, 8 threads per inch, free-fit (nominal pitch diameter, 3.388 inch).
3 x 8 3 x 9 3 x 10	¾	⅞	2-inch straight pipe thread, 11½ threads per inch, free-fit (nominal pitch diameter, 2.296 inch).

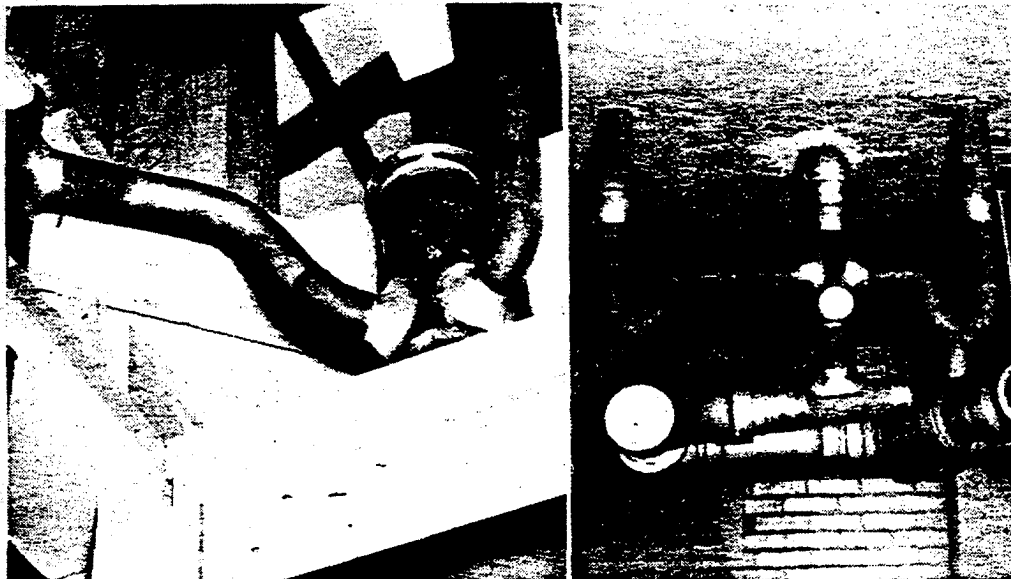
BENDS

1½-inch nominal inside diameter			3-inch nominal inside diameter			4-inch nominal inside diameter		
Dimensions (inches)	Total weight		Dimensions (inches)	Total weight		Dimensions (inches)	Total weight	
	(Pounds)	(Ounces)		(Pounds)	(Ounces)		(Pounds)	(Ounces)
4 x 7	2	12	5½ x 10	7	3	5½ x 10	9	5
4 x 12	4	1	5½ x 12	8	3	5½ x 12	10	10
4 x 15	4	13	5½ x 15	9	12	5½ x 15	12	10
4 x 18	5	10	5½ x 18	11	4	5½ x 18	14	10
4 x 20	6	2	5½ x 20	12	4	5½ x 20	16	0
7 x 7	3	8	10 x 10	9	8	10 x 10	12	5
7 x 12	4	13	10 x 12	10	8	10 x 12	13	10
7 x 15	5	10	10 x 15	12	0	10 x 15	15	10
7 x 18	6	6	10 x 18	13	8	10 x 18	17	10
7 x 20	6	15	10 x 20	14	8	10 x 20	18	15

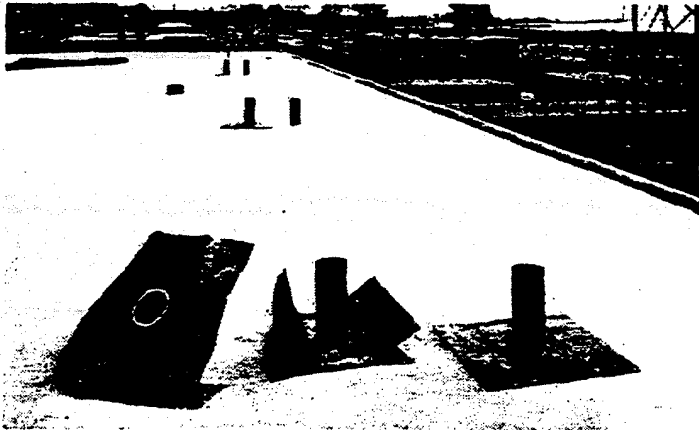
Reducing bends shall be considered as meeting this standard provided (1) the reduction in diameter occurs exclusively on the top and sides, leaving the bottom of the bend, when in the installed position, smooth and straight so that it cannot form a trap for substances passing through the bend, and (2) they meet the requirements of this standard in all other respects except total weight.



Left. Lead reducing bend 4 x 3-in. used to connect water closet to 3 in. stack. *Right.* Two properly vented wall-hung water closet connections installed on opposite sides of access space using lead bends and lead vent connections.

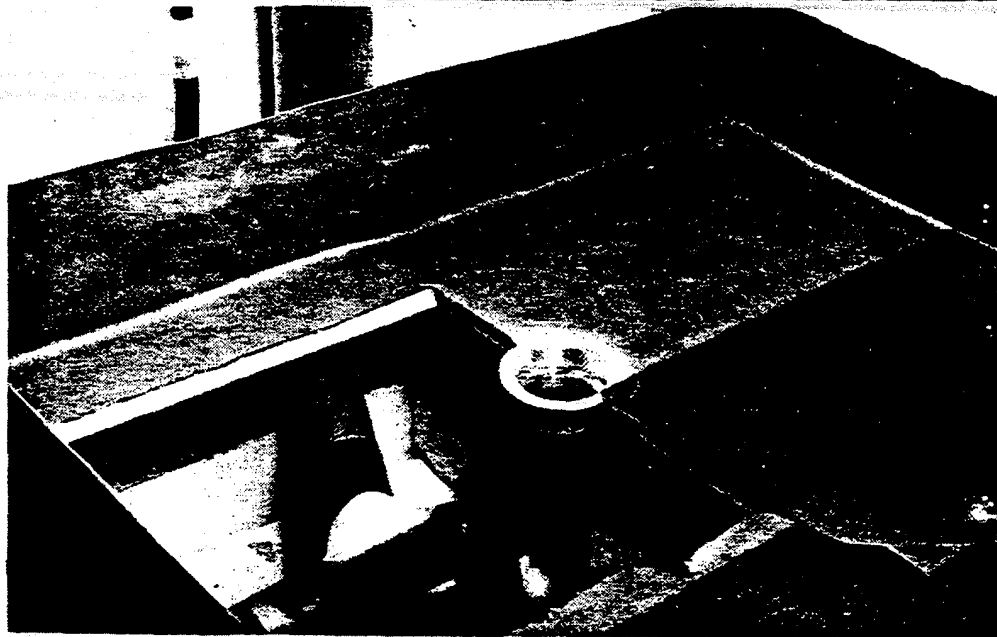
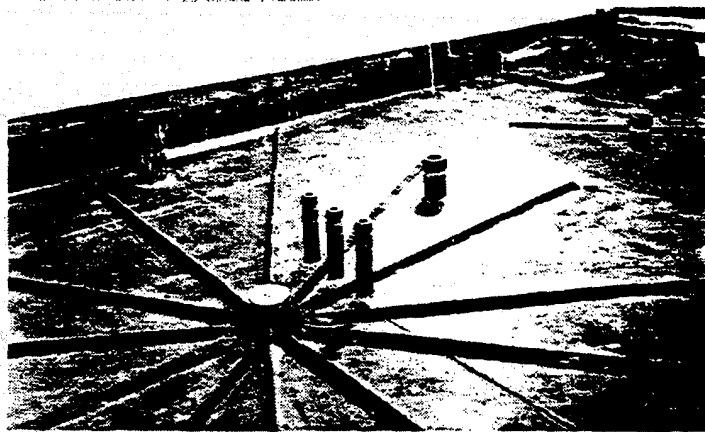


Left. Lead drum trap for bath fixture using lead waste and vent connections. *Right.* Two lead P-traps for urinals with lead waste and vent connections.

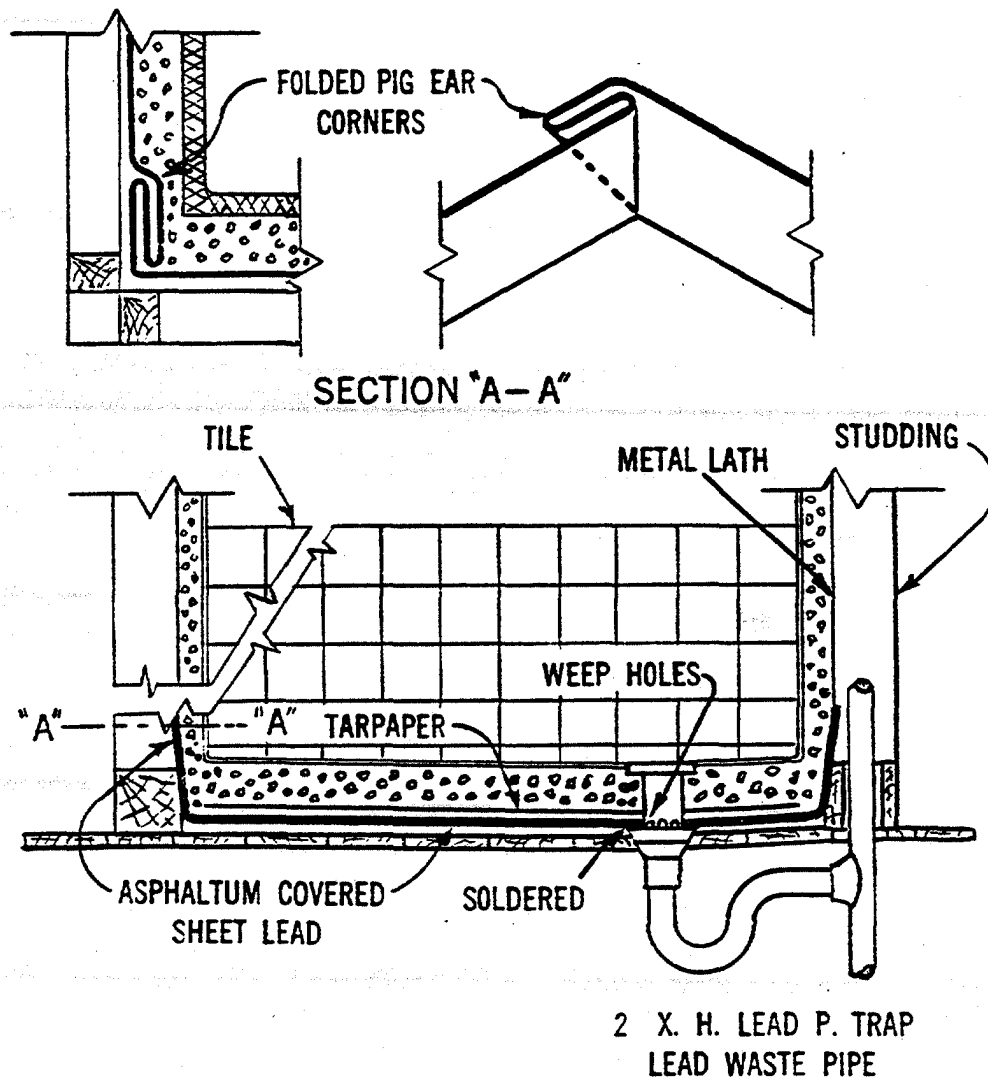


Vent pipe flashings made from 4-lb. sheet lead on roof of apartment house.

A large lead floor pan under a restaurant kitchen. Note lead bleeders in place and lead sleeves around penetrating pipes.



Cut-away sheet lead shower pan, lead P-trap and vent, showing the proper method of first coating the sheet lead with asphaltum and then covering with tar paper.



Lead shower pan installation.

Hangers for rigid pipes are often lined with about 8-lb. sheet lead. This prevents transmission of vibration from the pipe line to the structure and also permits adjustment to the movement of the structure without damage to the rigid pipe. The method is often used, for instance, on pump lines and on pipe lines on ships.

Shower pans and other waterproofing are additional important uses of lead. Shower pans should be made of at least 4-lb. sheet lead and should turn around the edges to finish 1 or 2 in. above the finished floor level. Corners are made as shown in the drawing. Tops of upstands should be dressed tight against masonry walls or set back about $\frac{1}{4}$ in. into notches in wood studs. Concrete under pans should be smooth and the lead coated on both

sides with asphaltum. If the pans are set on wood floors, the boards should be firm and even, nail heads set, and covered with asphalt impregnated building paper, while the inside of the pans should be coated with asphaltum. A cement and sand mixture should be used on the pans as a foundation for the tile. Pans should be graded to the drain to which they should be soldered, clamped or calked. The trap flange should be countersunk and weep holes provided just above the lead. The trap should be plugged and tested with water before tiling. Pans which are left open for some time before tiling should be protected by heavy building paper until tiled over.

Lead shower pans properly installed will give long, trouble-free protection against leakage. They are easy to fit to irregular spaces and dress down tight against floor and walls.

CHAPTER TWELVE

Lead in Modern Architecture

LEAD roofing and flashing has a successful background of hundreds of years under all sorts of climatic conditions. In addition to being used on many European buildings erected centuries ago and on early American structures, it is widely used on modern buildings, large and small, here and abroad.

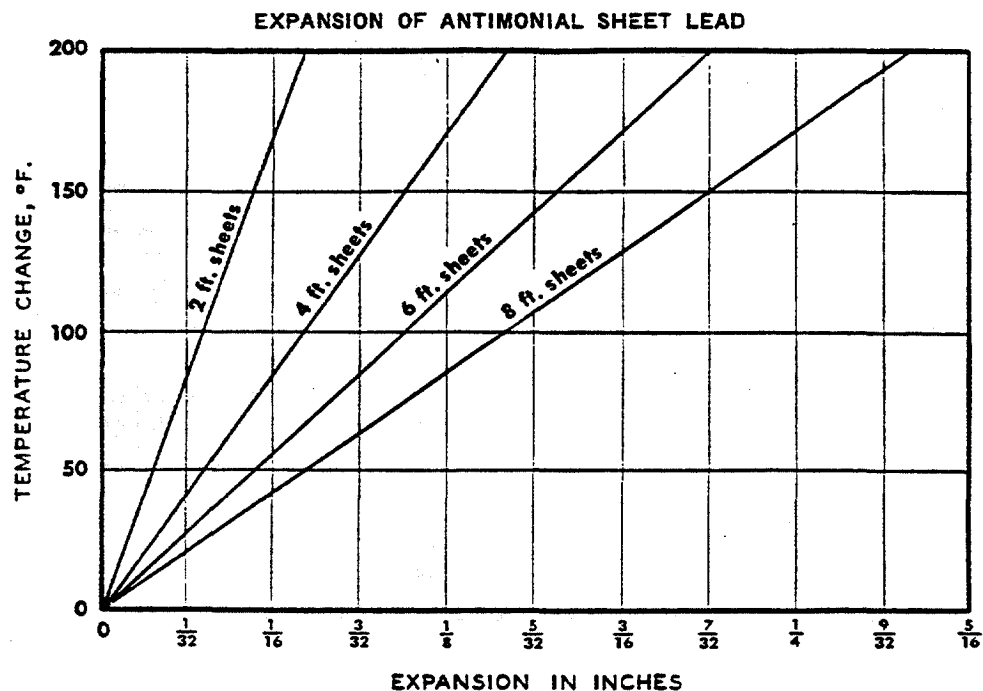
Lead's appeal to architects, engineers and builders for these purposes largely arises from its great durability, ease of installation and the fact that it does not cause unsightly stains or discoloration on adjacent materials. Its pleasing grey color blends well with any color scheme. Lead's long life makes its ultimate cost extremely low.

Modern alloys have made possible reduction of thickness, and consequently, costs comparable with other roofing materials, without sacrifice of any of lead's advantages. Modern practice is to use antimonial sheet lead, usually composed of lead with about 6 or 7 percent of antimony, which has about twice the strength of soft lead and greater stiffness. Certain patented lead alloys are also available as well as the long familiar soft sheet lead.

This section gives some general considerations to be followed in the installation of antimonial sheet lead roofing and flashing. The patented alloys should be installed in accordance with the recommendations of their manufacturers. Soft sheet lead may be used in much the same way as antimonial sheet lead, but the weights of sheets should generally be increased 1 to 2 lb. per sq. ft., and often smaller sheets and more support are desirable.

All metals expand and contract with temperature changes, and roofing and flashing are exposed to wide temperature variations. Therefore, provision must be made for expansion and contraction in metal roofing. The coefficient of linear expansion of antimonial lead is about 0.000015 in. per in. per deg. F. That means that

for every 100 deg. temperature change, antimonial lead will expand or contract about $\frac{1}{50}$ in. for each foot in length of the sheet, or that a 4-ft. sheet will expand or contract slightly less than $\frac{1}{12}$ in. for 100 deg. temperature change.



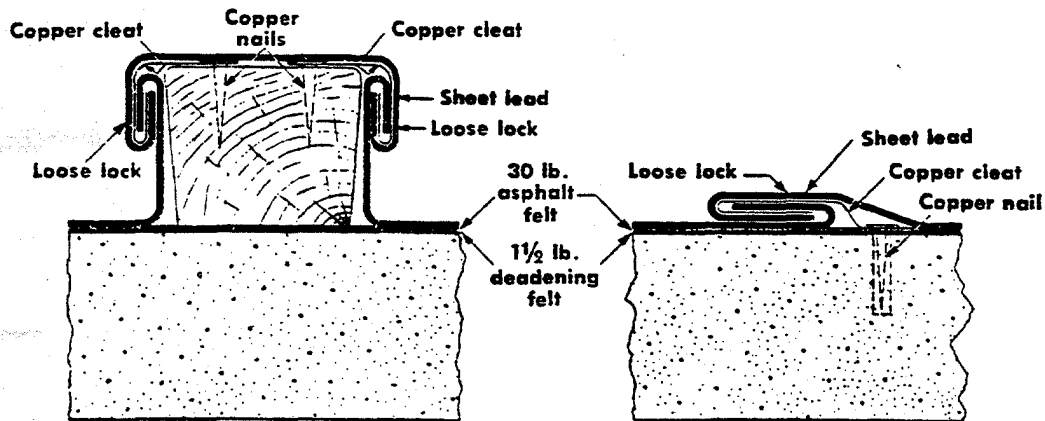
The expansion of soft lead is slightly greater than antimonial or "hard" lead under the same conditions of temperature change, and sheet length. A similar expansion graph for soft lead appears on page 187.

One step in providing for these dimensional changes is to limit the size of sheets in order to minimize expansion and contraction in any one sheet. This is useless, however, if the sheets, when installed, are soldered or joined together in any way that will make two or more sheets expand and contract together as a unit. Obviously such a procedure would be virtually equivalent to installing one large sheet the size of all the smaller sheets combined. Therefore, joints between sheets should always be unsoldered loose-locked or overlapped joints, the use of lock or overlap depending upon conditions which will be described later.

In making loose-locks, a space should be left between the edge of one sheet and the bend of the other to provide for contraction. The size of this space will depend upon the size of the sheets and the temperature conditions. Normally about $\frac{1}{8}$ in. should be sufficient, but if the temperature is unusually high when laying, or if

unusually great temperature drops may be expected in the locality, or if the sheets are larger than usual (which should be avoided so far as possible), this space should be increased.

If the foregoing precautions are not taken, expansion and contraction may be cumulative over an entire roof area or run of flashing and may amount to several inches. In that event, buckling and tearing of the sheets would occur. This can be avoided by minimizing and properly providing for expansion and contraction as suggested. This is nothing new, for all metals expand and contract.



Sections through a sheet lead roof batten (left) and horizontal seam (right).

Specifically, antimonial lead roof sheets, which may be installed by either the batten or standing seam method, should not usually exceed 2 ft. by 4 ft. in size, the greater dimension being installed parallel to battens or standing seams. Forming of sheet metal so that part of the sheet is at right angles to the plane of the rest of the sheet naturally reinforces the metal, and the narrower the part of the sheet between such breaks, the greater the reinforcement. Flashing should be installed so that flat widths, as a rule, are not more than 6 or 8 in. wide without forming. Therefore, flashing sheets may be longer than roof sheets, but should not exceed 6 or 8 ft. in length. Judgment should be used in determining the length of flashing sheets, based on the amount of forming and the width of unformed flat surfaces.

When more than 4 or 5 in. of a flashing that is built into a wall is exposed, a loose-lock should be provided where it emerges from the wall and a separate sheet used for the exposed part. Likewise,

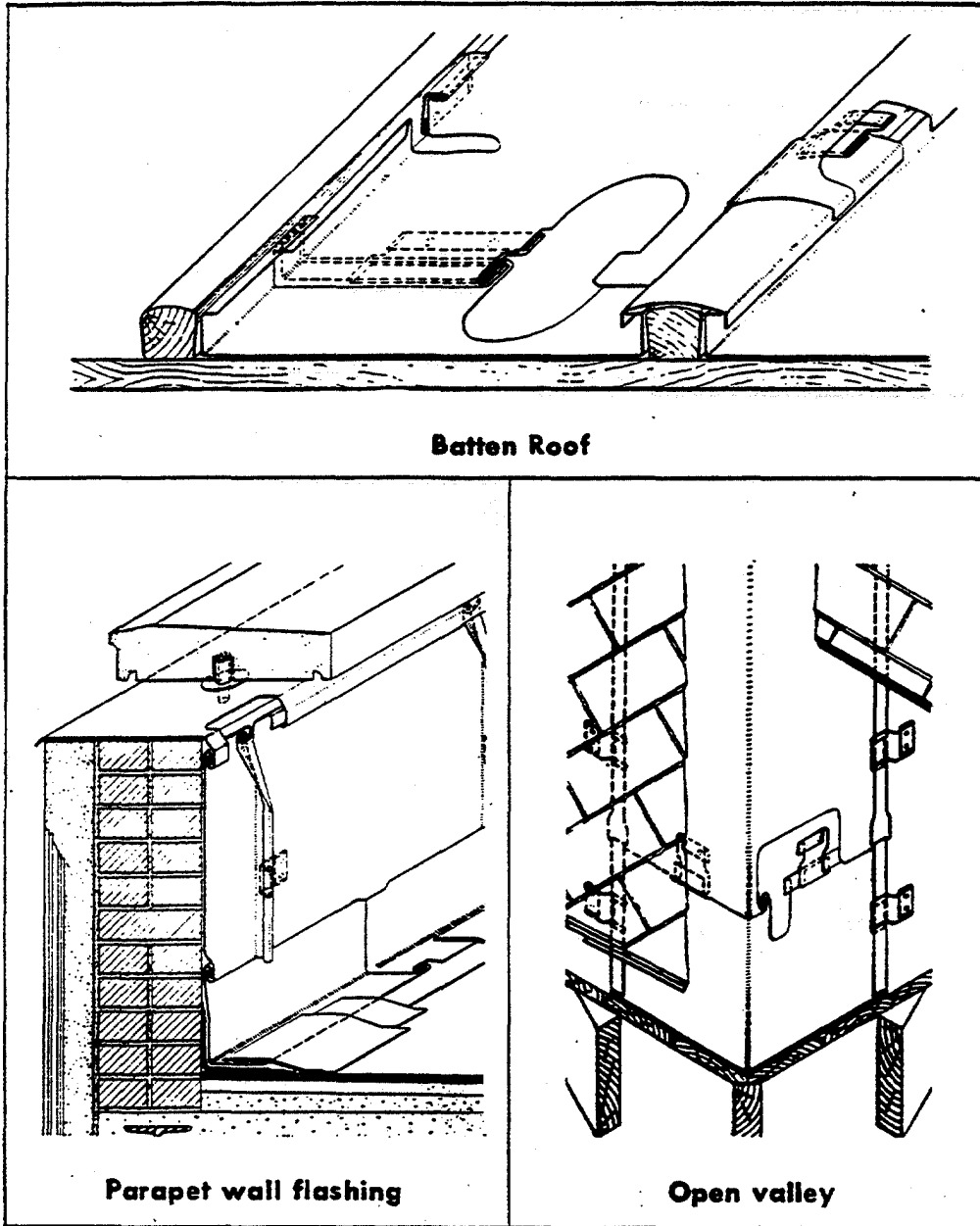
when flashing must be calked into a reglet, a separate locking strip should be installed in the reglet and the flashing loose-locked to it.

Proper thickness of antimonial lead sheets is also an important factor. For general roofing and flashing purposes, cornice coverings, gutter linings and other architectural sheet lead, 3-lb. antimonial lead is the proper weight. For certain purposes, such as small pieces of flashing interwoven with shingle or slate courses, 2½-lb. antimonial lead may be employed, and in special cases where it is impossible to avoid unusual strain or wear on sheet lead, 4-lb. antimonial lead is the weight preferred.

In order to avoid tearing or buckling resulting from expansion and contraction, cleats should always be used for fastening lead roofing and flashing. Nails should never be driven through lead sheets unless the sheets are less than 18 or 20 in. long and the nails covered. Even in this case, the sheets may be nailed at one end only. Cleats, if concealed, may be 16-oz. soft copper, but if exposed, they should be 3-lb. antimonial lead. One end of the cleat should be folded into the loose-locks between lead sheets or into a hem on the edge of the sheet if it is an overlap or if no joint occurs at that point and the other end should be turned back over the heads of the nails holding it to prevent the nail heads damaging the lead. Continuous cleats, when necessary, should be in not greater than 8 ft. independent lengths, so the cleats will not buckle when they expand, which would in turn cause the lead sheets to buckle.

Frequently flashing must come in contact with cement, concrete, or mortar, as, for instance, in the case of through wall flashing. Free lime which occurs in "green" cement, concrete or mortar, may corrode lead in the presence of moisture and oxygen. As the cement, concrete or mortar cures, the free lime carbonates and no longer has an effect on the lead. Therefore, it may be advisable to protect lead against this form of possible corrosion, particularly in locations where the cement, concrete or mortar may not become thoroughly cured for some time. This can be readily accomplished by coating the lead wherever it comes in contact with new cement, concrete or mortar with a layer of black asphaltum.

Surfaces over which lead is to be laid should be carefully pre-



Methods of installation of some typical architectural sheet lead applications. Antimonial lead (6 percent antimony) of 3-lb. weight is commonly used in these applications.

pared. Nail heads should be set and screws countersunk. Concrete and similar materials should be screeded to a smooth surface and the lead should be laid over a layer of roofing felt weighing at least 15 lb. to the square. Sharp edges under the lead should be rounded off so they will not cut into it.

As previously mentioned, joints between lead sheets should either be loose locks or overlaps. For general roofing, base flashings, cornice coverings and other purposes where water or snow are likely to stand or where the length of the joint might make overlaps liable to open up, loose locks should always be employed. On the other hand, in valleys with a pitch of more than 6 in. per ft., on batten caps, ridges and hips, and on cap flashings or through flashings built into the walls, overlaps may be used. In general, loose locks should have a turn back of $1\frac{1}{4}$ in. and should be filled with a non-hardening compound. Overlaps should be 3 or 4 in. in the direction of pitch, or where horizontal, as on ridding, should be made away from prevailing weather, and the overlaps should be bedded in non-hardening compound.

When lead sheets are formed in a brake on the ground, flat stages should be provided for hoisting to the roof so they will not get out of shape. The brake should be adjusted to the extra thickness of the lead so the metal will not be cut and bends will have an easy sweep.

Because of the ease with which lead is formed, this work is often done on the roof. In such cases, tongs are handy for bending the lead. Much lead work can be accomplished simply with the hands and a wooden mallet. Tools should always be used that will not cut into lead's soft surface or damage it.

Lead anchors are commonly used for fastening objects to concrete, stone or brick facings. This application utilizes the calking characteristics of lead; i.e., softness and lack of elasticity, by anchoring or cinching a steel bolt or similar object within a masonry hole. The lead may be either cast in or inserted as a pre-cast ring or rings and cinched mechanically.

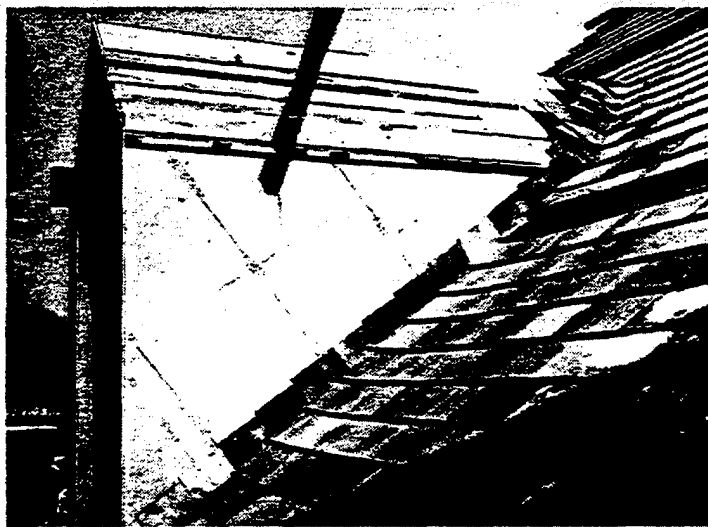
VIBRATION ISOLATION

Lead has been used in a number of ways to prevent the transmission of vibration. Most materials employed for this purpose

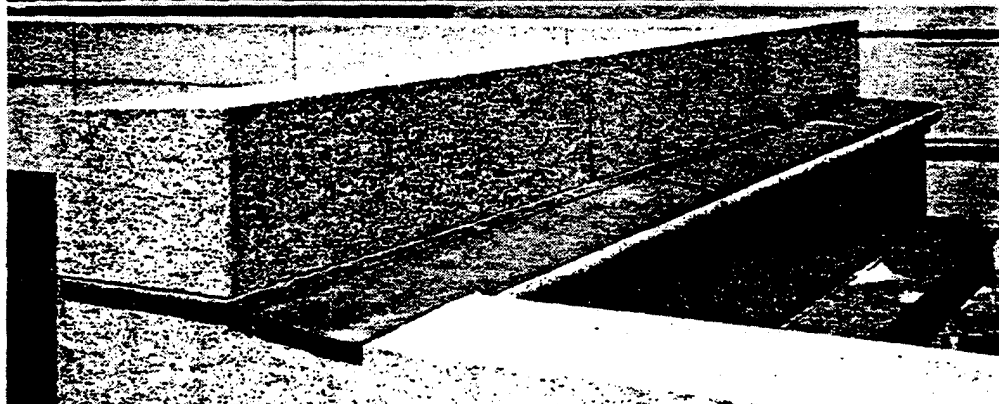


Yale University

Left. An ornamental cast lead fountain dating from 1769. *Right.* Leaded windows, sheet lead spandrels and lead roofed bay are attractive examples of other ornamental architectural applications of lead.



Side-wall and valley sheet lead flashings for a dormer window on a private dwelling. Flashings are interlaid with the shingle courses.

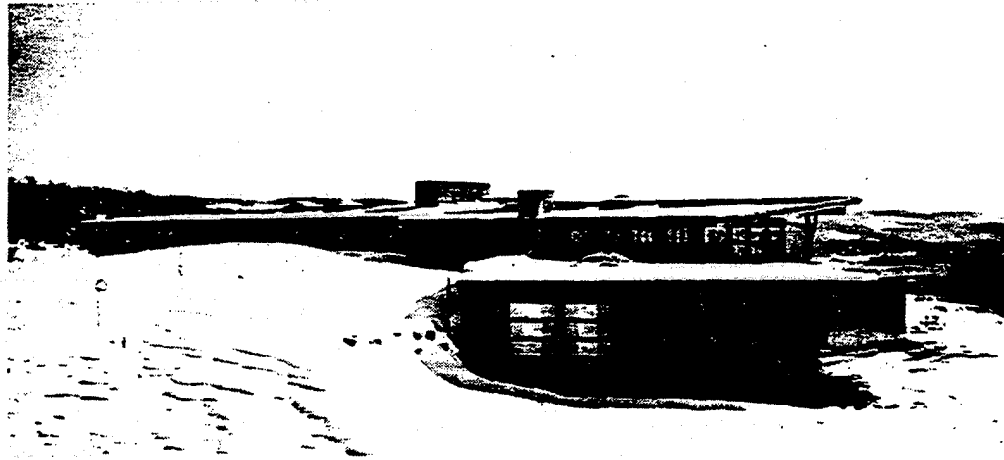


Through-wall and parapet sheet lead flashing on the coping of a public building, the Federal Court House in New York City.

Lead covered dome
400 feet in circumfer-
ence on the New Jersey
Reformatory, Rahway,
N. J.



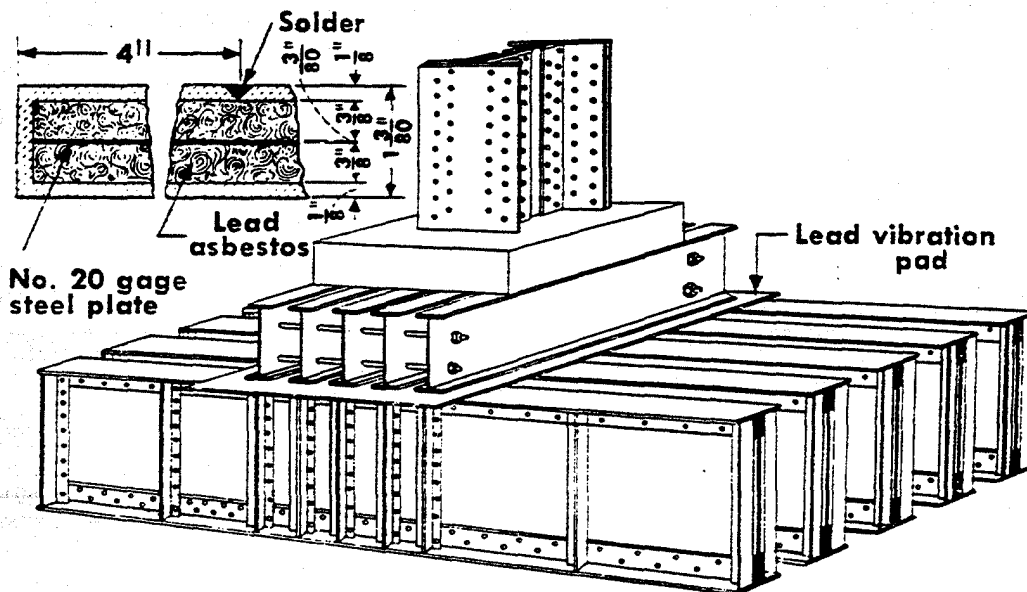
Close-up of loose-locked bat-
ten type roof used on the above
dome. The loose-locked sheets
are held by copper cleats nailed
to the battens. One lead batten
cap is seen loose-locked in place.



A modern private dwelling with a lead gravel stop and fascia piece, lead
chimney caps and flashing and lead skylight flashing.

are non-metallic and some are more efficient than lead, yet lead has certain properties that make its use either desirable or essential under certain conditions.

Among these properties are the strength of lead, which is sufficient in comparison with other materials used so that heavy loads can be carried without distributing them over a large area. Also being highly corrosion resistant, lead is little affected by moisture, oils and other substances and consequently does not deteriorate either in strength or vibration-isolating ability when exposed to them.



Construction and method of installation of lead vibration pad between steel columns and footings.

The widest used of lead in isolating vibration is in the foundations of buildings adjacent to railroad tracks or other sources of vibration. In such cases the use of a combination lead-asbestos pad has become virtually standard practice in railroad terminal construction and they have been employed under many other structures, such as most of the large buildings along the Park Avenue underground tracks leading to Grand Central Terminal in New York.

The pads are composed of a bottom layer of sheet lead $\frac{1}{8}$ in. thick, a layer of $\frac{3}{8}$ -in. asbestos board, a sheet of 20-gage steel, another layer of $\frac{3}{8}$ -in. asbestos board and a top sheet of $\frac{1}{8}$ -in.

lead, making a total thickness of about 1 in. The bottom lead sheet is sufficiently larger than the rest to be turned up onto the top sheet and soldered or welded to it. This makes a moisture-proof lead envelope to protect the inner layers.

These pads are placed on top of the foundations and under the grillages or column footings, preventing transmission of vibration from the ground, through the foundations and into the building itself through the columns.

Similar pads are also frequently used under machinery foundations in buildings to prevent the vibration of machines from being transmitted to the building. Solid blocks of lead are often employed under delicate laboratory instruments so they will not be affected by vibration. Pipe lines, particularly from pumps, are insulated from their hangers by pieces of 6 or 8-lb. sheet lead, sometimes folded over once. This method of vibration isolation is commonly used on shipboard piping.

In the manufacture of nitroglycerin, a powerful liquid explosive highly sensitive to percussive shock, lead plays an important triple role. It is used to line various reaction tanks, floors, table tops, etc., because it effectively resists the attack of the corrosive acids used in the manufacturing process and also because of its excellent non-sparking characteristic. But in addition, lead is capable of absorbing shock waves much as it blankets vibration. Therefore, to prevent accidental detonation of the nitroglycerin it is stored and transported in leaden vessels which if dropped or jammed would not transmit the shock to the explosive. The containers also would deform instead of breaking, thereby preventing the nitroglycerin from spilling.

ORNAMENTAL LEAD

Lead occupies an honored place in the list of mediums of artistic and decorative expression. Through the past centuries, the decorative uses of lead have ranged from primitive amulets, coins, vases and statuettes to monumental sculpture and architectural decoration. The easy working qualities of lead have always been attractive to artists.

Probably the best known decorative uses of lead are architectural. Ornate lead gutters, leader heads and downspouts are

excellent examples. Other architectural uses are spandrels, roofing features such as cupolas and spires, comes, grilles and lighting fixtures. Closely allied to architectural details are garden ornaments and sculpture, sundials and fountains. The great fountain of Apollo at Versailles is an outstanding example of this use.

The pleasing surface color of weathered lead, called patina, is due to an exceedingly thin oxide film which develops upon prolonged exposure to the elements. This patina, sought after by architects and lead sculptors may be artificially produced or altered with the aid of chemicals. By wiping clean lead with linseed oil, the surface acquires a natural, evenly distributed patina as the oil wears off.

A tried and effective method for preparing lead and lead-base alloys for subsequent plating is as follows: (a) degrease, (b) clean cathodically in a mixture of 1 oz. soda ash, 1 oz. trisodium phosphate, for a few seconds only (do not overclean), (c) rinse, (d) if necessary, scrub with pumice to remove any film, (e) rinse, (f) pickle in 10 percent fluoboric acid for about 15 sec., (g) rinse, and (h) plate.

For producing a green imitation bronze finish cleaned lead may be dipped in or painted with a solution made according to the following formula:

Copper nitrate.....	8 ounces
Ammonium chloride.....	4 ounces
Acetic acid.....	4 ounces
Chromic acid.....	1 ounce
Water	1 gallon

The following solution has also been used successfully for obtaining a green patina on lead.

Nickel chloride.....	150 parts by weight
Copper sulphate.....	150 parts by weight
Potassium chlorate	100 parts by weight
Water	1 quart

Swab on this solution. The lead first turns brown and then becomes green producing an antique effect.

A perhaps less artistic but nevertheless decorative use of lead is in souvenir badges and insignia, novelties and bric-a-brac. These are usually made of a lead alloy rather than pure lead and

they can be found in shops wherever tourists travel as well as in the cheaper stores.

Lead is adaptable to all of the common metal working procedures. Its natural color is pleasing and it weathers well. It will take plating or paint and can be finished smooth or textured. It is adaptable to high speed production such as die casting or it can be hand wrought by the artist into individual artistic creations. For these reasons it is one of the most versatile of metallic mediums for artistic expression available. While lead is relatively low in cost, it has great durability. Therefore, its decorative uses can well range from the most inexpensive novelties to elaborate enduring monuments.

CHAPTER THIRTEEN

Radiation Protection

THE harnessing of atomic energy has brought with it the problem of controlling the powerful rays emitted during atomic disintegration. Basically the problem of protection from these rays is the same as from X-rays and radium. Technicians have for many years known the hazards involved and they have worked out several methods of protection. But while today's radiation problems are similar, they are far more significant both because of the wider use of radioactive materials and the potentially greater intensities to be worked with.

The various types of rays—alpha, beta, gamma, neutron—differ chiefly in their ability to penetrate and ionize matter. It is the latter characteristic which injures living tissue and which must be guarded against. The alpha particle is a positively charged helium nucleus which is completely stopped by 3 or 4 inches of air or a piece of paper. Beta particles are high-speed electrons of varying energies. In general, they produce less ionization in matter than alpha particles but are more penetrating. Most common substances such as 1 in. of wood will completely absorb beta rays. Gamma radiation on the other hand has great powers of penetration. High energy gamma will not be wholly absorbed by even a foot of lead while lower energy gamma may be safely absorbed by $\frac{3}{16}$ in. or less of lead. Gamma rays produce large scale ionization by a secondary process, that is, the gamma ray first produces a high-speed electron and this, in turn, produces the ionization. Neutrons emitted by the cyclotron and the atomic pile are uncharged particles which will also ionize certain material indirectly. Neutrons are classified according to their energy levels as very fast, fast, slow and thermal, the last having the lowest energy level.

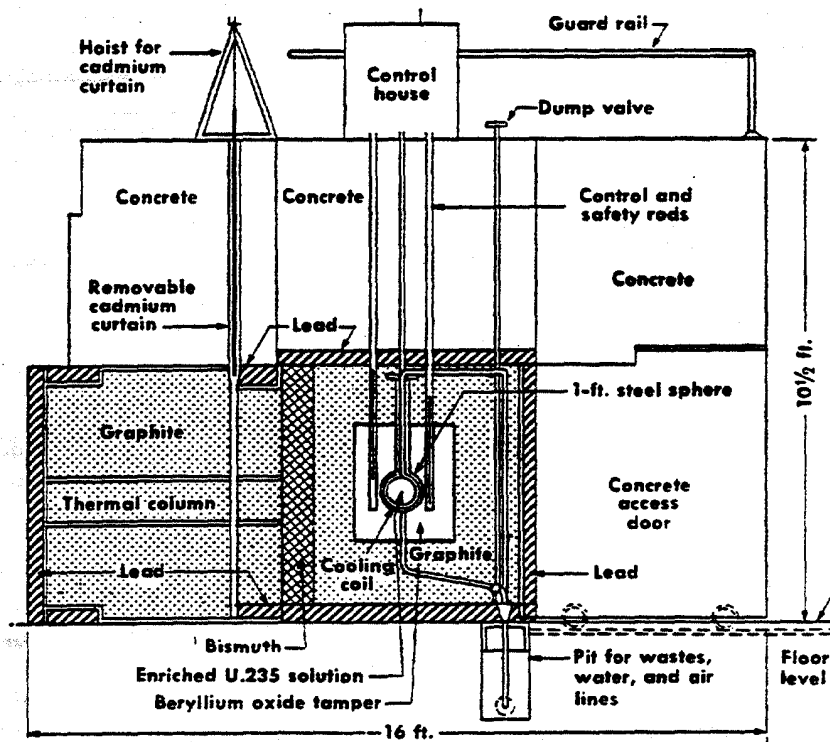
The dangers of exposure to radiation are classified into two separate categories: internal and external. The former is primarily a hygiene and medical problem and because it does not involve shielding as such it will not be discussed here. External radiation comes from a source outside the human body such as an X-ray tube, cyclotron, radium or radioactive samples. Protection against external radiation is a question of shielding the body from the rays, keeping a safe distance away from the rays, and limiting the time of exposure to the rays.

In shielding against neutrons metallic cadmium or a hydrogenous material such as water or paraffin is generally used. However, because gamma rays are emitted when the neutrons are absorbed, it is still necessary to provide a protective shield of lead. The use of protective shielding is identical in all cases, regardless of the type of ray, the thickness of the shielding depending upon the penetrating power of the rays.

The first consideration in preventing penetration of rays is density. Lead enjoys the advantage of being the densest of any commonly available material. Where space is at a premium and utmost radiation protection is paramount lead is always prescribed. Another advantage, particularly in shielding neutrons and gamma rays, is that lead does not become contaminated. It may be used continuously without fear of itself becoming radioactive and emitting its own harmful rays. For this reason it is important that lead specified for shielding purposes be free of alloying elements, particularly those which may become radioactive upon exposure to high energy radiation.

Being a metal, lead has an advantage over various aggregate materials such as concrete in that a uniform density is guaranteed throughout. In addition, because its surface is smooth it cannot become contaminated with dirt or other material which, in turn, may become radioactive. Oftentimes where exceptionally high energy levels are being shielded and where the concentrated load of the quantity of lead required would be prohibitive, a combination of concrete and lead has been employed. The lead may be sandwiched as a sheet between layers of concrete or may be used on either side of the concrete. Lead cast or extruded into bricks has proven especially useful in atomic shielding because the bricks can be easily moved to areas where special temporary

shielding is needed and can be built up to any thickness or placed in position desired.



Lead and concrete shielded atomic reactor.

In atomic reactors or "piles" operated by the Atomic Energy Commission, cadmium, lead, concrete and distance are used to protect operating personnel from exposure to all types of dangerous radiation, chief among these being neutrons and gamma rays. Neutrons escaping from the uranium section of reactors are absorbed by a thin cadmium shield. This absorption causes the cadmium to emit gamma rays which are in turn stopped by a lead shield. Thus personnel during the loading and unloading of atomic fuel are protected from neutrons by the cadmium and from gamma rays by the lead.

In one type of reactor a 4 in. shield of lead-cadmium alloy surrounds the reaction area and fits snugly inside a concrete shield 8 ft. thick which encases the entire reactor. The lead-cadmium alloy protects the concrete from direct exposure to neutrons and gamma rays. An extra 1-ft. shield of lead bricks is located on top of the reactor to compensate for the absence of concrete. The thick lead shield at the side and bottom is constructed with

internal copper tubing for circulating cooling water to remove heat generated in the shield itself and the exterior of the reactor chamber.

A column made of graphite bricks extends into the heart of the reactor to provide a path for thermal and slow neutrons. The end of the column protruding through the outer concrete shield is covered with a cadmium curtain and a 2-ft. lead and iron shield in which an 8-in. square opening is provided for access.

The first uranium-graphite reactor, breeder of the original Atom Bomb, looked like a windowless two-story square concrete building, 30 ft. wide, 32 ft. long and 21 ft. high. On the sides of this early reactor concrete alone was depended upon for protection. The top of the pile was paved with 6 in. of lead, totalling about 185 tons. On top of the lead was an additional layer of 4 ft. of solid wood. Resting on this shield was a small experimental laboratory in which operating personnel worked, secure in the trust that they were being protected from the tremendous energy being generated beneath them by the 4-ft. layer of wood and 6-in. layer of lead.

The table given below prepared by the National Bureau of Standards may be used to determine the required thicknesses for shielding from gamma ray sources in the laboratory. To use the table select the column for the energy required (use next higher if exact value is not given). The entry gives thickness in centimeters of lead for different source strengths at 1 meter for 8 hr./day to give 50 milliroentgens. Then add algebraically the correction terms for other working ranges or times to obtain the shield thickness required.

Example: Shield is required for the manipulation of 500 millicuries of radioactive material emitting 1.8 million electron volts (Mev) gamma rays at a minimum working distance of 50 cm., and for 4 hr./day.

$$\text{Shield thickness} = 8.60 + 2.77 - 1.39 = 9.98 \text{ cm. of lead}$$

(a) (b) (c)

in which

a=basic entry.

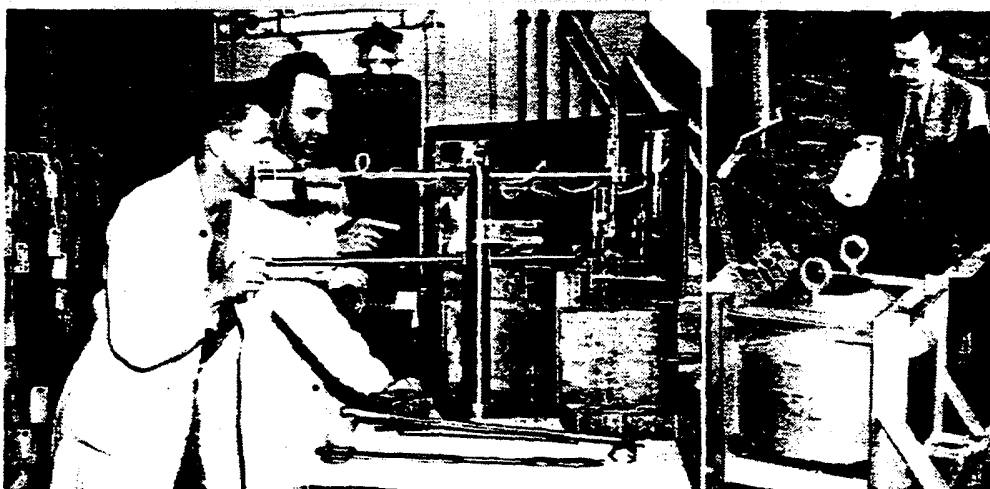
b=correction for danger range=50 cm.

c=correction for 4 hr./day.

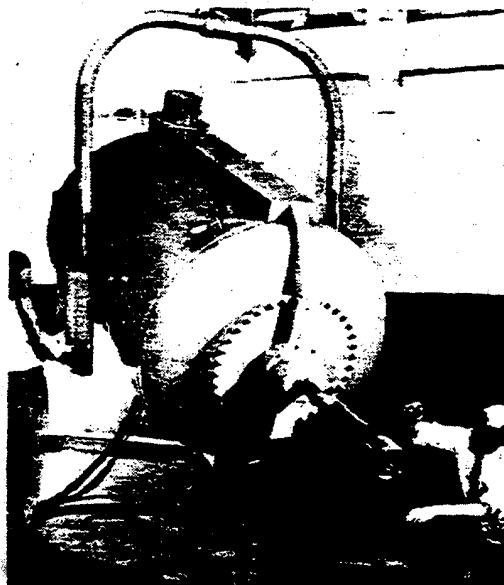


Atomic Energy Commission

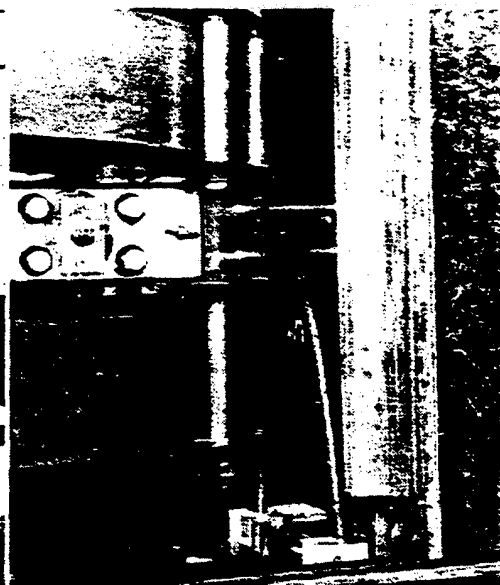
At the shield face of a nuclear reactor, a cast lead entry port and lead bricks protect operating personnel from radiation injury.



Left. In a radioisotope laboratory, special purpose lead castings and lead bricks protect the technicians. Radioisotopes are stored in the lead brick "hot" cave on the left. *Right.* Highly radioactive cobalt 60 is shipped in this lead lined steel container.

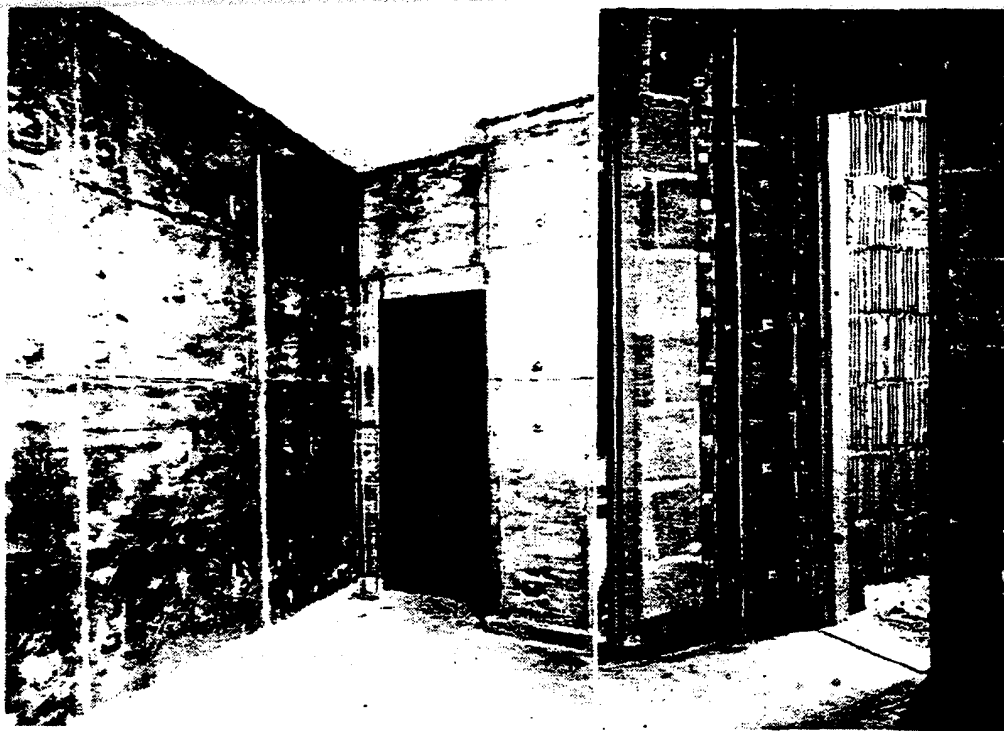


General Electric X-Ray Corp.



Allis-Chalmers Mfg. Co.

Left. Two million volt X-ray unit with lead collimating core for directing the rays. *Right.* Twenty-two million volt betatron with lead collimator and movable lead shield.



Left. A sheet lead lined hospital X-ray room and door. *Right.* A sheet lead covered X-ray room floor with cement block-lead sandwich wall construction.

REQUIRED LEAD SHIELDING THICKNESS FOR GAMMA RAYS

Activity	Energy (Mev)							
	0.2	0.5	0.8	1.0	1.5	2.0	2.5	3.0
10 mc.	-0.14	-0.36	-0.27	-0.11	+0.37	+0.78	+1.15	+1.40
20 mc.	-0.09	0.00	+0.41	+0.76	+1.57	+2.16	+2.63	+2.91
50 mc.	-0.01	+0.47	+1.31	+1.90	+3.15	+4.00	+4.57	+4.90
100 mc.	+0.06	+0.82	+1.99	+2.77	+4.34	+5.38	+6.05	+6.41
200 mc.	+0.10	+1.17	+2.67	+3.63	+5.54	+6.77	+7.52	+7.92
500 mc.	+0.17	+1.64	+3.57	+4.78	+7.12	+8.60	+9.47	+9.91
1 c.	+0.23	+1.99	+4.25	+5.65	+8.31	+9.99	+10.95	+11.41
2 c.	+0.28	+2.35	+4.93	+6.52	+9.51	+11.37	+12.42	+12.92
5 c.	+0.36	+2.81	+5.82	+7.66	+11.09	+13.21	+14.37	+14.91
10 c.	+0.41	+3.17	+6.50	+8.52	+12.28	+14.59	+15.85	+16.42
20 c.	+0.47	+3.52	+7.18	+9.39	+13.48	+15.98	+17.32	+17.93
50 c.	+0.54	+3.99	+8.08	+10.54	+15.06	+17.81	+19.27	+19.92
100 c.	+0.60	+4.34	+8.76	+11.40	+16.25	+19.20	+20.75	+21.43
Danger range	Plus	Plus	Plus	Plus	Plus	Plus	Plus	Plus
20 cm.	+0.26	+1.64	+3.16	+4.02	+5.55	+6.44	+6.85	+7.00
50 cm.	+0.11	+0.71	+1.36	+1.73	+2.39	+2.77	+2.95	+3.01
1 m.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 m.	-0.11	-0.71	-1.36	-1.73	-2.39	-2.77	-2.95	-3.01
5 m.	-0.26	-1.64	-3.16	-4.02	-5.55	-6.44	-6.85	-7.00
10 m.	-0.37	-2.35	-4.52	-5.76	-7.94	-9.21	-9.80	-10.01
Working time, hr./day	Plus	Plus	Plus	Plus	Plus	Plus	Plus	Plus
1	-0.17	-1.06	-2.04	-2.60	-3.59	-4.16	-4.42	-4.52
2	-0.11	-0.71	-1.36	-1.73	-2.39	-2.77	-2.95	-3.01
4	-0.06	-0.35	-0.68	-0.87	-1.20	-1.39	-1.47	-1.51
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	+0.09	+0.56	+1.08	+1.37	+1.89	-2.20	+2.34	+2.39

NOTES

(1) Source activity is quoted in millicuries or curies, where 1 curie is that amount of radioactive material that disintegrates at the rate of 3.7×10^{10} disintegrations per second. However, the table is computed on the further assumption that each disintegration yields one gamma photon of the selected energy. This will lead to inaccuracies whenever the disintegration is complex. More accurate calculations can be made by obvious methods when the disintegration scheme is known.

(2) The tabulation ignores the increased effective transmission of shields under wide beam irradiation.

(3) This form of shielding table is intended to form a guide to rapid erection of temporary shielding structures in the laboratory. Where permanent installations of maximum economy are planned, more detailed calculations by conventional methods are required.

LEAD EQUIVALENTS OF VARIOUS MATERIALS

Material	Mean density, g. per cu. cm.	Lead equivalent, mm.	Corresponding thickness of materials, mm.			
			X-rays excited at peak voltages of			
			150 kv.	200 kv.	300 kv.	400 kv.
Iron	7.9	1	11	12	12	11
		2	25	27	20	18
		3	37	40	28	23
		4	50	55	35	28
		6			48	38
		8			60	45
		10			75	55
		15				75
		20				
		50				
		100				
Concrete:	2.2	1	85	80	60	50
2 parts ballast.....		2	160	150	95	75
2 parts sand.....		3	230	210	125	100
1 part cement.....		4	295	275	150	120
		6			210	150
		8			260	185
		10			300	220
		15				300
		20				
		50				
		100				

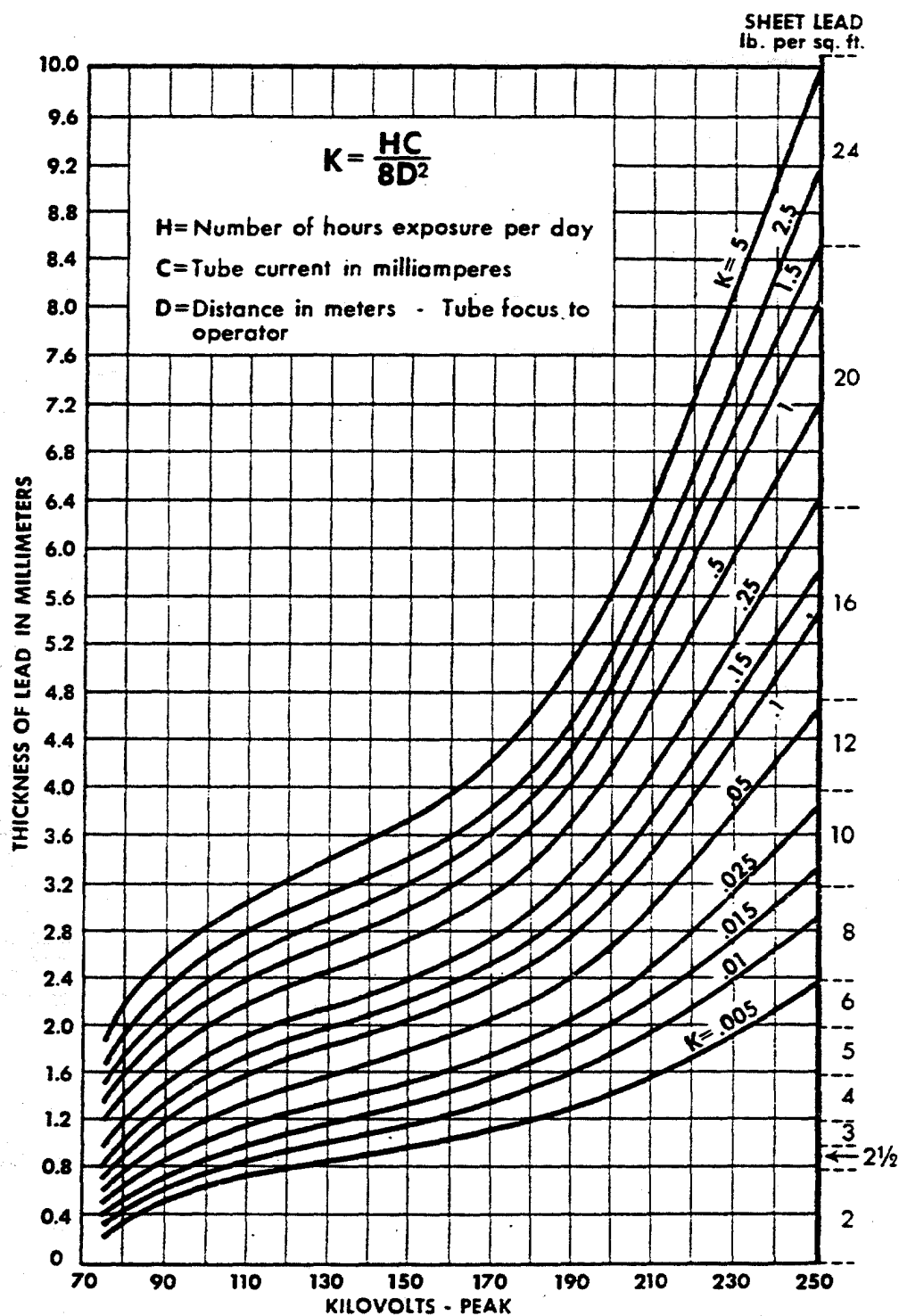
Some common applications of lead in the development of atomic energy and in the handling of radioactive materials include: lead bricks (interlocking or ordinary rectangular), lead plates and castings, "hot" laboratory table and sink tops, storage, carrying and shipping containers, lead rubber gloves and aprons, lead glass aprons, lead glass windows, Geiger counter tube shields, lead shot, lead sheet sheathing, lead headed nails, lead plywood, lead lined cinder blocks, lead safes, and so on.

X-RAY PROTECTION

X-rays are widely used both by the medical profession and by industry. Since these rays can cause physical damage to persons exposed to them it is necessary to enclose X-ray generating units in chambers made of or lined with a material which is resistant to X-ray penetration. Since the impermeability of the shielding material is a function of its density, lead, which is the densest commonly available material, will give the greatest protection per unit of thickness. Lead is the least bulky and usually the lightest and most economical material for such shielding.

Although certain types of X-ray machines intended for production line operation are self contained in lead lined cabinets with automatic controls to shut off the course of power before the doors can be opened, a general X-ray department usually requires the provision of a lead lined room. Such a room must be carefully planned and constructed with the lead lining of sufficient thickness to keep the exposure of persons in its vicinity below safe tolerance limits. The principal factor in determining the proper thickness of lead is, of course, the intensity of the X-rays to be generated but consideration must also be given to the cumulative time of operation during the working day, the distance of the operator and other persons outside the room from the X-ray tube and the generation of scattered or secondary radiation given off by objects in the path of the useful beam.

The intensity of the rays is a function of the voltage impressed on the tube and therefore it is customary to use voltage as a primary guide in selecting the proper thickness of lead required for X-ray protection. An accompanying chart gives the thickness of sheet lead protection recommended for installations of various voltages and correlates these recommendations with commercial



Thickness of lead barrier required to reduce X-ray dosage rate of the useful beam to 6.25 milliroentgens per hour under indicated conditions.

thickness of sheet lead. Having selected the proper thickness of sheet lead, the principal feature to watch in obtaining effective shielding is to see that no even minute space exposed to the rays is left unshielded. Thus no screw or nail holes, *with or without screws or nails in them*, or cracks around doors are left without being completely shut off or shielded by lead.

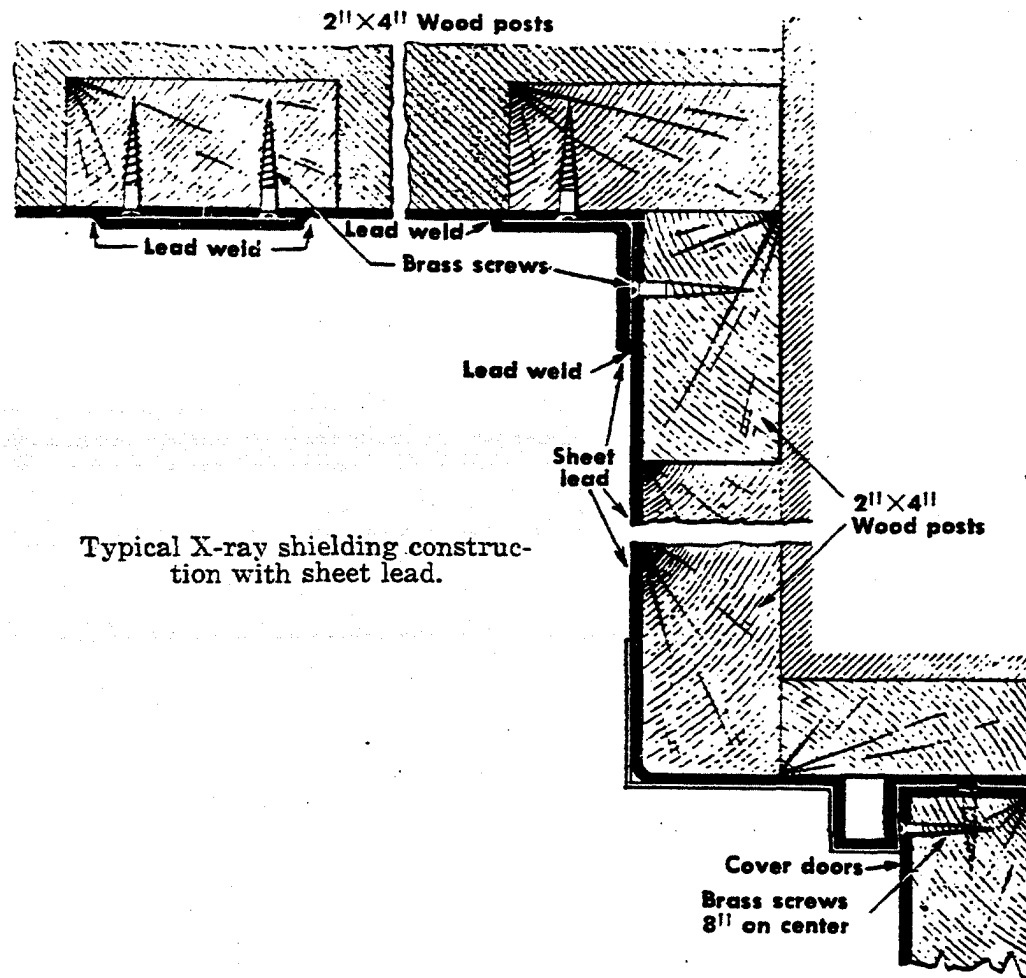
LEAD SHIELDING CONSTRUCTION

There are a number of methods of applying lead for X-ray protection. Several special devices incorporating lead are available for wall construction. These include sheet lead bonded at the factory to plywood, wall or other board materials on one or both sides with special lead covered strips for covering the joints and special lead headed nails for securing the material in place. Another device is a concrete or gypsum block with an unperforated sheet of lead anchored at its center. The two halves of this block on each side of the lead are about 1 in. off center so that their edges are offset by that amount. The sheet lead, however, extends to the outer edge all around. Thus when a wall is built up of these blocks, the lead in one block overlaps that in all adjoining blocks by 1 in. and provides a continuous lead lining. Other special devices include lead-lined doors and lead-covered windows glazed with glass containing a high percentage of lead.

If such special methods are not used, there are a number of ways of applying sheet lead linings, all of which are satisfactory and the choice of which may depend upon the type of construction and other installation conditions. Some of these methods are described here.

In one method sheet lead is placed against the wall surface or studs with the long dimensions of the sheets running vertically. Sheets should not exceed 36 in. in width for ease of handling and should be of such width that joints will occur over vertical supports. Such joints should have 2-in. overlaps. At the top, sheets should turn out at least 2 in. onto a continuous horizontal support. Over the lead at joints and at about 16 in. intervals, 2 x 4 in. wood strips or steel angles or channels are placed running from the floor to ceiling. These are secured top and bottom and

at intermediate points, the spacing of which depends on the weight of the lead but in no case should be more than 4 ft., by bolting through the lead to the wall. One or two horizontal braces between each pair of studs may be used to give additional support to thick linings. Lead patches are then welded or soldered to the lead on each side over all bolts. These patches should extend several inches in each direction beyond the bolt hole so that rays striking at an angle cannot penetrate the bolt holes. Metal lath can then be fastened to the supports and the wall finished in the usual way. Patches should be of the same thickness of lead as the lining to eliminate any possibility of leakage.



A method suitable for masonry walls is to build 2 x 4 in. wood studs into and flush with the wall at 16 in. intervals. Sheet lead with the long dimension running vertically may then be screwed

to these studs. A perforated steel strip against the lead under the screw heads helps to distribute the load. Strips of lead may then be placed over the screw heads or steel strip and welded or soldered to the sheets on each side. Screws should be about 6 in. apart. A slight variation of this method is to screw the edge of only one sheet to each stud, allowing the edge of the adjoining sheet to overlap the screw heads and steel strip and be welded or soldered to the first sheet, thus covering the screw holes.

Still another method is to use horizontal wood sleepers built into and flush with the wall at 2 ft. intervals. The sheet lead is then applied as in the previous methods, but with the long dimensions running horizontally, the screw heads being covered as before by overlapping.

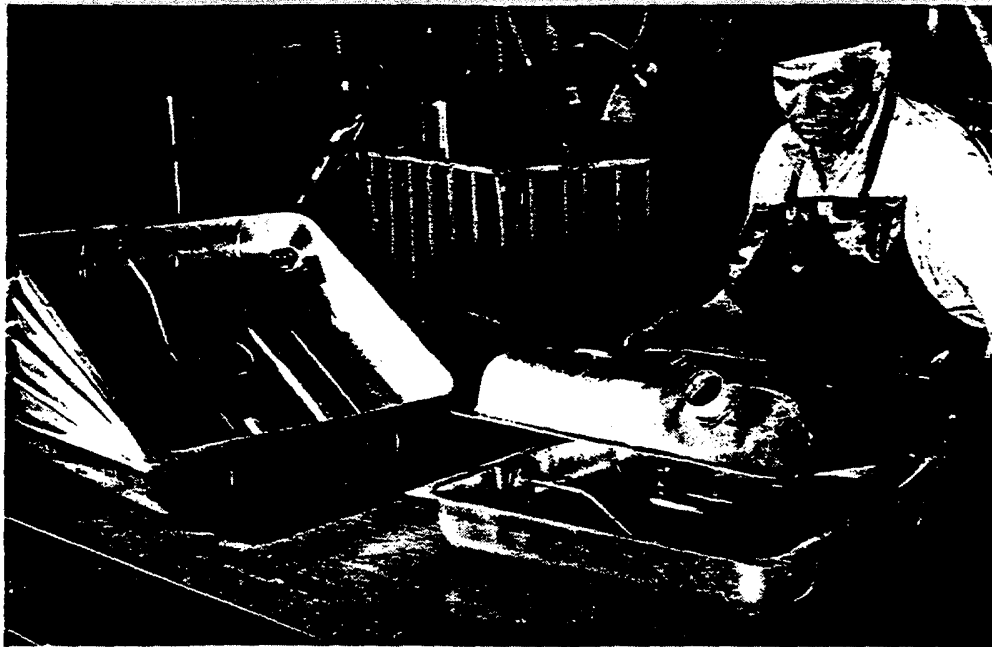
Another method successfully used is to employ boards screwed horizontally to regular studs. The lowest boards are applied first to a height of about 18 in. and are then covered with a sheet of lead which is turned back over the upper edge of the top board and then turned upward about 1 in. against the studs, where it is screwed. Another tier of boards 18 in. wide is then applied in the same way, fitted down over the set-back of the first sheet of lead, and covered with lead in the same manner. The joints between the lead sheets are then soldered or welded.

Sheets in all cases should be bent around corners and at intersections so that they can be welded or soldered to the sheets on the adjoining wall to make the lining continuous. Wall sheets should be turned out several inches on the floor to insure ample lap between wall shielding and floor shielding. The lead lining should also be carried around the rabbet of door jambs so that it will overlap the lining of the door itself when in the closed position.

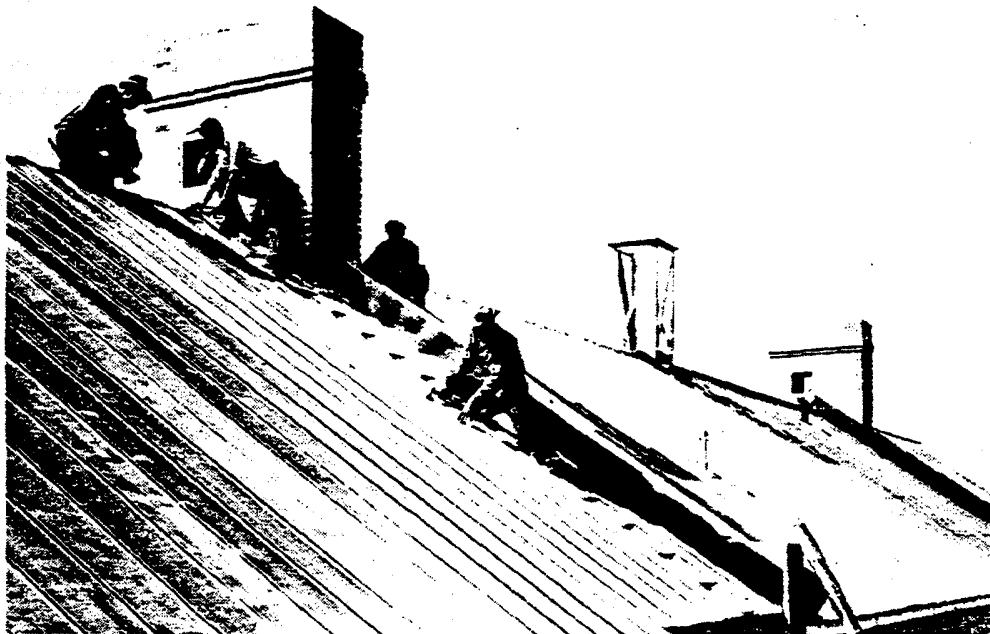
Where pipes or wires penetrate the lead lining, they should be fitted with flanged lead elbows welded or soldered to the lead lining and so designed as to prevent passage of rays through the opening. Pipes or wires passing through the wall may be offset so that the opening through the lead lining can be backed with a large lead patch on the outside. Electric switch boxes should also be backed with lead patches much larger than the opening so that rays cannot pass through even at an angle.

Protection on ceilings may be accomplished most easily by laying lead, with overlapped joints, on the floor above or on a drop ceiling. In such cases, the lining should be extended well beyond the lead walls below it. This projection of the floor lining should be enough to prevent passage of the rays through the gap of the floor construction between the lead walls and the lead on the floor above, as the rays travel in a straight line at an angle to the wall and ceiling.

Lead takes paint well without special preparation, so lead linings may simply be painted to present a pleasing appearance. If such treatment is intended, a baseboard and a chair rail should be provided to prevent damage to the lead by being struck by feet or furniture. If a plaster finish is desired, metal lath may be applied to the supports previously described and the wall plastered in the usual manner. Wall board may also be applied to these supports. Wood floors to be laid over lead linings either in the X-ray room or in rooms overhead should be laid on floating sleepers, care being taken that no nails penetrate the lead. Cement floors may be laid over lead linings but if the lead is left exposed without immediately pouring the concrete, it should be protected against mechanical damage by a layer of heavy building paper or 15-lb. felt. In either case it is advisable to protect the lead from the action of "green" concrete by coating it with a thin layer of asphaltum.

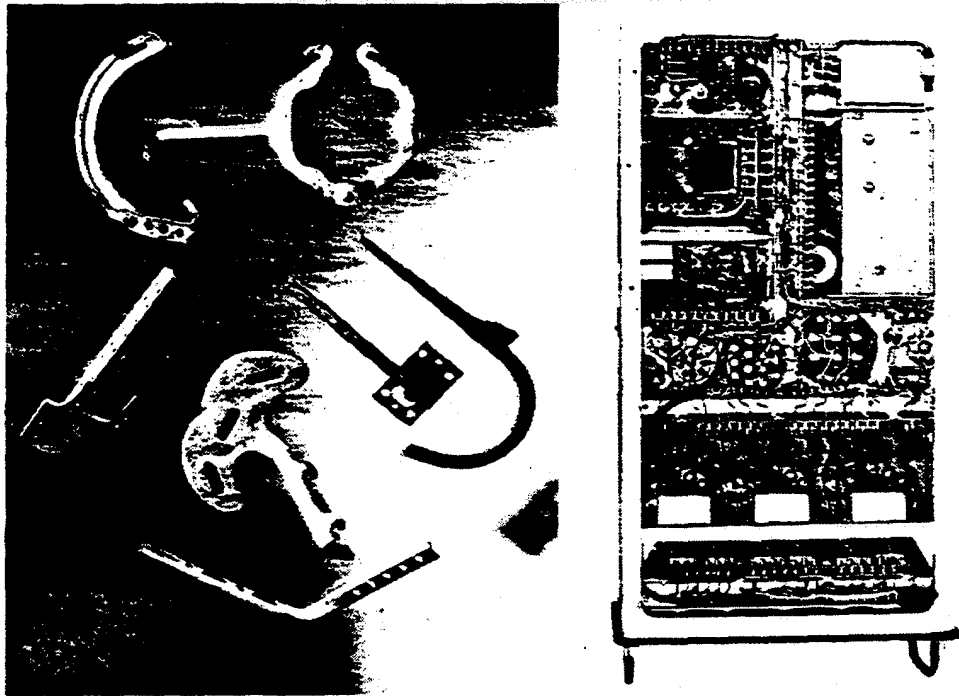


A terne-plate gasoline tank for a Ford car. The lead-tin alloy makes the forming operation easier and guards against corrosion during use.



Follansbee Steel Corp.

Installing a loose-locked, standing seam terne-plate roof. The terne alloy protects the roofing metal from atmospheric corrosion and provides an excellent base for paint.



Left. Hot dip lead alloy coated steel building hardware. *Right.* Wiring in a Sperry Automatic Pilot. All wire terminals in this assembly have been electroplated with an alloy of lead and tin (40-60) to facilitate soldering.



Spraying pure lead on parts of a sheet metal exhaust system to be used for venting sulphuric acid fumes.

CHAPTER FOURTEEN

Lead and Lead Alloy Coatings

TERNE PLATE

LEAD and certain of its alloys are widely used protective coating materials for iron and steel. Best known perhaps is terne metal, an alloy of lead and tin, the tin content being usually between 10 and 25 percent. Uncoated, the steel is known as "black plate." It is first cleaned and pickled in dilute sulfuric acid and then passed through the alloy bath in which rolls are immersed, the resultant coated steel being known as "terne plate." Sheets requiring extra heavy coating are redipped by hand.

Terne plate is produced in two grades, 1) short terne and 2) long terne. Short terne, used largely for roofing, usually carries a coating of 8 to 40 lb. per package of 112 sheets, 20×28 in. in size. They are comparatively light in weight and last for a long time if painted at intervals of four or five years. Long terne is a sheet mill product produced in larger sizes than short terne—up to 48×120 in. Long terne is utilized in the manufacture of gasoline tanks and automobile body parts, in buildings for frames and doors and other fireproof construction, and in caskets. Terne plate is used extensively for packaging paints, lubricating oils, greases and similar products.

A common weight of coating on long terne plate for the manufacture of these articles is about 8 lb. per base box, a base box representing a unit of area 112 sheets 14×20 in. For roofing, valleys, eaves, troughs and conductor pipe, coatings up to 40 lb. are used. In the nomenclature peculiar to this industry coating weight refers to the total weight of terne metal distributed on both sides of 112 steel sheets 14×20 in. in size.

The surface of terne plate is soft and has a greasy feel. The metal will not flake off, is very ductile and is much used for

deep drawing operations where a corrosion resistant material is desired. Because of the unusual ductility of such coatings they are ideal for articles to be formed as the lead also acts as a lubricant in die drawing or stamping operations. Terne coatings form an excellent base for paint and are therefore especially useful on articles that may or must be painted. Terne plate is used for gasoline tanks where any products of oxidation might clog the fuel line. In addition, it is easily soldered with non-corrosive fluxes and welds without difficulty.

HOT DIP LEAD ALLOY COATINGS

The virtues of lead and lead alloy coatings containing little or no tin have become generally recognized. Lead and lead alloy coatings have a number of advantages over other commercial coatings. The coating is highly resistant to corrosion. If some pinholes are present, as may be expected in almost any metal coating, it has been learned that they do not permit rust to penetrate or spread under the coating, although some rust discoloration may appear in early stages of exposure. In actual practice, these pinholes become sealed by corrosion product against further attack.

While lead is being used successfully as the coating metal, the most widely used coating consists of lead base alloys. There are several such suitable alloys on the market. In general, they run from 90 to 95 percent lead with additions of smaller percentages of tin, usually 2.5 percent or less, the balance being other metals such as antimony, zinc, silver in some amounts. These alloys are designed to have greater fluidity in the molten state than pure lead and contain such elements as tin and antimony because they alloy readily with both steel and lead. Also, they tend to harden the coating metal for greater mechanical wear without accompanying brittleness.

Both water solution and molten fluxes are being used in lead alloy coating, with the molten fluxes apparently preferred. Zinc-ammonium chloride or special fluxes made by manufacturers of the lead alloys are employed. It is good practice to pre-heat the articles to be coated in the molten flux at a temperature about the same or slightly higher than the lead alloy bath. This is

particularly true of large articles as it prevents chilling of the lead alloy and insures a well-bonded coating.

Strangely enough the heavy metal, lead, results in one of the lighter weight coatings. This is because adequate protection is gained with thinner coatings than those often employed with other metals. The thickness of coating required naturally depends to a large extent on the use to which the article will be put. It can be said, however, that lead alloy coatings weighing about 0.7 oz. per sq. ft. both sides, equivalent to a thickness of about 0.0004 in., usually give good protection against normal atmospheric corrosion. Coatings may be much thicker, nevertheless, to resist special conditions, or may be lighter if intended to serve only as a die lubricant or paint base, or to protect only for short periods.

Lead alloy coated sheets have been employed for a number of purposes, such as building sheet metal work, duct work, and for forming into a variety of objects like ammunition boxes and deep drawn articles. In addition, lead alloy coatings are being applied to a variety of fabricated articles. Radio and radar parts and telephone pole line hardware are prominent among these. Some other articles being coated are mufflers, battery boxes, nails, condenser cans, seamless tubes and unit heater assemblies.

ELECTROPLATING

Pure lead or lead-tin alloys can be electroplated on iron or steel. Several different types of solutions are available, such as the fluoborate and sulfamate solutions. These are now available as powders or master solutions which are readily dissolved or diluted for use in plating, thus adding greatly to the convenience of the process. High current densities may be employed in lead plating.

This process has been used for various purposes for a number of years. Shells coated twenty years ago have been found to be in excellent condition today. Among products now being electroplated with lead are battery hardware, bearings and bushings, nuts and bolts and many other items.

The following table gives some data on various lead electroplating solutions:

LEAD ELECTROPLATING SOLUTIONS *

Plating solution: grams per liter	Anodes corroding or chemical Pb	Current density; amp./sq. dm. 0.54 to 5.4 (av. 2.2)	Voltage; volts	Temp. °C. 25-40	pH	Current efficiency 100%
2 PbCO ₃ ·Pb(OH) ₂ , 150 50% HF 240 H ₃ BO ₃ , 106 Glue 0.2						
2 PbCO ₃ ·Pb(OH) ₂ , 300 50% HF 480 H ₃ BO ₃ , 212 Glue 0.2		0.54-7.6 (av. 3.2)				100%
Pb 75 Total fluosilicate 150 Glue 0.2		0.54 to 8.8	0.1 to 0.2	35-40		100%
Sulfamate Pb process Sp. gr. soln. 30° Be		0.5 to 4.5	(a) 3-8 (b) 9-14	25-50	1.3-2.0 (av. 1.5)	100%

(a) Still.

(b) Barrel.

* Data from "Metal Progress."

The rate of electrodeposition of lead is high. Tabulated below are the ampere minutes per square foot required to deposit a coating equivalent to one pound of coating metal per base box, showing clearly the high rate for lead as compared with tin. The rate for lead is also high compared with other metals as well as tin.

Coating per base box	Electrolyte	Amp. min. per sq. ft.
1 lb. lead.....	Sulfamate	16.2
1 lb. tin.....	Halogen	28.27
1 lb. tin.....	Stannate	56.54

The following table shows the time required to deposit various thicknesses of lead plating at different current densities:

RATE OF DEPOSITION—ELECTROPLATED LEAD COATINGS

		Cathode current density in amp. per sq. ft. at 100% cathode efficiency					
Oz. lead per sq. ft.	Thick-ness in inches	10	20	30	40	50	60
Time required in minutes (414 amp. min.—.001 in. per sq. ft.)							
0.094.....	0.0001	4.14	2.07	1.38	1.03	.83	.69
0.188.....	0.0002	8.28	4.17	2.76	2.06	1.66	1.38
0.376.....	0.0004	16.56	8.28	5.52	4.14	3.31	2.76
0.564.....	0.0006	24.84	12.42	8.28	6.21	4.99	4.14
0.752.....	0.0008	33.12	16.56	11.04	8.38	6.62	5.52
0.94.....	0.001	41.40	20.70	13.80	10.35	8.28	6.90
1.88.....	0.002	1 hr.	41.40	27.60	20.70	16.56	13.80
		23 min.					
3.76.....	0.004	2 hr.	1 hr.	55.20	41.40	33.12	27.60
		46 min.	23 min.				
5.64.....	0.006	4 hr.	2 hr.	1 hr.	1 hr.	49.68	41.40
		8 min.	4 min.	23 min.	2 min.		
7.52.....	0.008	5 hr.	2 hr.	1 hr.	1 hr.	1 hr.	55.20
		31 min.	46 min.	50 min.	23 min.	6 min.	
9.4.....	0.01	6 hr.	3 hr.	2 hr.	1 hr.	1 hr.	1 hr.
		54 min.	27 min.	18 min.	44 min.	23 min.	9 min.
18.8.....	0.02	13 hr.	6 hr.	4 hr.	3 hr.	2 hr.	2 hr.
		48 min.	54 min.	36 min.	28 min.	46 min.	18 min.
47.0.....	0.05	34 hr.	17 hr.	11 hr.	8 hr.	6 hr.	5 hr.
		30 min.	15 min.	30 min.	38 min.	54 min.	45 min.

SPRAYED COATINGS

Lead coatings may be applied by spraying. The lead in wire form is fed into a spray gun which melts the metal and blows it onto the surface to be coated. Since there is no chemical bond

between the lead and base metal, the latter is first sand-blasted or otherwise roughened and cleaned in order to provide good mechanical anchorage for the coating. Pin holes may be minimized by peening the surface after coating.

Because of lead's low melting point, it is more rapidly and economically applied by spraying than are most other metals. Sprayed coatings may be built up to any desired thickness. This method is especially useful for applying protective coatings to equipment already in place, although its usefulness is by no means confined to such conditions.

Spray guns may be obtained from manufacturers by those who wish to apply their own coatings. There are also many jobbing shops equipped to do spray coating for others.

COATING THICKNESS CONVERSION TABLE

Several different methods are used to describe the thickness of lead coatings. For instance, coatings on steel sheets are sometimes expressed in decimals of an inch, sometimes in pounds per base box, and sometimes in ounces per square foot. Expressed in thickness reference is usually made to the thickness on one side of the sheet only, whereas weight usually refers to the coating on both sides of the sheet. Therefore, the following conversion table should prove helpful, it being kept in mind that this table refers to pure lead and that when alloys are used some adjustment may have to be made for differences in density.

CORRELATION OF DECIMAL THICKNESSES OF LEAD COATINGS TO WEIGHTS PER UNIT OF AREA

Coating thickness (one side) In.	Coating weight (both sides)	
	Lb. per base box	Oz. per sq. ft.
0.00001.....	0.26	0.0189
0.00005.....	1.30	0.095
0.0001.....	2.60	0.189
0.0005.....	12.90	0.947
0.001.....	25.80	1.89
0.002.....	51.60	3.78
0.005.....	129.00	9.47
0.01.....	258.00	18.92
0.02.....	516.00	37.84

CHAPTER FIFTEEN

Soft Solders

ONE of the most useful groups of alloys is the tin-lead series commonly called soft solders. With varying amounts of tin and lead, depending upon the application, these alloys have solved a wide range of metal joining problems.

The eutectic alloy of this group contains 62 percent tin and has a melting point of 361 deg. F. That is also the solidus of all except the very low and very high tin-content alloys in this group. See tin-lead phase diagram on page 188. As tin content is reduced below that of the eutectic, the liquidus rises and the plastic or freezing range becomes wider. Consequently with low-tin solders, higher soldering temperatures are necessary and care must be taken to eliminate "hot shortness" difficulties (brittleness when hot). Furthermore, the lower tin-content solders do not as a rule have as good flow characteristics and are apt to be more porous. Solders containing about 40 percent tin and 60 percent lead or 50 percent of each, with or without small percentages of antimony, are probably most widely used.

Considerable work has been done recently with solders containing less tin. These include lead alloyed with silver, with silver and small percentages of tin, and other combinations. With fluxes and soldering techniques adjusted to the particular alloys used, favorable results have been obtained in many instances. For instance, the canning industry, using highly mechanized methods which can be adjusted to the new solders and closely controlled, is using solder containing as little as 2 or 3 percent tin, naturally with a considerable cost saving because of the lower tin content and no loss in quality of the joints. In that and some other industries these economies have resulted in permanent use of lower tin content solders than formerly. However, in many applications and particularly for hand soldering

operations, the higher tin content solders will probably continue to be preferred. Among the reasons for this are less corrosive fluxes, lower temperatures, better flow characteristics, greater strength and less porosity.

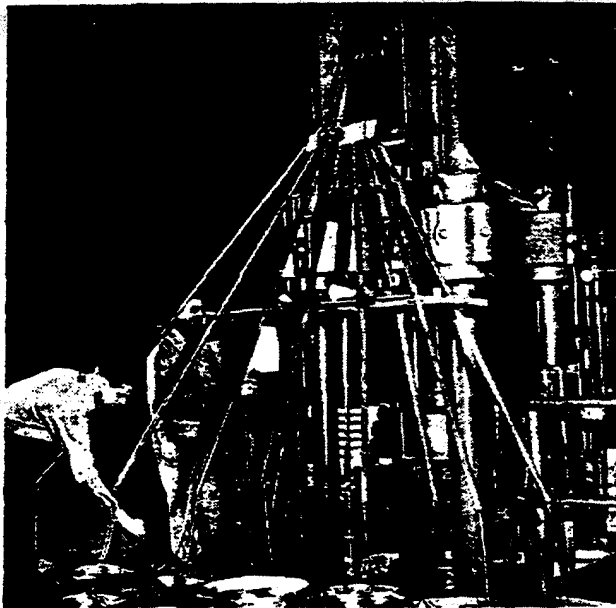
The following table lists some of the familiar tin-lead solders and some of the alternates that have been recommended, along with melting point data:

TIN-LEAD AND ALTERNATE SOLDERS

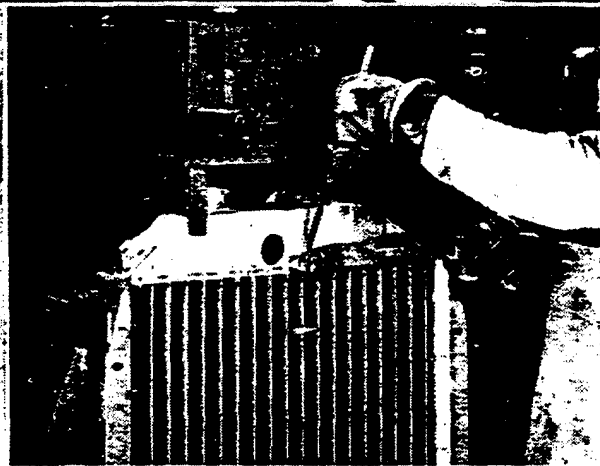
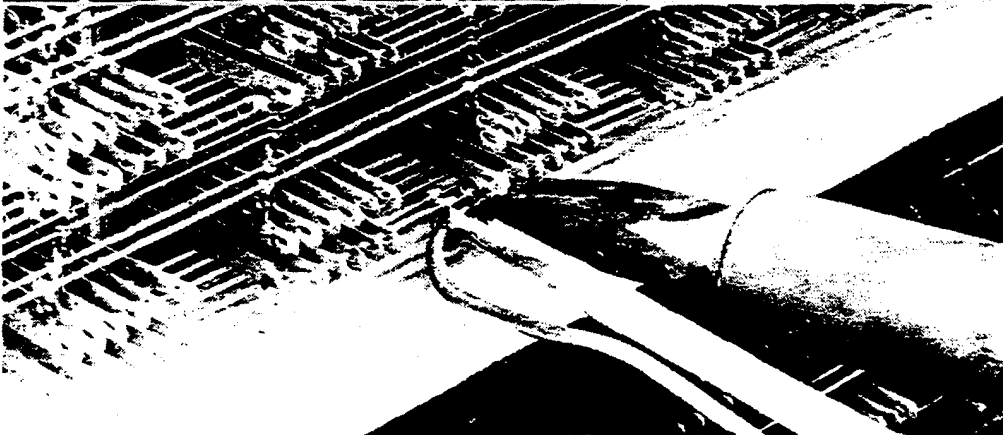
Composition, percent				Temperature					
				Solidus		Liquidus		Freezing range	
Tin	Lead	Anti-mony	Silver	Deg. F.	Deg. C.	Deg. F.	Deg. C.	Deg. F.	Deg. C.
2.5	97.5	—	—	574	301	606	319	32	18
5	95	—	—	518	270	592	311	74	41
10	90	—	—	361	183	567	297	206	114
20	80	—	—	361	183	523	273	162	90
30	70	—	—	361	183	486	252	125	69
40	60	—	—	361	183	453	234	92	51
50	50	—	—	361	183	421	216	60	33
60	40	—	—	361	183	372	189	11	6
62	38	—	—	361	183	361	183	0	0
70	30	—	—	361	183	378	192	17	9
80	20	—	—	361	183	397	203	36	20
49	50	1	—	367	186	410	210	43	24
39	60	1	—	367	186	446	230	79	44
29	70	1	—	367	186	486	252	119	66
19	80	1	—	365	185	523	273	158	88
20	78.75	—	1.25	356	180	518	270	162	90
10	88.50	—	1.50	252	178	554	290	202	112
0	97.50	—	2.50	579	304	579	304	0	0

The foregoing table is not intended to include the compositions of all available commercial solders but will give a good idea of melting points and freezing ranges of a wide variety.

Solder containing in the neighborhood of 50 percent tin is the most popular general purpose solder. Somewhat higher tin contents, about 60 to 70 percent, are used for "fine solder," particularly where temperature requirements are critical. For wiping solder, those having tin contents around 37 to 40 percent are most generally used, although somewhat lower tin contents have been employed for this purpose in emergencies for joints not under pressure. Automobile radiator solder also falls in this group. For coatings, the low tin-content alloys are usually em-



Left. Hydraulic press for extruding wire solder. *Below.* Soldering with an electrically heated "iron" and cored solder.



Linde Air Products Co.

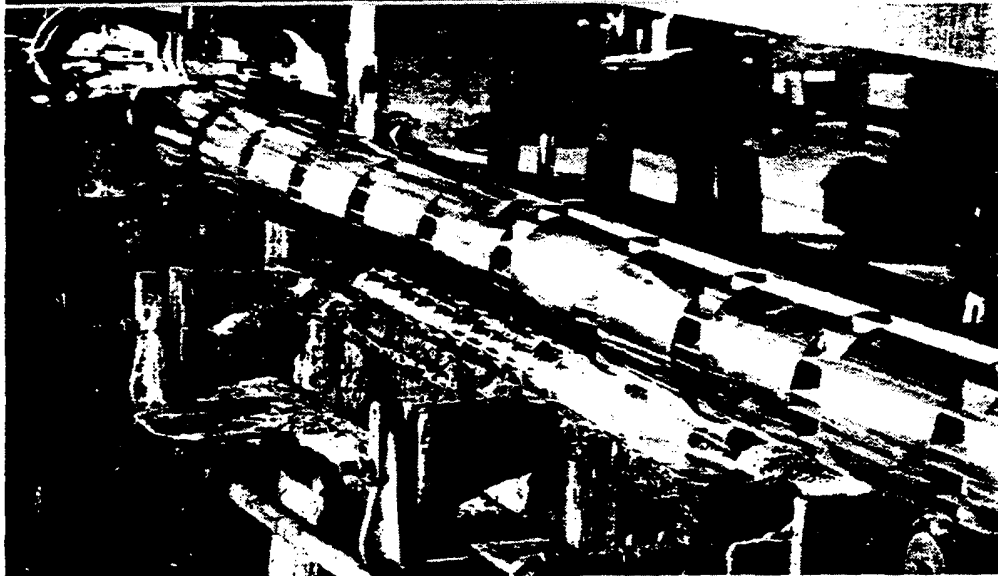
Left. Torch soldering the handles on stainless steel cans using tin-lead wire solder. *Right.* Soldering an automobile radiator with stick solder and a hot "iron."



Wiping a solder joint between a lead alloy cable sleeve and a lead alloy sheath.



Body solder being used to repair an automobile fender.



An automatic side seam can soldering machine.

ployed, running up to 25 percent tin forterne metal and as low as about 2 percent tin for lead alloy coatings. Since automobile body solder requires comparatively little strength and a wide plastic range, the low tin-content solders are also used for this purpose. Low tin-content solders are also frequently employed for dip soldering operations where design of the objects soldered is such as to assure a strong enough joint. For high temperature, high strength solder, lead-silver solder has enjoyed some popularity, particularly for machine soldering operations.

In addition, solders can be obtained with melting points down to lower than the boiling point of water for special purposes where extremely low melting is necessary to avoid warping of the metal joined or for other reasons. They are usually alloys of lead and tin with either bismuth or cadmium or both (see page 133).

Solder is available in a variety of forms. These include bars, cakes, slabs, wire (with or without flux cores or flux on or near the surface), ribbon, foil or sheet, drop, powder and paste.

CHAPTER SIXTEEN

Bearing Metals

SOME of the first pieces of machinery with rotating parts were so constructed that wood functioned both for shafts and bearings. Later metal replaced wood for these purposes. In 1839 Sir Isaac Babbitt obtained a patent on an alloy containing 88.9 percent tin, 7.4 percent antimony and 3.7 percent copper, for use as a bearing metal. Other alloys, many of them now lead base, have since replaced the original babbitt metal because they are less expensive and often superior. Common usage has now applied the term "babbitt metal" to a wide variety of white metal bearing alloys differing from Babbitt's original formula. In modern machinery, there is a tendency to use replaceable bearings, consisting of a steel, brass or other strong metal shell lined with babbitt metal.

Although ball and roller bearings have a lower starting friction than bearings made from babbitt or bronze, the running friction is approximately the same owing to the high internal friction of ball and roller bearings at high speeds. Furthermore, total resistance of a vehicle is not entirely due to bearing resistance, by any means. Therefore, before an installation of bearings is made, all factors should be considered. With proper design and lubrication, babbitt and bronze bearings may give as good or even better service than roller bearings at greatly reduced cost. Ease of replacement and ability to adjust to the alignment of the shaft are other advantages of the white metal bearing alloys. Furthermore, should lack of lubrication lead to trouble, the bearing metal can yield or melt without damaging the shaft. White metal bearing alloy compositions and properties will be found on page 201.

Bronzes are used for unlined bearings or for the backing of babbitt lined bearings. They generally consist of copper alloyed with smaller amounts of tin and lead. There are a wide variety of these alloys, but the backing used for lined railroad journal bearings may be typified by the formula 73 percent copper, 20 percent lead and 6 percent tin, balance impurities. Bronzes for unlined bearings may be represented by the formula 80 percent copper, 10 percent lead and 10 percent tin. Phosphor bronzes contain in addition up to 1 percent phosphorus. In general industrial use, the 80-10-10 formula is probably most representative. Copper-lead alloys containing from 25 to 40 percent lead, balance mainly copper, are also widely used for bearing linings, particularly in aircraft. These are sometimes made by sintering copper-lead powder to steel strip on one or both sides. Copper-lead bearings are said to be inferior in non-scoring to tin and lead base babbitt but superior in fatigue resistance.

LEAD-BASE BEARING ALLOYS

Although lead-base alloys containing little or no tin have been used for certain kinds of bearing linings for many years, only recently has it become generally recognized that, if proper precautions are taken, lead-base alloys can satisfactorily replace tin-base alloys in practically all applications. By lead-base alloys is meant those containing less than 10 percent tin and in many cases having a much lower tin content. They may be alloys of lead, antimony and a small percentage of tin with or without small quantities of arsenic, or they may be essentially lead hardened with the alkaline earth metals such as calcium and sodium.

For light loads, bearings of the same design as those employing high-tin alloys may be used with complete satisfaction. For heavy loads, however, bearings should be redesigned to have as thin linings as possible. In any case, proper bonding of the lining to the shell is essential. If these precautions are observed, it is possible to use lead-base alloy linings for virtually all purposes with excellent results at lower cost.

Methods of preparation of the shell for lining with lead-base bearing metal vary to suit the condition and the metal of the

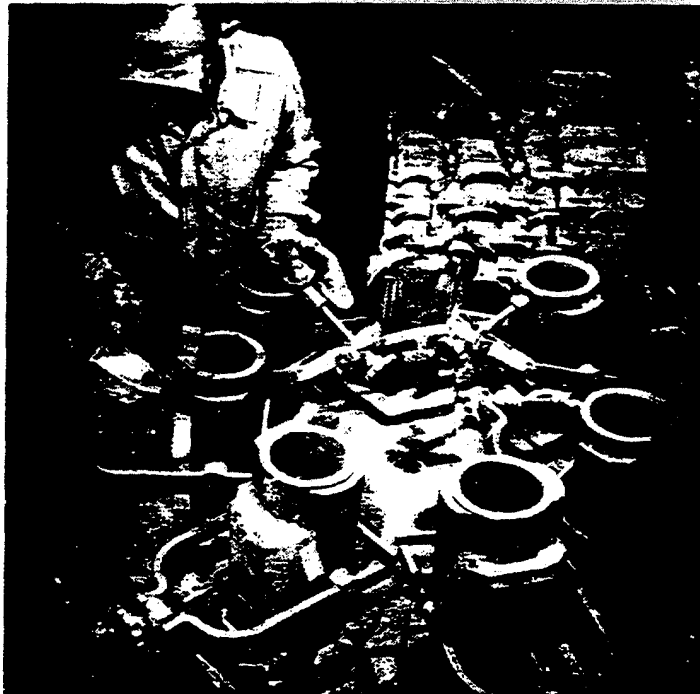
bearing shell. In general, for steel back shells, the conventional methods usually used for tin-base babbitts may be employed.

Another process of shell preparation which has been successfully employed on cast iron and malleable iron as well as on steel is using a molten catalyzed salt bath at a temperature of approximately 850 deg. F. Briefly, the essential steps of this process are as follows: machining or abrasive cleaning, immersion in molten catalyzed salt bath of controlled temperature for 5 to 15 minutes, water rinse, immersion in solution of salts to dissolve ferric oxide, water rinse, etching in hydrochloric acid solution, immersion through a floating layer of molten zinc-ammonium chloride flux into a bath of lead-antimony-low-tin tinning metal which bonds with the iron shell. The operations are carried through in rapid sequence and the result is a thin coating of tinning metal which bonds readily with the lining. A recent variation of this process involves electro-cleaning in the molten salt bath, the current being reversed during the operation. This eliminates the second salt bath.

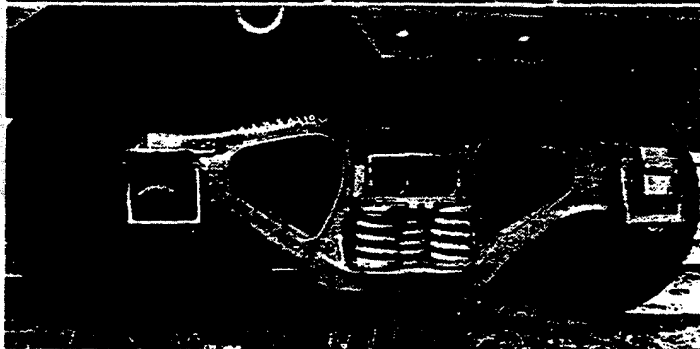
Other processes involve special machining and handling methods, chemical cleaning or other means of providing scrupulously clean surfaces suitable for the application of the tinning metal which in some methods is deposited electrolytically. Whatever the method, the tinning must be continuous over the entire bearing if the application is to be successful. Lead-base babbitt is not recommended for use in those bronze back bearing shells where the operating temperatures may be 275 deg. F. or higher. After prolonged heating at elevated temperatures, the bond of lead-base babbitt is materially weakened when the backing material is bronze. Temperatures of this order are found in gasoline and diesel engines, but steel mill bearings, railroad car journal bearings, and many other types generally operate at much lower temperatures.

The thickness, or rather, thinness of the actual bearing metal definitely influences its performance in use under many conditions. In the automotive industry, linings as thin as 0.002 to 0.006 in. are employed. Pouring temperatures for the lead-base alloys are slightly higher than for tin-base.

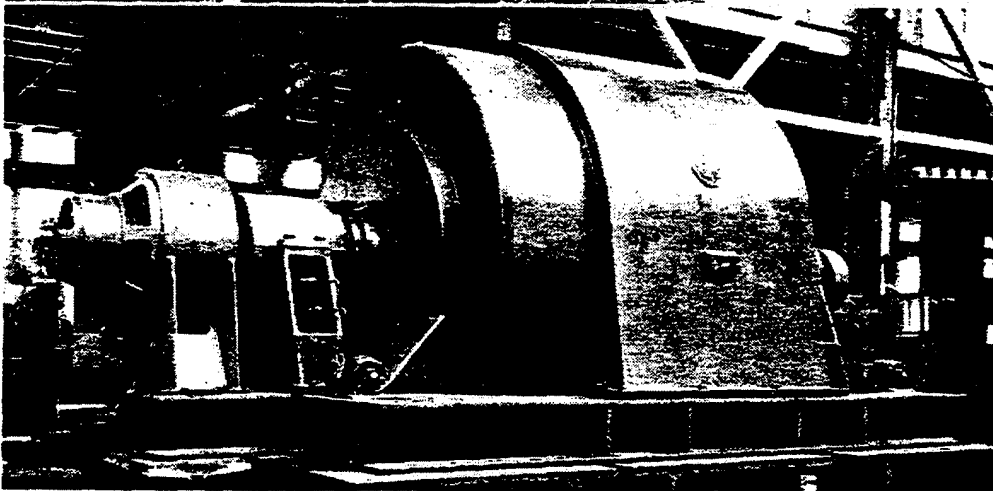
Lead-base alloys are being used successfully today in almost all kinds of bearing applications. Among these are automotive



Pouring the babbitt linings in standard AAR railroad freight car bearings.



Railroad freight car truck equipped with solid-type lead-base bearings.



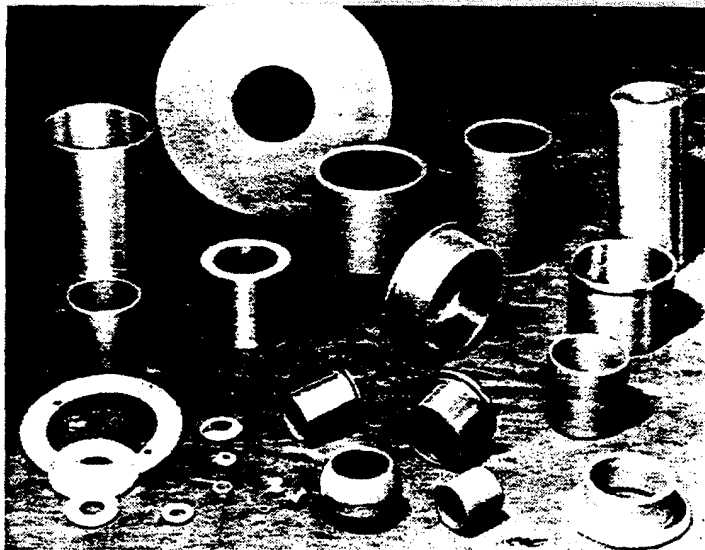
Heavy machinery makes use of lead-base babbitt metal for bearings.



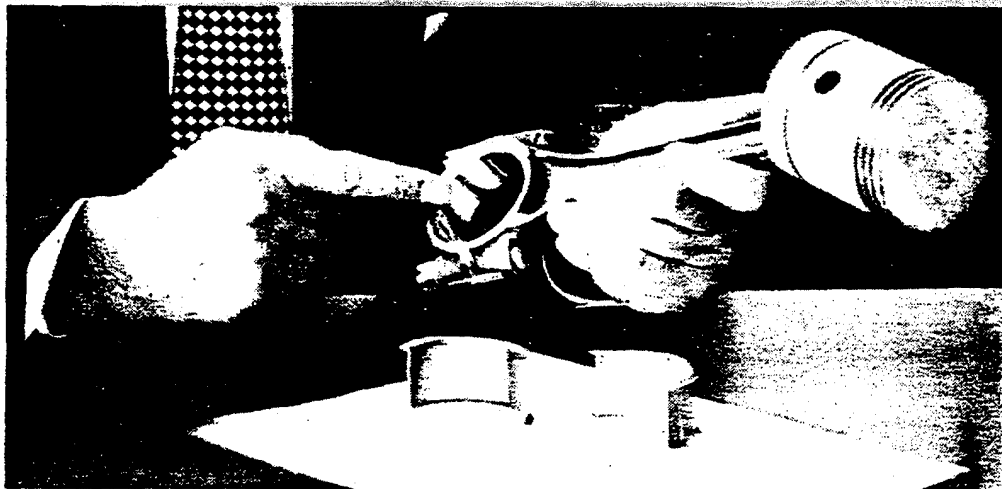
Cleveland Graphite Bronze Co.

Federal-Mogul Corp.

Left. Cross-section of lead-copper-tin bearing alloy electrodeposited on steel with a lead alloy overlay bearing surface. $\times 100$. *Right.* Cross-section of a bearing made from copper and lead powders sintered to a steel backing. $\times 100$.



Oil-impregnated metal powder sleeve, thrust, flange and self-aligning bearings containing lead powder.



Automobiles use high lead content bronze steel backed bearings.

connecting rod, main and camshaft bearings, diesel engine bearings, steel mill bearings, railroad car journal bearings, all kinds of electric motor bearings and a variety of other industrial applications. Speeds range from 25 to 3,600 r.p.m. and loads up to 2,000 lb. per sq. in.

Steel back copper-lead lined bearings manufactured from powdered copper and lead provide a practical solution to the problem of casting molten copper-lead alloy by eliminating the melting and casting steps. Essentially copper and lead in the form of powders are spread upon a continuously moving steel strip, sintered in a controlled atmosphere furnace, rolled, again sintered and the lining strip stamped into bearing blanks. Up to 45 percent lead is used in this process to make bearing material which reportedly possesses mechanical properties higher than those of bearing linings made by centrifugal or gravity casting methods.

Iron-lead bearings containing up to 10 percent lead, an alloy that would be practically impossible to cast, illustrate another lead alloy bearing application that utilizes the advantage of powder metallurgy. The addition of lead not only adds to the efficiency of the bearing but it is said also inhibits corrosion of the iron.

Composite bearings consisting of thin lead babbitt coatings on a matrix of copper and nickel powders sintered to a steel backing show very desirable characteristics regarding resistance to both fatigue and corrosion.

Bearings made of pure silver, cast, rolled, or plated on a steel backing and then plated with lead and indium or lead and tin have been used for very heavy duty service where the extra cost is warranted.

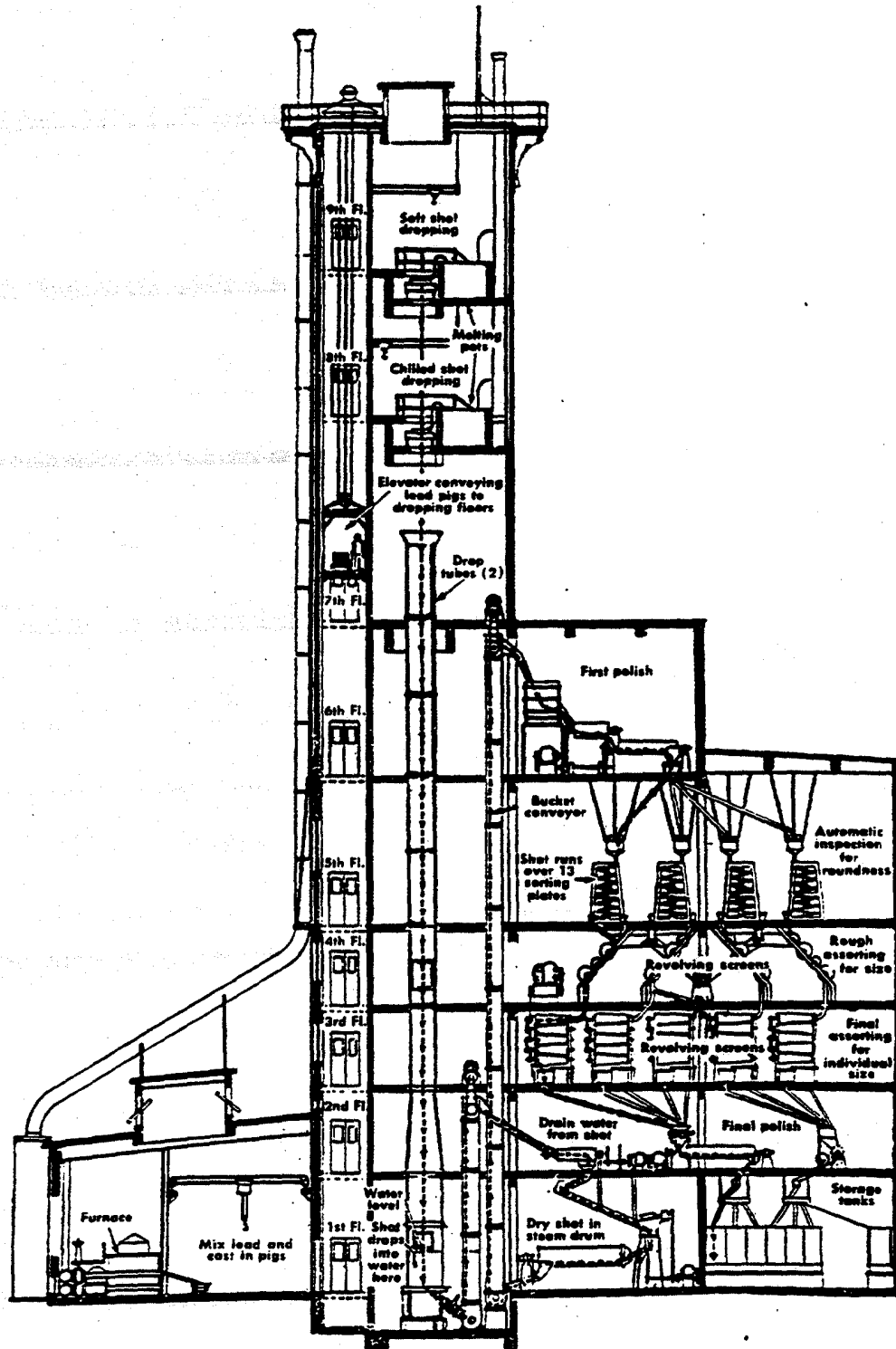
CHAPTER SEVENTEEN

Ammunition

IF YOU have ever gone home with your limit of duck, tried your marksmanship on clay pigeons at the traps or skeet, or brought a buck crashing to earth, you will understand why Americans use about 40,000 tons of lead in ammunition in a peace-time year. In the early days of this country, every section had its shot tower and lead shot was handled everywhere in grocery, hardware and other stores. With the advent of the breech-loading shotgun, a demand arose for shot loaded in shells, and ammunition manufacturers were quick to realize their opportunity. Shot towers all over the country gradually disappeared, save a few preserved for historical reasons, such as one in Philadelphia erected in 1808 and probably the first built in this country, while the shot business passed to ammunition manufacturers whose shot towers are now the only active ones remaining.

The method of manufacturing shot in towers is said to have been invented in 1782 by a plumber in Bristol, England, named Watts, who one night dreamed he was out in a rainstorm but that it was raining lead instead of water and the drops of lead were perfectly spherical like raindrops. The next morning he decided to try the experiment and poured molten lead from the tower of St. Mary Redcliffe Church into some water below. The trial was successful and he is said to have sold the invention for a considerable sum of money.

Lead's great density has always made it the ideal metal for bullets and shot. It permits the attainment of the high momentum necessary to maximum striking power and accuracy and decreases the surface against which the air resistance can act. Shot up to 0.23 in. in diameter, nearly $\frac{1}{4}$ in., is made in shot towers. Molten lead is poured from the top of the tower through a pan perforated with holes smaller than the shot desired. The necessary height



Modern lead shot tower.

of the pouring floor in the tower depends on the maximum size of the shot to be poured; the larger the shot to be made, the higher must be the pouring floor. The bottom of the pan is covered with a sludge of oxidized lead, so that the molten metal will ooze slowly through and form round drops. Small amounts of arsenic, up to 1 percent, are added to the lead to increase fluidity and allow it more easily to assume the perfect spherical shape desired, while from 2 to 6 percent antimony is also added to shot for long range loads to increase hardness. The smaller sizes of shot usually contain the higher percentages of arsenic and antimony. As the drops rain down the tower, they solidify and are caught in a tank of water at the bottom so that the spheres will not be flattened on landing. In order to decrease the height of shot towers, an upward blast of air sometimes blows against the falling lead, which has the same effect as a longer fall. The maximum height used in modern shot towers is about 125 ft.

After the shot is collected in the water, it is dried and mixed with graphite to polish it and then screened to eliminate odd sizes. It is next rolled down sloping glass tables which have a narrow trough running along the bottom. The perfectly round shot gather enough momentum to leap this trough, but those slightly flattened are slowed in their descent so as to fall into the trough and subsequently are remelted. The grading operation is repeated four times. The shot is then loaded into shells and becomes ready for use.

Shot greater than 0.23 in. in diameter is too large to manufacture by this method and is cast in revolving split-ring molds. The molds are placed around the circumference of a vertical ring several feet in diameter. The lead is poured in at the top and solidifies as it passes down one side until the split-ring opens and drops it out at the bottom.

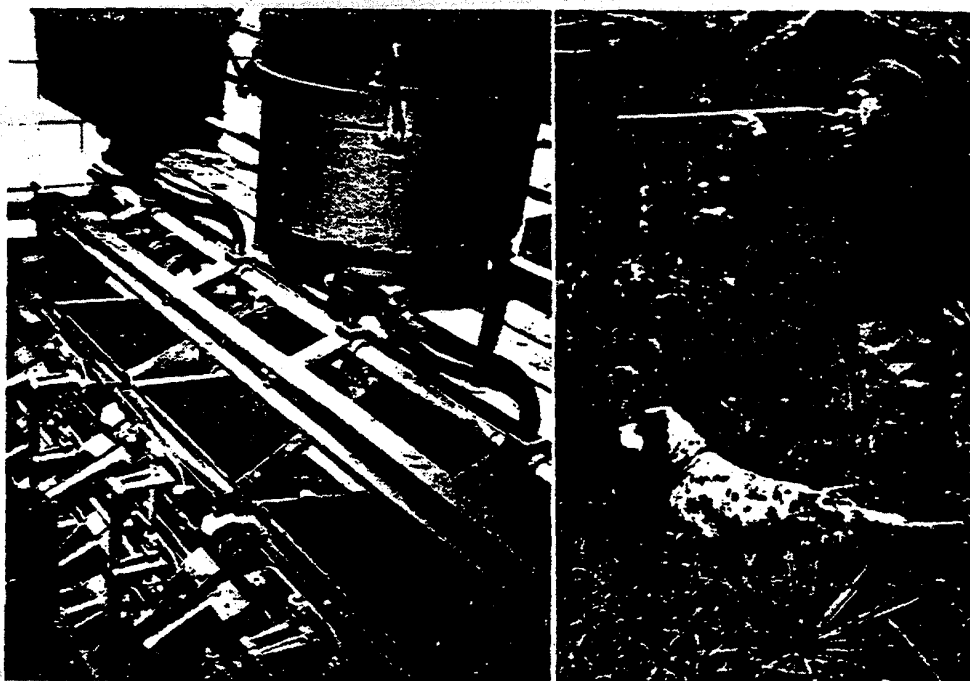
The smallest shot manufactured is 0.04 in. in diameter and 4,565 weigh an ounce. The largest cast shot is 0.44 in. in diameter and three weigh about an ounce.

For bullet cores, lead is usually extruded as wire, which is cut to length and swaged to the approximate shape of the bullet. This core is then inserted into a gilding metal (90 percent copper, 10 percent zinc) jacket which has been drawn from a disc to the shape of the bullet. The size and shape of the cores vary



Winchester Repeating Arms Co.

Molten lead falling through a sieve in the time-honored method of making lead shot in a shot tower.

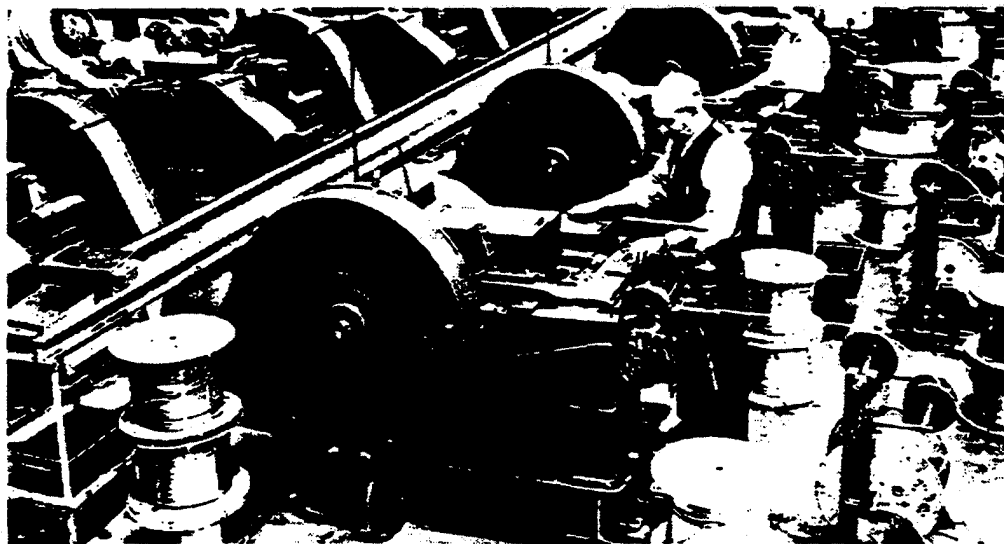


Winchester Repeating Arms Co.

Left. Sloping glass tables help separate the off-shape lead shot from perfectly formed pellets. Imperfect shot lags behind and drops into a reject trough. *Right.* Most lead shot goes into shells for sporting ammunition.



Lead bullets and bullet cores for small arms ammunition.



Cutting and swaging lead wire into bullets and bullet cores.



U. S. Army

Compared to its use in sporting ammunition lead is not a principal wartime metal. Military ammunition applications chiefly consist of pistol, rifle and machine gun bullets and bullet cores.

depending upon the type of bullet and the composition is usually between 97.5 and 100 percent lead with the balance antimony. In "ball" cartridges the entire core is lead alloy, but in tracer and incendiary bullets, the lead core is somewhat shorter than the jacket, the remaining space being filled with the tracer or incendiary chemicals. Armor-piercing bullets have a special alloy steel core which is more blunt than the jacket. The space between the tip of the jacket and steel core is filled with a small piece of lead. The lead helps the steel core to penetrate armor plate by acting as a lubricant.

The modern pointed bullet has an interesting history. Originally, round balls were fired from smooth bore muskets, but it was recognized that pointed bullets offered much less resistance to the air and were therefore more desirable. However, a pointed bullet fired from a smooth bore simply tumbled end over end and would not stay on its course. Then it was decided to impart spin to the bullet, so rifling was tried but was not really successful for many years because bullets capable of gripping the rifling when fired could not be easily loaded down the muzzles. Various types of expanding bullets and bullets with rings around them to fit the rifling were tried unsuccessfully. It was not until the early part of the eighteenth century, at which time the invention of the greased patch in America made possible the remarkable shooting of such men as Daniel Boone and Davy Crockett, that rifles attained any real measure of success. The invention of the patch brought forth the famous Kentucky Rifle made in Pennsylvania and called "Kentucky" because of the great demand for it by settlers of the then newly opened territory of Kentucky. The deadly accuracy of the American marksmen with the long Kentucky rifles played a very decisive part in ruining the morale of British troops as the accuracy attained by these backwoodsmen was far ahead of that attainable by the use of any other available weapons of the time. The patch, a greased piece of cloth or buckskin, was inserted ahead of the bullet and cleaned the powder fouling from the previous shot, lubricating the bore sufficiently to allow the bullet to be seated home. Breech-loading arms, made practical by the development just before the Civil War of the cartridge case to form the gas seal at the breach, are responsible for the great modern development of rifles but it was several

years before accuracy comparable with the best of the muzzle-loading arms was obtained.

After the shot or bullets have been manufactured, they need to be inserted in shells or cartridges before use. Shot gun shells consist of weatherproof paper tubes, capped at the breach end with a brass cap into which the primer is placed. Powder, wads and shot are loaded into the open end which is then closed by turning the paper over onto a "top wad." Rifle bullets are inserted in brass cartridges containing powder and primer and the cartridge is firmly crimped to the base of the bullet. This is of course all done automatically.

Today there are scores of types and sizes of bullets and shot manufactured for cartridges for the many kinds of guns, rifles, pistols and machine guns that exist. About five tons of shot are made in the United States for every ton of bullets in peace-time.

Antimonial lead is used for shrapnel balls, but modern armored warfare has reduced greatly the amount of shrapnel used. Antimonial lead is also employed for practice bombs used by military fliers. They are usually die-cast. Ammunition used to train airplane gunners is made from a mixture of lead powder and a plastic. The bullets shatter when they strike the target plane's special armor, instead of penetrating it.

A number of chemical compounds of lead are also important in ammunition. Lead azide is probably most important as a detonator explosive, while lead sulfocyanate, nitrate, peroxide and styphnate may also be employed.

CHAPTER EIGHTEEN

Other Metallic Lead Products and Alloys

TYPE METAL

AMONG the alloys which have contributed heavily to modern civilization are the type metals, usually combinations of lead, tin and antimony.

A large part of the advancement in the art of printing may be attributed to the use of lead alloys as type metal, for lead or lead alloys have been relied upon for this purpose ever since the invention of movable type in the fifteenth century. Linotype or monotype machines, marvels of ingenuity with keyboards similar to those of typewriters, cast type metal kept molten in small pots into the shape of the type desired. An alloy must be used that can be depended upon not to clog the expensive type-setting machines.

Type may be used directly or stereotype plates may be made from it. Stereotypes are usually preferred for long runs, such as newspaper printing. A modern newspaper plant may use 100 tons of stereotype metal cast several times over within twenty-four hours. Stereotype plates, often curved to fit the rolls of rotary presses, are made by impressing the form of type in wet papier-maché. After this has been baked dry, stereotype metal, a lead alloy, is cast in the mold. Electrotypes are formed by making impressions in wax or in sheet lead, called impression lead, instead of papier-maché and electro-depositing copper or nickel followed by copper upon the impressed material so that a thin sheet metal replica is produced. This copper shell is removed from the impression, fluxed, and coated on the back with a sheet of solder foil to cause a backing metal to adhere when it is cast. The backing metal is called electrotype metal.

Lead base type metals or electrotypes are often chromium

plated on the printing face so as to give a longer life; sometimes twice as much printing can be done by chromium plating.

Type metal varies in composition with the use to which it is to be put. Here are some typical formulas.

TYPE METALS

(Percent by weight)

	Lead	Tin	Antimony	Copper
Electrotype	94	3	3	—
Linotype	84.5	4	11.5	—
Monotype	76-72	7-9	17-19	0-0.1
Stereotype	80.5	6	13.5	—
Small type	64	12	24	0-0.5

POWDERED LEAD

A number of commercial uses exist for finely divided metallic lead (powdered lead). It is available in irregular granular, spherical and flake form. The degree of fineness varies widely depending upon the use, and the powder may either be of relatively uniform particle size or a mixture of various sizes.

Lead powders are used as a constituent of bearings, brake and clutch facings, as a plastic filler, in the manufacture of rubber, free-machining steel, paints, lubricants and pipe joint compounds.

High quality lubricants contain an average of 20 percent by weight of metallic lead which is introduced to a calcium base grease during agitation. In use, the grease acts as a vehicle to carry particles of lead powder to the gear or wearing surface where, under pressure, the individual particles coalesce and form a uniform layer or film of lead. An important and valuable property of such a lubricant is the fact that the extremely tenacious lead lining fills score marks, pitted or worn surfaces and thus, in effect, renews them. Once this has taken place, the lead coating itself becomes the bearing surface and since lead has excellent anti-friction properties, the result is smooth, friction-free, quiet operation.

Lubricants containing powdered lead are especially useful in applications where gears and bearings are open or exposed to dirt, grit and abrasives. The comparatively soft film of lead is capable of absorbing such materials without injuring the bearing

surface. Wire rope is generally lubricated with powdered lead grease to prevent excessive squeezing of the hemp fibres and knicking of the wire strands.

During the last war leaded greases played an interesting and important rôle in the protection of allied submarines. Ordinary greases when freed from various underwater bearing surfaces would float to the surface and form a tell-tale oil slick. To overcome this, a special grease loaded with powdered lead was developed so that if any became detached it would sink instead of rising to give away the sub's location. Furthermore the lubricating characteristics and water- and corrosion-resistance were enhanced by the presence of the lead.

Another unusual use of lead powder is in frangible training bullets. The powder is mixed with powdered plastic and pressed into bullets. Such bullets resist the forces of firing but shatter when they strike the target, specially armored airplanes, which are used to train aerial gunners.

Through the use of powder and by applying the principles of powder metallurgy, lead may be mixed with metals or non-metals with which it does not readily combine in any other way. Uniform mixes of materials having widely different specific gravities and melting points and other mechanical characteristics may be obtained in this way.

Certain lead alloys such as solder are also sometimes used in powder form. Lead powder, the particles of which are coated with copper, has also been produced.

LEAD WOOL

This product consists of fine strands of metallic lead loosely wound into a rope that weighs about 1 lb. for every 2.5 ft. It is made by pouring molten lead through a fine sieve, the lead solidifying in fine strands as it falls through the air. The strands are caught in an inclined metal trough some distance below and as they emerge at the bottom of the trough are wound loosely into a rope.

Lead wool is used for the same purposes as calking lead, but since it is used in solid form without heat, it can be employed under water or in gaseous locations where heat would be danger-

ous or impossible. It is also employed for plugging oil wells to prevent water seepage and for other calking purposes. When calked, the individual strands lose their identity and the wool becomes a solid mass of lead. To calk deep joints, the lead wool should be placed in the joint one strand at a time and calked before another strand is placed on top of it. This assures solid calking clear through the joint.

MOLDS AND DIES

Lead, which itself is so easily molded, is used for molding other materials, largely because of this very reason. Examples are found in molds for plastics, for rubber hose, and in impression lead used in the printing trades, as well as in dies for stamping aluminum.

Molds for plastics are sometimes die-cast of lead alloy, the molds being produced in quantity, remelted after use and recast for use again. However, molds for plastic articles of simple design are made in another ingenious way. A pattern or group of patterns of the finished article is made of polished steel and attached to a steel plate. These patterns are lowered into a bath of molten lead, the adjacent lead solidifying as a shell around the cold steel patterns, which are then withdrawn from the lead kettle and plunged into water. The patterns are removed from the lead, leaving a smooth lead mold into which the plastic can be cast. After the plastic has solidified, the lead mold is knocked off and thrown back into the melting pot for re-use.

In the manufacture of rubber hose, a rubber tube is first extruded, around which is braided one or more plies of strong cord, and a rubber cover applied. Lead is then extruded around the hose through a fluted die, just as cable sheath is extruded around cable. From 12,000 to 18,000 ft. of lead covered unvulcanized hose, depending on size, are wound on huge reels and vulcanized at one time. This is accomplished by the application of high pressure steam on the outside and hot water running through the inside of the hose pressing it against the lead mold. Air under pressure is sometimes used instead of water. The hose takes a permanent form corresponding to the impression on the inside of the mold, which is either corrugated or smooth. After vulcanization, the lead is stripped off, remelted and used again.

Antimonial lead is often used for male dies in sheet metal or plastic stamping operations. The female die is usually a zinc alloy. The advantages of lead alloy dies is that they can be easily and cheaply cast as compared with steel dies, and are particularly suitable for short or experimental runs, or where designs may change rapidly. The metal can of course be re-used.

An interesting application of lead is as a mold or pattern for producing extremely thin-walled articles of other metals. For instance a lead rod may be extruded and a thin layer of copper electroplated onto it. When the copper plating has reached the desired thickness the lead is melted out, leaving a thin-walled copper cylinder or tube. Such devices are widely used in radar.

For making large precision castings low melting lead alloys are used for the model instead of wax. Oftentimes the wax models for this method of casting are made in lead alloy molds.

Impression lead is described in an earlier section on Type Metal.

PACKAGING

Lead foil, collapsible tubes and seals all play important rôles in modern packaging.

Lead collapsible tubes usually contain small percentages of antimony and may or may not be lined or coated with tin, the tin amounting to only a few percent. They are used for paste products, such as mucilage, shaving and dental cream, and colors-in-oil.

Lead foil naturally does not permit destructive light rays to pass through it and also protects against moisture. In fact, through the use of low melting lead alloys, lead foil may be soldered by an extremely simple process so that it seals the package hermetically. Being soft, lead foil bends readily without cracking.

Taking advantage of the flexibility and water-proofing characteristics of lead foil, the military Ordnance Department uses lead foil backed up on silk cartridge cloth for packaging various ordnance material. X-ray film is customarily packaged in lead foil to protect the photo-sensitive film from light rays. X-ray film for both dental and industrial radiography use is also backed up with lead foil 0.0025 in. thick. A new type of camera, a unique development which produces completely developed and

printed pictures in 60 seconds, uses lead foil to prevent leakage of the special chemicals contained in capsules within the camera as well as to shield them and the film from stray light.

Many kinds of packages are closed with tamper-proof seals, often made of lead. These are found on money bags, freight cars, express packages and elsewhere. A newer development is the use of lead seals for closing moisture-proof plastic packages. These are sometimes merely lead rings, which are slipped over the gathered end of the pliable plastic envelope and crimped tightly together. The soft lead thus seals the package tightly without damaging the plastic. These rings can be pried open and re-used when necessary.

LEAD FOIL

In addition to its use as a packaging material, foil made from lead and lead alloys has found extensive use in the manufacture of paper-wound condensers and mica condensers for use in various electronic circuits including television and radio sets. Foil in this case is 0.0004 in. thick and is used because of its excellent electrical characteristics and the ease with which it may be soldered. Lead foil is used in metallic packing. It is a familiar sight at Christmas time as a Christmas tree decoration in the form of tinsel, a lead alloy foil containing 1 percent antimony and 1 percent tin. A recent application for lead foil 0.01 in. thick and 1/2 in. wide is as a tape for wrapping coaxial cable used in television transmission.

LOW MELTING ALLOYS

Lead is a constituent of a number of extremely useful low melting alloys in which it is usually combined with bismuth, tin, cadmium or a combination of these metals. Some of these alloys melt at a temperature lower than the boiling point of water, and those containing appreciable amounts of bismuth expand slightly upon solidification.

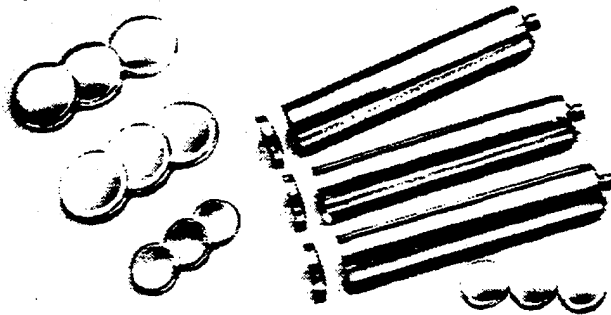
Low melting alloys are employed for many purposes; in safety devices such as sprinkler systems and boiler plugs, for special solders where high temperatures cannot be used, for molds, patterns, punches and dies, for anchoring punches in



The Texas Co.

Bell Telephone Laboratories

Left. Manufacturing leaded lubricants containing lead soaps as well as powdered lead. *Right.* Sealing a wiped cable joint with a special low-melting lead alloy.



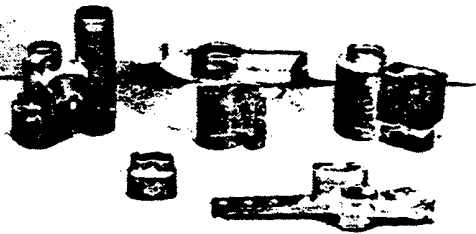
Left. Three 2 1/2 in. lead anchors on a bolt for fastening machinery to concrete. *Right.* Collapsible tubes and the lead blanks from which they are made by impact extrusion.



Left. Metallic packing made from shredded or wrinkled lead foil. *Right.* Lead wool being used for balancing airplane propeller blades.



Lord Baltimore Press



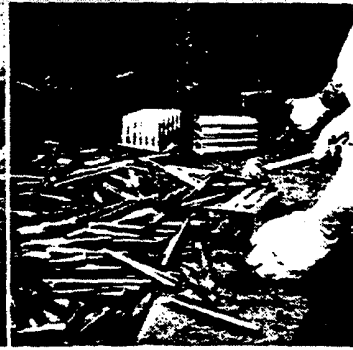
Left. Lead alloy type metals are chiefly linotype and electrotpe. *Right.* Lead base die cast parts for a fire extinguisher.



(A)



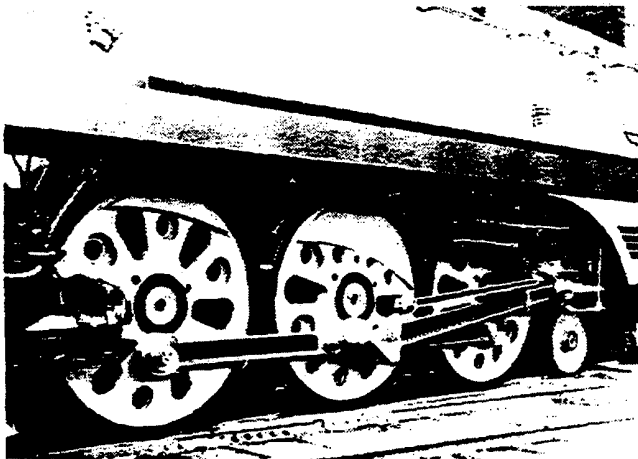
(B)



(C)

Marblette Corp.

(A) Dipping a steel die in molten lead. (B) Removing the lead mold from the die. (C) After filling molds with molten plastic, the finished plastic piece is removed and the mold remelted for reuse.



Lockheed Aircraft Corp.

Left. Each pair of drive wheels of steam locomotives are counterbalanced with as much as 2500 lb. of lead enclosed in the solid sections of the wheels. *Right.* A hard lead punch (upper) and zinc alloy die (lower) as used for forming sheet metal in airplane manufacture.

punch plates, for bending tubing, and for the addition of lead and bismuth to aluminum and other metals and alloys to obtain free-cutting materials.

The use of matrix alloy, for instance, saves many hours of highly skilled machine work in anchoring punches in intricate dies such as lamination dies. Similar alloys are excellent for forming dies and punches for relatively short runs and for experimental models. They are quickly and inexpensively made from almost any kind of pattern. Hardening by freezing in liquid nitrogen temporarily gives some lead alloy dies the properties of steel dies. Tubes are bent without deformation by pouring low melting alloy into the metal tube to be bent and quenching rapidly in cold circulating water to solidify it. After bending, the alloy is melted out by submerging the tube in boiling water.

LOW MELTING ALLOYS

Alloy	Melting temperature		Composition			
	Deg. F.	Deg. C.	Pb	Bi	Sn	Other
Matrix	248	120	-28.5	48	14.5	9Sb
Bending (Wood's metal)	160	71	-25	50	12.5	12.5Cd
Mold and pattern.....	255	124	-44.5	55.5	—	—
Anatomical	140	60	17	53.5	19	10.5Hg
Lipowitz	158	70	-26.7	50	13.3	10Cd
Rose's	212	100	-28	50	22	—
Eutectic	203	95	-32	52.5	15.5	—
Eutectic	198	92	-40	52	—	8Cd

LEAD HEAT TREATING BATHS

Molten lead baths are widely used for the heat treatment of steel at temperatures between 650 and 1,700 deg. F. Lead is the only metal so used commercially and has a number of advantages over salts used for the same purpose. For the thermal properties of lead, see page 185. The following table gives the heat content of lead at various temperatures:

HEAT CONTENTS OF LEAD

Temperature Deg. F.	Heat content B.t.u.
400	11
600	17
621, solid	18
621, liquid	28
800	34
1,000	41
1,200	48
1,400	55
1,600	62
1,700	65

Lead's greatest advantage, perhaps, lies in its high heat conductivity which results in rapid heating, high output, uniform temperature throughout the bath, and high thermal efficiency. Lead does not decompose but does tend to oxidize. This is usually minimized in practice by covering with a layer of charcoal, coke or other suitable material. These carbonaceous coverings protect the lead from oxidation by the reducing effect of CO gas generated as they burn. Molten salt coverings, such as mixtures of sodium chloride, sodium carbonate and potassium carbonate are also employed. These result in exceptionally clean work and low lead loss, but are expensive.

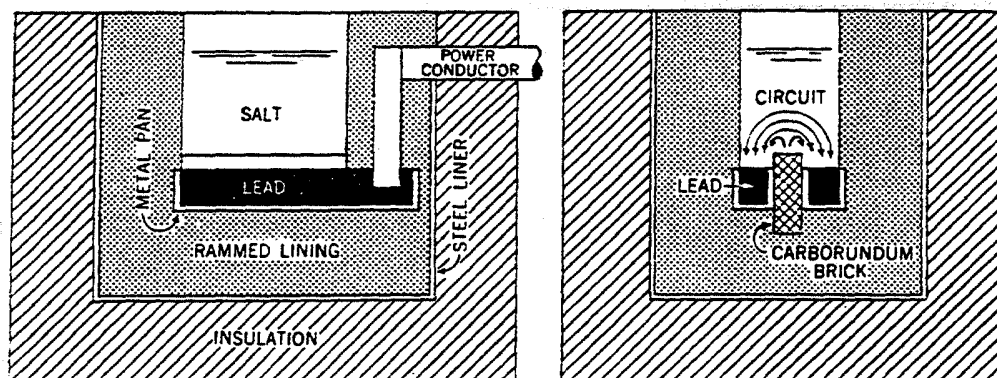
Among the other advantages of lead are that it has no appreciable chemical action on the pot material and it does not absorb water as do most salts. Furthermore lead does not tend to pit or decarburize the steel treated in it.

Lead has a high specific gravity and arrangements must be made for submerging the work in it.

If all conditions are not right, there is some tendency for lead to adhere to the stock. This occurs particularly when the lead bath is operated at low temperatures, below 850 deg. F. At higher temperatures with suitable coverings remarkably clean work results. Adherence is best prevented by avoiding oxidation of the lead as much as possible. Sulphur and tin in the bath also promote adherence. Adherence is sometimes prevented by dipping the stock in a hot saturated brine solution before dipping it in the lead, leaving a light deposit of salt on the stock. This method can be used up to 1,475 deg. F., the melting point of sodium chloride. In difficult cases the stock is dipped in molten

caustic soda immediately after removal from the lead, and is then quenched in water.

Three types of pots are used for lead baths—cast iron, cast, welded, or pressed steel, and special alloys such as high or low nickel-chromium steel or chromium steel. Pot design is important, all corners, particularly below the lead level having large radii and abrupt changes in pot thickness being avoided. Electrical heating apparently results in longer pot life, but good results can be obtained with gas or oil firing if the furnace is properly designed with respect to location of burners and vents, adequate combustion space, vent area, length of flame travel, location of splash brick and height of combustion chamber.



Liquid lead pool electrode furnace.

Lead or lead alloy compositions are being used as a liquid electrode in electric salt furnaces for heat treating purposes. The liquid electrode principle is simple and, in practice, has demonstrated several advantages over ordinary electric salt furnaces. A pool of molten lead alloy lying in the bottom of the furnace chamber contacts a source of electrical power on one end and a molten salt bath on the other. The flow of current between two such electrodes in the same salt bath creates the heat necessary to keep both the salt and the lead alloy molten. The greatest advantage of the lead pool furnace is that "over-the-side" electrodes which tend to corrode badly at the salt line can be dispensed with. Other advantages are easy sludge removal and lower power consumption because the usable heat treating area of the furnace is the only area heated.

To avoid steam eruptions which may be dangerous to operators

through splashing of molten lead, all material should be thoroughly dry when dipped into the molten bath.

Lead baths are especially useful for local hardening and tempering, and in fact are probably the only kind suitable for such work. Lead baths may be operated by either batch or continuous methods, the batch method generally being used for tempering and both methods for hardening.

Molten lead is also used in the bottom of galvanizing pots or in the outer compartment of double galvanizing pots to distribute heat more uniformly and prolong the life of the pots.

MISCELLANEOUS ALLOYS

A variety of lead alloys are mentioned in other sections of this book, either under the process of manufacture employed with them or the uses to which they are put. Thus antimonial lead is used in storage battery grids, cable sheathing, for pipe and sheet and for castings. Both lead foil and collapsible tubes usually contain small percentages of antimony and both may be coated with tin by rolling lead and tin together during manufacture. Shrapnel contains antimony up to 12 percent and bullet cores may have up to 2.5 percent antimony in the composition. Shot usually contains from 0.5 to 1 percent arsenic and 2 to 6 percent antimony. Foil for condensers may have as little as 4.5 percent tin or as much as 50 percent in some cases, whereas foil for making tinsel contains from 1 to 4 percent tin. A few typical alloys are listed here.

MISCELLANEOUS LEAD ALLOYS

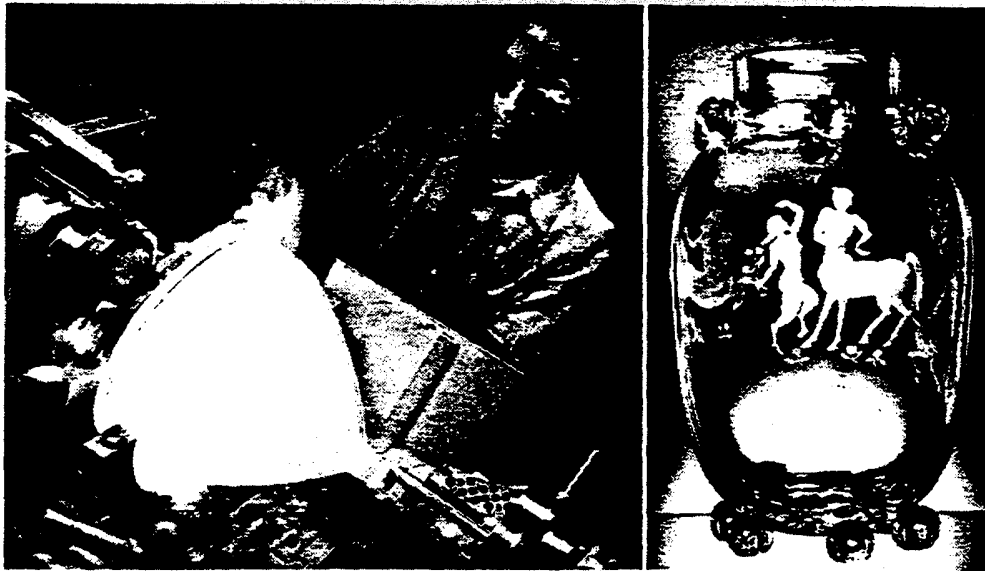
	Percent by weight				
	Lead	Antimony	Tin	Copper	Other
Battery grid metal....	93-88	7-12	0-0.25	—	—
Shrapnel	88	12	—	—	—
Bullet cores	100-97.5	0-2.5	—	—	—
Shot	100-93	2-6	—	—	0.5-1As
Cable sheaths	100-99	0-1	—	—	—
Collapsible tubes	100-97	0-3	—	—	—
Condenser foil	92-48	2-3.5	4.5-50	—	—
Tinsel	97.5-05	<1.5	1-4	—	—
Machine brass	1-4	—	—	88-62	10-35Zn
Metallic packing	100-96.5	0-2	0-1.5	—	—
Packaging foil	98-88	1-2	1-10	—	—

LEAD WEIGHTS

Because lead has the highest specific gravity (11.34) of the common metals, it is frequently used for counterbalances, weights and ballast. An additional advantage for this purpose is the ease with which it may be fabricated into almost any desired shape. Thus lead weights not only concentrate the greatest weight in the smallest practical volume but may also be made in the most convenient shape without difficulty. The low melting point makes lead easy and economical to cast, and where the design is such as to make other methods of fabrication preferable, weights may be extruded or stamped from sheet.

The uses of lead as weights or balances are too numerous to mention. A few are balances for machinery, locomotive and train wheels, automobile wheels, anti-aircraft guns, divers' equipment, industrial trucks, airplane control surfaces and propellers, naval ballast, fishing sinkers and seine weights.

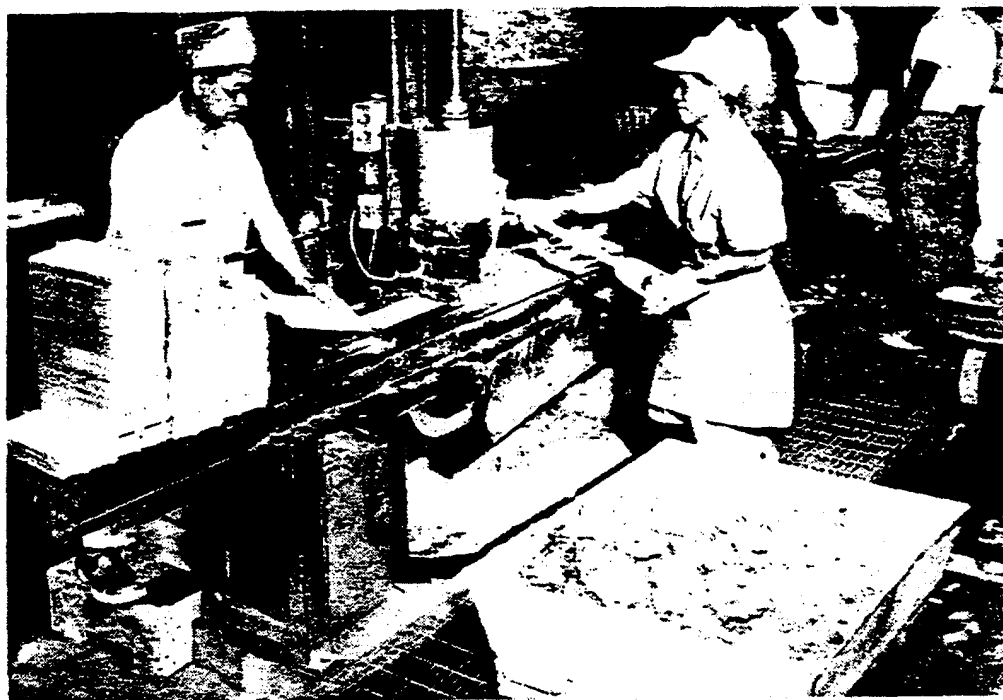
Lead weighs approximately 707 lb. per cu. ft. or 0.41 lb. per cu. in.



The television tube shown here being welded together contains up to 30 percent lead by weight. Lead, introduced to the glass batch as an oxide, also gives brilliance to the fine "crystal" glassware on the right.

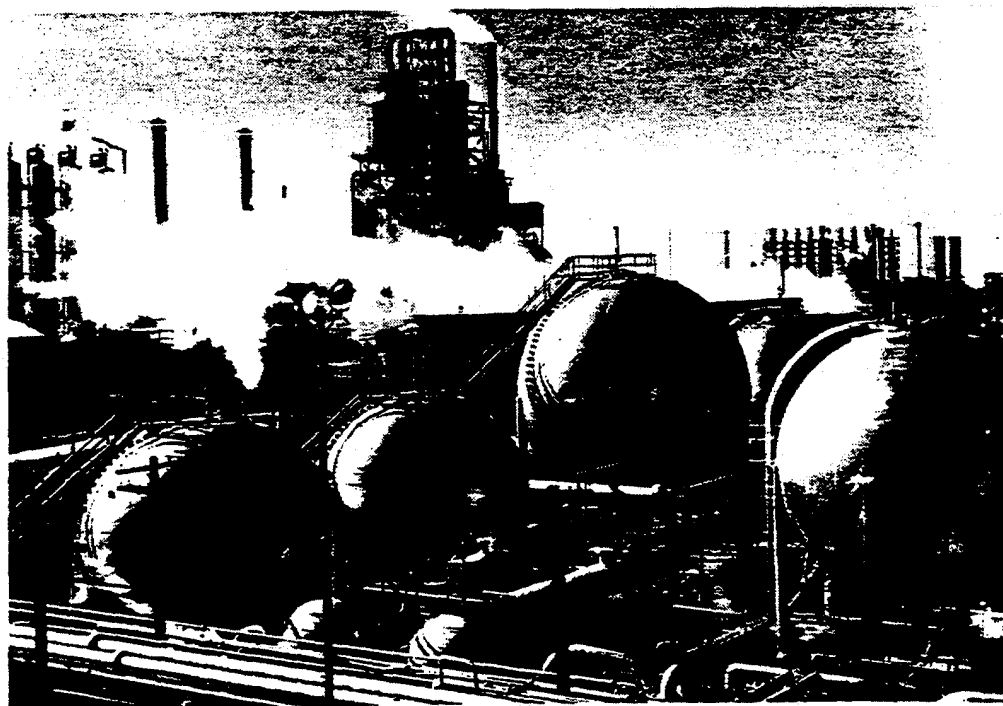


Left. Lead-bearing glazes are widely used on artware, tile and other pottery products to give brilliance, luster and smoothness. *Right.* Spray applying a water-suspended leaded glaze on a vitreous china plumbing fixture prior to firing.



The Electric Storage Battery Co.

Litharge, red lead and black oxide form the "paste" shown being applied to storage battery grids.



Standard Oil Co. (N. J.)

Litharge is important in the "sweetening" of certain gasolines. It is mixed with caustic soda to form sodium plumbite "doctor" solution. During treatment the litharge is converted to lead sulphide, then oxidized and re-used.

CHAPTER NINETEEN

White Lead

BASIC CARBONATE WHITE LEAD, or simply white lead, is the oldest and most widely used of the lead pigments; it is the only white pigment which will produce a durable exterior paint if used alone without other pigments.

Alone, or in combination with other pigments, the use of white lead in paint is so widespread that this subject is discussed in greater detail in another section (see page 151). White lead is also used in glazing pottery and enameled ware, in putty, in the manufacture of orange mineral and in other industries.

The composition of basic carbonate white lead is often indicated by the formula $2\text{PbCO}_3 \cdot \text{Pb}(\text{OH})_2$, which corresponds to a combined lead carbonate content of 69 percent. The range in composition of commercial white leads is from 62 to 75 percent. At 62 percent lead carbonate content, the formula of basic carbonate white lead is more closely represented by $4\text{PbCO}_3 \cdot 2\text{Pb}(\text{OH})_2 \cdot \text{PbO}$. If the total lead carbonate content exceeds 75 percent, the quality of the pigment suffers since the presence of uncombined lead carbonate is indicated which, by itself, is a poor pigment.

The recently developed white leads of low lead carbonate content (62 to 66 percent) and greater basicity are characterized by finer particle size, higher hiding power and greater paint-thickening power.

Possibly the most outstanding characteristic of white lead is its remarkable chemical affinity for paint vehicles; it becomes an integral part of the paint film and actually reinforces the paint, resulting in a tough, flexible film, unusually resistant to embrittlement.

White lead is manufactured in this country by several different methods: the Carter, Euston, Sperry, Thompson-Stewart and

other processes. The Old Dutch process, most widely used some years ago is no longer employed.

In the Old Dutch process, thin, perforated discs or "buckles" of metallic lead about six inches in diameter were placed in earthenware pots with a small amount of dilute acetic acid, and the pots placed on moist spent tan bark. The fermentation of the tan bark produced heat (up to 180° F.) and also gave off carbon dioxide. The heat caused the acetic acid to evaporate and its fumes attacked the lead buckles, which had since been oxidized, and formed a coating of basic lead acetate. The carbon dioxide from the tan bark decomposed the basic lead acetate, thus producing basic carbonate white lead.

The Carter process is basically the same as the Old Dutch process except that the metallic lead is blown with steam or air to a fine powder and treated with acetic acid, air, water and carbon dioxide gas in large, revolving wooden cylinders. Under these conditions, the corrosion of metallic lead into white lead proceeds at a much more rapid rate than in the Old Dutch process which required approximately 3 to 4 months for conversion. In contrast only 12 to 14 days are needed in the Carter process, principally because the particles of blown, Carter-process lead are very small.

In the Euston process, metallic lead is treated with lead acetate solution in the presence of air to form basic lead acetate from which white lead is precipitated by suitably controlled contact with carbon dioxide gas.

In the Sperry process, the lead acetate solution is obtained by the electrolytic decomposition of a metallic lead anode in an electrolytic cell, white lead being precipitated almost instantaneously from the lead acetate by sodium carbonate present in the solution.

The Thompson-Stewart process for the manufacture of white lead is a fairly recent development. The chemical reactions involved are essentially the same as in the Carter process. However, the reaction rate is controlled until all the metallic lead has been oxidized to lead oxide (PbO) and this reacted with acetic acid, water and CO_2 to produce basic lead carbonate.

Basic lead sulphate, also called basic sulphate white lead or sublimed white lead, finds its main use in paint. As a paint pigment it has the same properties as basic carbonate white lead. A

fine, opaque, amorphous white powder, it is usually represented by the formula $\text{PbO} \cdot \text{PbSO}_4$. It is used extensively in the mixed paint industry.

Prior to 1930, basic lead sulphate contained 4 to 6 percent zinc oxide. Commercial basic lead sulphate now being produced by either the fume or chemical processes does not contain zinc oxide.

The two fume processes now in use differ chiefly in the raw materials used. In one, the pigment is manufactured in a Scotch Hearth type of furnace by feeding galena concentrates with the proper fluxes directly into the furnace. The lead and sulphur are sublimed and, in the gaseous state, oxidized to form basic lead sulphate. The gases and fume are cooled, depositing the pigment as a fine powder which is collected in a cloth filter bag.

In the other fume process, it is produced by the atomization of lead in the presence of an excess amount of air and sulphur dioxide.

In the chemical process, sulphuric acid is added to a litharge slurry, precipitating basic lead sulphate. The product, because of the controlled conditions possible with this process, more closely approximates the theoretical composition of basic lead sulphate than that produced by other processes.

White Lead-Varnish Cement. This unusual cement is made by mixing paste white lead with a good grade of varnish to a heavy brushing or troweling consistency. A typical composition consists of $1\frac{1}{4}$ to $1\frac{1}{2}$ gallons of varnish and 100 lb. of heavy paste white lead. Uses for this product include the mounting of canvas murals on the walls of public buildings, cementing canvas decking in place on boats or porches, applying metal letters to glass, and setting marble. In the latter, white lead-varnish cement is particularly advantageous because the joints can be made practically invisible by applying the cement in very thin layers (less than $\frac{1}{16}$ in. thick) without impairing its adhesive characteristics.

CHAPTER TWENTY

Lead Oxides

LITHARGE

LITHARGE—lead monoxide (PbO)—is one of the most widely used and commercially important of all metal chemical compounds. It has a buff color, is made in either flake or powdered form and in a wide range of particle size. It contains roughly 93 percent lead and 7 percent oxygen by weight.

Litharge is made by melting pig lead in reverberatory or cupel furnaces in the presence of air. The product of the reverberatory furnace is usually powdered litharge; of the cupel furnace, flake litharge. From 24 to 36 hours are generally required for the process. Some litharge is also made by burning lead to a fume in the presence of oxygen. Obviously it is possible to obtain a litharge suitable for practically any application providing the requirements are known. As a matter of fact, the various grades used commercially are generally known by the uses to which they are put.

Storage batteries account for the largest consumption of litharge. Battery litharge is very pure and is used, with red lead, to form the active material on the plates (see page 31).

Glassmakers' litharge is either in powdered or flake form. Particle size is not important since it is melted with other materials such as silica and potash to form complex silicates which make an exceptionally tough glass. Glass high in lead exhibits much greater resonance and by increasing the refractive index of the glass, it also adds to its brilliance. It imparts to glass lead's power of stopping X-rays, and glass with a high lead content is therefore used for X-ray room windows. Litharge for this purpose should be of high purity to avoid discoloration of the glass which might result from impurities such as iron.

What has been said of glassmakers' litharge also applies to pottery makers' and enamelers' litharge, since it is used as a constituent of the glaze for pottery or enameled ware.

Colormakers' litharge is in powdered form. It is dissolved in acetic or nitric acid and used to produce chrome yellow and chrome green color pigments.

Rubbermakers' litharge is finely powdered and serves as an accelerator, toughener and controlling ingredient in the manufacture of rubber. Recent work has shown it to be particularly useful in the compounding of synthetic rubber and synthetic-natural rubber mixtures. For instance, in Buna S stocks, it has been shown that the product has excellent aging and physical characteristics with a rapid rate of cure and an extremely wide curing range.

Varnishmakers' litharge, usually in powdered form, is used to give proper drying qualities to varnish by the formation of lead soaps. As a catalyst, litharge promotes more rapid polymerization of fatty acids in the oils used in varnish making.

Oil refiners' litharge is finely powdered. It is dissolved in caustic soda and employed to break up some of the complex organic sulphur compounds in the petroleum products. Lead sulphide forms and settles out, removing the sulphur.

Although the foregoing are the principal uses for litharge, this interesting compound has many other applications. For example, added to red lead paint (about 10 percent litharge by weight in the top coat), it makes a harder film for painted surfaces subject to continued soaking under water, as in water tank painting. Litharge is added as a stabilizer to improve high temperature and high pressure characteristics of petroleum lubricants.

Litharge—Glycerin Cement. Litharge when combined with glycerin also makes a useful quick-setting, acid-resisting cement for joining metals, ceramics, etc. The accompanying tables give data which may serve as a guide in using litharge-glycerin cements. Colormakers' litharge is recommended for this purpose and should be fresh, as aged litharge retards the setting time. Since water speeds up the setting of these cements, any water taken up by the glycerin, which it has a tendency to do, speeds up the setting. As can be seen from the table, for fastest setting some water should be used in the mix. However, for maximum strength, the mix should be free of water. These cements will safely stand temperatures up to 350 deg. F. in use. Glycerin or

the desired mixture of glycerin and water is usually added to the dry litharge to make only enough cement at any one time to be used up within the short pouring and setting time.

LITHARGE-GLYCERIN CEMENT COMPOSITIONS AND CHARACTERISTICS

Formula	Pouring Time	Setting Time	Paste Condition	Tensile Strength After 4 Months, Lb. per Sq. In.
100 cc. glycerin 1 lb. litharge	1 hr. 19 min.	3 hr. 48 min	Fairly viscous	626
90 cc. glycerin 1 lb. litharge	40 min.	1 hr. 50 min.	Fairly viscous	668
80 cc. glycerin 1 lb. litharge	19 min.	43 min.	Very viscous	662
86 cc. glycerin 1 lb. litharge 14 cc. water	8 min.	18 min.	Fairly liquid	394
80 cc. glycerin 1 lb. litharge 20 cc. water	5½ min.	15½ min.	Fairly liquid	411

RED LEAD

Red lead (Pb_3O_4) is another lead oxide of great commercial importance. It is bright orange-red in color and contains about 91 percent lead and 9 percent oxygen by weight. It is manufactured by heating powdered litharge at a carefully controlled temperature, lower than for the manufacture of litharge. The litharge takes up more oxygen and forms red lead. A part of the litharge usually remains unconverted in the form of minute cores in the red lead. "True red lead" is the actual Pb_3O_4 in the commercial pigment. "Pure red lead" may contain some unconverted litharge but is otherwise free from impurities.

Red lead is made in a wide range of true red lead contents up to 98 percent true red lead. For some purposes high true red lead content is desirable. An example is ready mixed or paste red lead for paint, as any appreciable amount of litharge present may cause the paint to harden prematurely in the can because of the drying action of litharge. On the other hand, a low true red lead content is often specified for battery red lead since it is usually mixed with litharge anyway to form the paste for the plates.

The two biggest uses for red lead are in the production of storage batteries and metal protective paints. In storage batteries, red lead, like litharge, is an active ingredient on the plates (see page 30). The oxide is preferably fine but, as stated does not need a high true red lead content because it is usually mixed with litharge.

Red lead has long been recognized as the leading pigment for metal protective paints, particularly primers (see page 160). The true red lead content used in paints is generally in the neighborhood of 95 to 97 percent and the pigment is extremely fine.

Red lead has a number of other uses quite similar to the applications of litharge. Principal of these is its use as an ingredient in the mixes for glass, glazes and vitreous enamels. Red lead for this purpose is of high purity but does not have to be particularly fine nor have a high true red lead content. The latter depends largely on the other ingredients of the mix, which determine how much oxygen has to be added by the red lead. Red lead is added to certain greases for use as a drill stem lubricant in oil well drilling operations. It is also used as an anti-galling agent on threaded joints subject to high temperature service such as on locomotives and boiler installations.

OTHER OXIDES

At least two other lead oxides are of commercial importance. They are the peroxide or dioxide, PbO_2 , and orange mineral, Pb_3O_4 . The first is a strong oxidizing agent employed in the manufacture of dyes, matches, rubber substitutes and other products. Incidentally it becomes the principal ingredient on the positive storage battery plate after forming (see page 30).

Orange mineral has the same chemical composition as red lead, and is manufactured from basic carbonate white lead, or from litharge, by a process similar to that used for red lead. It differs from red lead principally in its color and tone. It has a brilliant vermilion color and is used largely by color makers and manufacturers of printing inks.

Black oxide, a mixture of litharge and finely divided metallic lead, finds its main use in the storage battery industry.

CHAPTER TWENTY-ONE

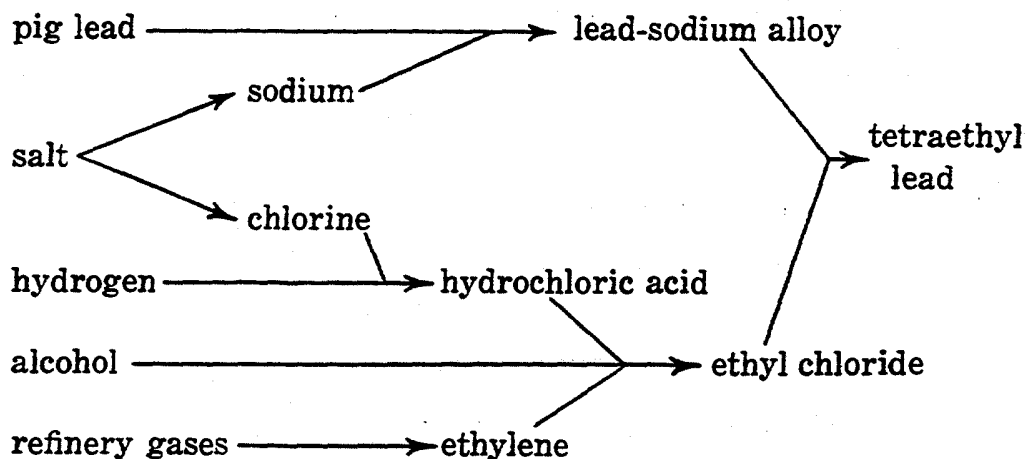
Tetraethyl Lead

TETRAETHYL LEAD— $\text{Pb}(\text{C}_2\text{H}_5)_4$ —is a heavy, colorless liquid used almost exclusively as an important ingredient in gasoline. It is the active component in the “anti-knock compound” which oil companies use to improve the anti-knock quality of aviation and automotive gasoline. The addition of only a few cubic centimeters of tetraethyl lead, often referred to as TEL, effects a substantial improvement in the anti-knock value or octane rating of a gallon of gasoline. The higher the octane rating of gasoline, the more power it can produce without knocking. High test or premium gasoline was first placed on the market in 1923, but it is only in the last fifteen years that the volume of lead used in its manufacture has reached important proportions.

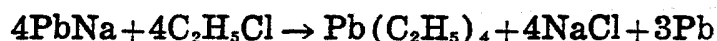
Premium gasoline for automobiles contains from 2 to 3 cc. of tetraethyl lead. Even ordinary gasoline contains lead but in lesser amount, from 0.5 to 1.5 cc. per gallon. Present day automobile fuel is composed of a blend of cracked, thermal or catalytic, straight run fuels and tetraethyl lead.

Through the past twenty years, as the anti-knock quality of automotive and aviation gasolines has been improved, the efficiency of engines has made corresponding progress. Today a gallon of gasoline produces approximately 50 percent more useful power in a suitably designed engine than in the average automobile of 1925. It is estimated that an automobile engine designed with a compression ratio of 12 to 1 will give approximately 50 percent more miles per gallon at 40 miles an hour than a 1940 model with a compression ratio of 5.25 to 1. In aviation, the increase in power produced by improvements in fuels and engines has been spectacularly large. This extra power has been used to provide extra speed and improved economy.

Tetraethyl lead is made from pig lead, salt, hydrogen, alcohol and refinery gases in the manner shown in the flow diagram.



The reaction may be represented by the chemical equation:



The pig lead is melted and mixed with sodium under a blanket of nitrogen to form a lead-sodium alloy. It is then solidified and ground. The alloy is reacted with ethyl chloride to form tetraethyl lead. This is steam distilled and otherwise purified and then blended with ethylene dichloride, ethylene dibromide and dyes to form the anti-knock compound.

CHAPTER TWENTY-TWO

Other Industrial Lead Compounds

ALTHOUGH the chemical compounds of lead which account for the largest tonnages of metal have been described in considerable detail, a number of other compounds are also of commercial significance.

Lead chromates—yellow, orange and red—are valued both for their color and protective properties. The normal chromate, PbCrO_4 , is made by precipitation from solutions of lead acetate or lead nitrate to which potassium or sodium bichromate has been added. The resulting precipitate has a brilliant yellow color and is known as medium chrome yellow. To obtain a paler yellow known as lemon chrome yellow, a little sulphuric acid or sodium sulphate is added to the solutions which causes some white lead sulphate to precipitate intimately with the lead chromate.

Orange chrome yellow is the partly basic lead chromate and is obtained by dissolving an alkali, such as caustic soda or soda ash, in the bichromate solution before adding the bichromate to the lead solution.

American vermilion, also known as Chinese scarlet and chrome red, is basic lead chromate usually made from white lead instead of from a lead acetate solution.

Between chrome red, which is a deep red of an orange tone, and lemon chrome yellow, lie many other gradations of color which are really mixtures of the different lead chromates. They are obtained by varying the conditions of manufacture described under the different lead chromate pigments.

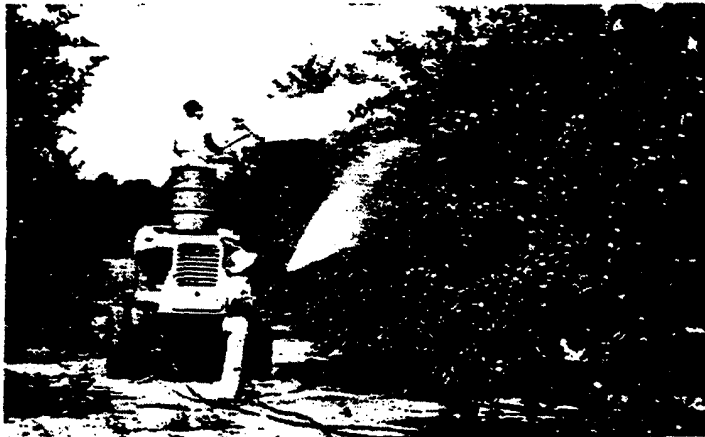
Chrome green, the most important green pigment, is a mixture of yellow lead chromate and Prussian or Chinese blue. It is made by precipitating the chromate in the presence of finely divided Prussian blue (ferric-ferrocyanide).

Blue lead, also referred to as basic lead sulphate-blue, is slate-grey in color and consists of basic lead sulphate, small amounts of lead sulphite, lead sulphide, and zinc oxide plus a trace of carbon. It owes its color to the carbon present.

It is manufactured in a specially constructed Scotch Hearth furnace from which it rises as a fume, is collected in bag filters, and retained as an extremely fine blue-grey pigment. The principal use of blue lead is in the manufacture of paint for the protection of iron and steel surfaces. Metal protective paints compounded with blue lead are described beginning on page 171. Blue lead is also used in the compounding of special lubricants, electrical and mechanical rubber stocks where, in the latter case, it acts as an accelerator.

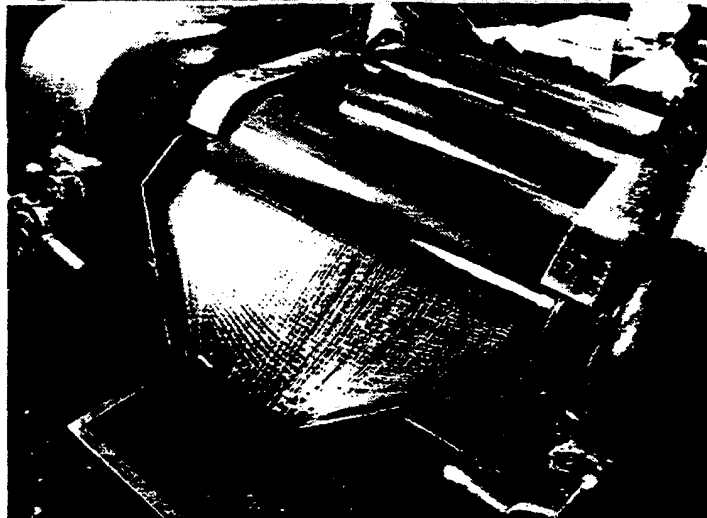
Lead azide— $\text{Pb}(\text{N}_3)_2$ —has become a standard detonator explosive, being used in place of the more dangerously sensitive detonators previously employed. It is a fine, cream-colored compound. Its sensitiveness and efficiency are less affected by absorption of moisture than other commonly used detonators, its hygroscopicity at 30 deg. C. and 90 percent relative humidity being only 0.03 percent. It is practically insoluble in water. It is not easily decomposed by heat, having been stored, in tests, for 15 months at 80 deg. C. with no noticeable impairment in sensitivity or brisance. It is more readily detonated by flame than by shock or friction, so when used in a detonator to be exploded by a firing pin, it has a covering or priming charge of a suitable sensitive explosive. It may be stored under water or alcohol and when spilled, may be destroyed by washing with a solution of ammonium acetate.

Lead arsenate is an essential insecticide for the protection of crops and large tonnages are used annually for that purpose. Several different lead arsenates are used as shown by the table on page 204. Litharge is the raw material employed for the manufacture of commercial lead arsenates. It may be dissolved in arsenic acid in the presence of acetic or nitric acid as a catalyst, or may be converted to lead acetate or nitrate and allowed to react with sodium arsenate. The latter method results in a mixture of mono- and dibasic lead arsenate and should not be used if the product is to be mixed with lime-sulphur solutions.

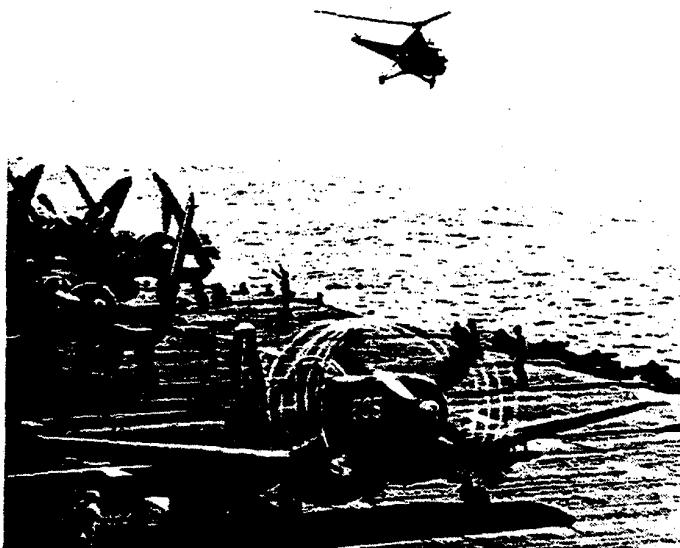


Lead arsenate sprays are used for controlling insect pests.

A roller mill grinding lead chromate pigments for paints.



A variety of lead compounds are used for plasticizing vinyl plastics (left) and stabilizing rubber as well as plastics (right).

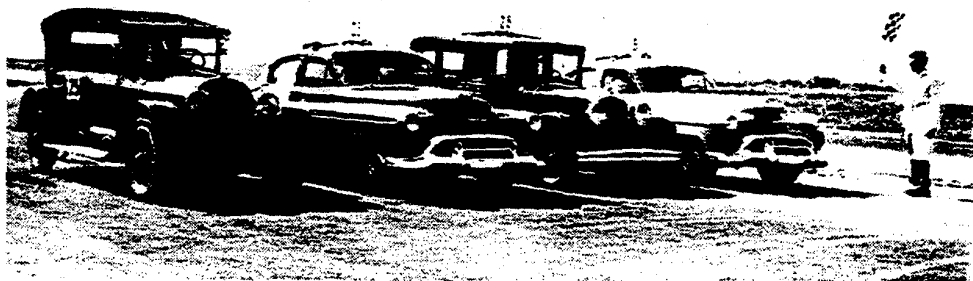


Military equipment powered by reciprocating gasoline engines such as these airplanes must use high lead content gasoline to operate at maximum efficiency.

U. S. Navy



Fueling a modern commercial airliner with high octane leaded gasoline.



Ethyl Corp.

Two "old-timers" and two later model cars line up for a fuel economy run. The event proved the remarkable gains in fuel economy made during a 25-year interval, due in large measure to the continual rise in tetra-ethyl lead content of gasolines.

The importance of lead arsenate and its contribution to modern agriculture cannot be underestimated, for it has brought about control of some of the most dangerous and damaging plant pests.

Lead silicates are used extensively as frits in the ceramic industry. There are many types of lead silicate frits including both the monosilicate and bisilicate. They meet the demand for lead-bearing material that can be used in glazes, enamels and glass without fritting and supply part of the silica, as well as the lead to the batch.

Basic silicate white lead is a compound of lead commonly used in the ceramics industry. As manufactured, it has a composition closely approximating $3\text{PbO} \cdot 2\text{SiO}_2 \cdot \text{H}_2\text{O}$. The method of manufacture involves the initial preparation of anhydrous lead silicate by fusing pure silica sand with litharge. The granulated anhydrous silicate may be hydrated by ball milling with water under controlled conditions. Basic silicate white lead has many desirable pigment properties similar to both basic carbonate and basic sulphate white lead. It is chemically reactive with paint vehicles and yields elastic films which are stable. As a pigment, basic silicate white lead is used to its greatest advantage in metal protective paints for submerged exposure. In both fresh and salt water it greatly increases the corrosion inhibitive properties of mixed pigment paints. It is also used as a stabilizer in the compounding of vinyl plastics.

Basic lead silicate—a new paint pigment—is a complex salt of lead oxide and silica. It is made from litharge and silica catalyzed with a small amount of sulphuric acid. The resulting pigment has a core of unconverted silica with a surface coating of the complex basic lead silicate salt. Important reasons for using lead pigments in house paints are their chemical reactivity with oil and their ability to stabilize the breakdown acids of the vehicle. Development of this pigment was based on the theory that, by concentrating the active material on the surface of each pigment particle, this reactivity would be retained with a pigment of lower weight per unit of volume.

Lead stabilizers. A whole series of lead compounds, most of them of too complex structure to describe in detail here, are used as stabilizers in vinyl plastics. These plastics, when exposed to

light and heat, are subject to deterioration unless they contain a stabilizer to react with decomposition products and arrest the reaction. Lead stabilizers are among the most economical and efficient to use and in some cases the only effective stabilizers. The lead stabilizers include certain basic sulphates and phosphites, complex silicates, and organic compounds like the salicylates and basic stearate, phthalate, maleate and so forth.

Miscellaneous lead chemicals. Many other chemical compounds of lead are of considerable commercial importance, while others have characteristics that make them interesting possibilities. A list of a large number of lead compounds and some of their properties begins on page 203 and includes those which have already been described elsewhere in more detail.

CHAPTER TWENTY-THREE

White Lead Paints

THE manufacture of paint is an industry of huge proportions and consumes an increasingly great variety of natural and manufactured chemical compounds. Despite the hundreds of raw materials used in paints, lead in the form of pigment contributes more valuable properties to paint than any other single ingredient as will be explained later in this chapter. For this reason the prospective user of paints, exterior paints in particular, will do well to make certain that the paint he purchases contains either a substantial quantity of white lead or is of the pure white lead type.

White lead, the oldest white paint pigment known to man, was employed by the ancient Egyptians, Greeks and Romans. Several descriptions exist, dating from before the Christian era, of methods of making it from metallic lead and vinegar or wine. The Old Dutch Process, by which the pigment was usually made until recently, is essentially the same in principle as the method used by the ancients. Most of the newer methods replacing the Old Dutch Process, which required 90 to 120 days for conversion, differ primarily in that they reduce the conversion period to 12 days or less. Manufacturing details for the various types of white lead pigments are described in detail beginning on page 138.

The early history of paint itself antedates any reliable written records. It is known to have been used by the Egyptians as far back as 2500 B.C.; the ancient Hindus and the Hebrews before the time of Moses also were well acquainted with the art of painting for decorative purposes. The Greeks were probably the first to recognize the importance of protecting their structures with paint. Remains of their edifices are often found showing evidence of its use.

Paint is now called upon to serve many purposes. Primarily, of

course, it is to protect and to beautify, but time has brought increasing responsibilities and greatly enhanced its value and serviceability. Well painted buildings, both inside and out, go hand in hand with improved sanitation.

In exterior house paints the liquid or vehicle part of the paint is composed principally of linseed oil and other vegetable oils having the same type of fatty acid glyceride chemical structure. White lead has a natural affinity for these oils possessed by no other white pigment. Actual chemical compounds, commonly referred to as lead soaps, are formed between the white lead and vegetable oils, greatly reinforcing the paint film.

Lead soaps are made up of flexible crystals with a long spiny structure. Under a microscope, they look like cockleburs, with the spines of adjacent crystals intermeshed. This intertwining or meshing forms a felted mat which reinforces the film and increases its coherence and elastic strength to an optimum degree.

White lead stabilizes paint, retarding its decomposition. Without a reactive pigment, a house paint film would have a relatively short life in outdoor service. As the paint slowly weathers, the vehicle breaks down to form acidic compounds such as formic, hydroxyacetic, propionic and related destructive organic acids. These liquefy or soften the film. Active lead pigments in a paint neutralize these products of decomposition as the film ages and form stable insoluble lead salts. In this way, the film is stabilized and its durability greatly improved.

Lead plasticizes paint, increasing its flexibility. In reality a paint film is a plastic, although it is not generally referred to as such. And, like many plastics, it would become hard, brittle and inflexible if it did not contain a plasticizer. Such a paint would crack easily under normal stresses, not only spoiling its appearance but also greatly reducing its protective value. White lead pigments permit the proper formulation of paints that provide flexible films not only after application, but throughout the life of the paint. Lead soaps act as plasticizers. In multiple pigment paints their effect is supplemented by other soaps usually present in the film.

The inherent reactivity of white lead and resultant lead soap formation also increases the elastic strength of a paint film. The paint film is reinforced mechanically as a result of chemical re-

actions. As the films containing the reactive lead pigments age they increase in toughness to an optimum degree. The lead soaps improve the adhesion, cohesion, flexibility, distensibility and the other factors that contribute to long life and improved protective ability of the paint film.

White lead pigmented paints possess high water repellency. Water attempts to dissolve and emulsify portions of a paint film causing it to swell and soften. This tends to break its cohesive bond and is probably the greatest single cause of loss of adhesion. Paints containing lead pigments are highly resistant to water; they absorb only a fraction as much water as non-lead paints.

A paint should preserve the surface over which it is applied, remain attractive for the longest possible period and eventually present a satisfactory surface for repainting. Ready-mixed house paints containing substantial percentages of white lead or pure white lead paints have repeatedly demonstrated their ability, in actual use, to outlast paints made from other pigments or combinations of pigments. Paints based on white lead slowly wear away, leaving an even, slightly chalky surface which enhances appearance throughout the life of the film and presents an excellent surface for eventual repainting. It does not crack or scale, whereas paints that do must be scraped or burned off before repainting. This adds another item to the already high cost per year of maintenance with inferior, rapidly deteriorating non-lead paints.

Aside from technical reasons, the preponderance of evidence in favor of white lead-containing ready-mixed paints and pure white lead paints is being increased daily. Performance alone dictates the use of white lead. Almost any paint will look well a year after application—or even two years. The real test of an exterior paint only begins then. Paints containing substantial percentages of lead, properly applied, will usually remain in excellent condition at least four or five years, often much longer.

Briefly, white lead adds more desirable qualities to paint than any other white pigment and has practically no undesirable qualities to nullify its advantages. It is one of the few chemically reactive pigments, and authorities are agreed that high percentages of reactive pigments are essential to durable paint. Its reaction, moreover, takes the most beneficial form, providing maximum re-

inforcement of the film. The hiding power of white lead is good and its brushability excellent. White lead, too, improves the adhesion of paints which in large measure accounts for its wide acceptance in primers. Among the other characteristics which white lead contributes to paint in good measure are mixing and grinding ease, package stability, leveling, drying, whiteness, film strength, flexibility, tint retention, gloss and, of course, weather resistance.

One other characteristic, foolproofness, deserves special mention. To the user this characteristic of white lead means that inaccuracies in thinning or inexperienced application will have little or no effect unless greatly exaggerated. To the specifier or formulator, it means greater latitude in the remainder of the paint ingredients without getting into trouble. This is an invaluable asset of any paint.

White lead for paint is marketed in several different forms. In dry form, it is used by manufacturers to make ready-mixed paint. For public use, then, it may be (1) an ingredient of ready-mixed multiple pigment paints, (2) a linseed oil paste (white lead in oil), or (3) a ready-mixed paint in which the pigment portion is entirely white lead.

White lead paints for generations have preserved many colonial landmarks through the rigorous climate of the Atlantic seaboard. Several current government house paint specifications require the inclusion of substantial quantities of white lead for both priming and finishing coats.

The profitable application of white lead in paints is not confined to exterior use. Pure white lead paints can be utilized to advantage for interior decoration, particularly in public and traditional buildings where elaborate decoration is used and it is very expensive and inconvenient to repaint often. In spite of frequent and repeated cleaning white lead paints maintain their original brightness and luster. For this reason many hotels use white lead paints exclusively in their rooms. Pure white lead paints may be easily tinted to practically any color desired. The professional or amateur decorator is not limited to a choice of a few standardized colors.

The following are suggested proportions for formulating white lead-in-oil paints for exterior use on wood.

NEW WOOD

Materials	First Coat	Second Coat	Third Coat
White-lead soft paste *.....	100 lb.	100 lb.	100 lb.
Raw linseed oil.....	4 gal.	1½ gal.	3½ gal.
Turpentine	2 gal.	1½ gal.	....
Liquid drier	1 pint	1 pint	1 pint
Gallons of paint.....	9½	6½	6½

PREVIOUSLY PAINTED WOOD

Materials	First Coat	Finish Coat
White-lead soft paste *.....	100 lb.	100 lb.
Raw linseed oil.....	2 gal.	3½ gal.
Turpentine	2 gal.	....
Liquid drier	1 pint	1 pint
Gallons of paint.....	7½	6½

* If white-lead heavy paste is used, add one quart of turpentine to all formulas.

The following are typical formulations for high quality ready-mixed multiple pigment exterior primer and house paints.

PRIMERS

The following primer formulations are designed as adherent undercoatings to provide a sound surface for subsequent finish coats. A substantial proportion of white lead was included in these formulas to assure the formation of paint films having a high degree of elastic strength and water resistance, primary requisites for durable house paint primers.

EXTERIOR PRIMER B1

	Pounds Non-Vol.	Pounds	Gallons
White Lead .....	....	553.7	9.8
Rutile Non-Chalking Titanium Dioxide....	....	74.6	2.1
Magnesium Silicate * .....	....	292.1	12.3
Litharge † .....	....	9.2	0.1
Raw Linseed Oil.....	165.0	165.0	21.3
Ester Gum Cold Cut (10 lb.).....	22.7	37.6	4.7
Low Acid Heat Bodied Linseed Oil (Z2-Z4) .	147.8	147.8	0.4
Cobalt Naphthenate (6%).....	....	2.8	0.4
Mineral Spirits .....	....	215.5	33.1
		1498.3	102.0

Pigment = 62.0%

Vehicle = 38.0%

P.V.C. = 36.7

Pig./Gal. Paint = 9.1 lbs.

Consistency = 80±2 K.U.

Pigment Analysis

	Percent
White Lead	59.6
Rutile Non-Chalking Titanium Dioxide	8.0
Magnesium Silicate	31.4
Litharge	1.0
	100.0

Vehicle Analysis

	Percent
Vegetable Oil	55.0
Resins	4.0
Thinner and Drier.....	41.0
	100.0

* 10% silica may be used to cut gloss if desired.

† The 9.2 lbs. litharge may be replaced by 35.4 lbs. (3.7 gals.) of lead naphthenate (24%) and compensation made by adjusting the mineral spirits content.

*EXTERIOR PRIMER B2***

	Pounds Non-Vol.	Pounds	Gallons	
Basic Carbonate White Lead.....	....	267.2	4.7	
Basic Sulfate White Lead.....	....	267.2	5.1	
Rutile Non-Chalking Titanium Dioxide * .....	....	105.8	3.1	
Barytes † .....	....	244.4	6.6	
Magnesium Silicate .....	....	173.4	7.3	
Litharge ‡ .....	....	10.6	0.1	
Raw Linseed Oil.....	159.8	159.8	20.7	
Bodied Linseed Oil (Z-4).....	143.3	143.3	17.1	
Ester Gum Cold Cut (10 lb.).....	22.0	36.4	4.6	2.4NV
Cobalt Naphthenate (6%).....	....	2.5	0.3	
Mineral Spirits .....	....	208.2	31.8	
		1618.8	102.0	

Pigment = 66.0%

Vehicle = 34.0%

P.V.C. = 39.7

Pig./Gal. Paint = 105.5 lbs.

Consistency = 86±2 K.U

Pigment Analysis

	Percent
Basic Carbonate White Lead	25.0
White Basic Lead Sulfate.....	25.0
Rutile Non-Chalking Titanium Lead	9.9
Barytes	22.9
Magnesium Silicate	16.2
Litharge	1.0
	100.0

Vehicle Analysis

	Percent
Vegetable Oil	55.1
Resins	4.0
Thinner and Drier.....	40.9
	100.0

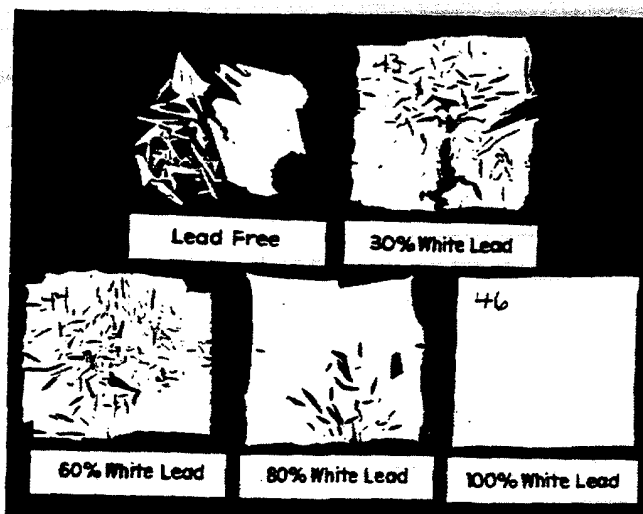
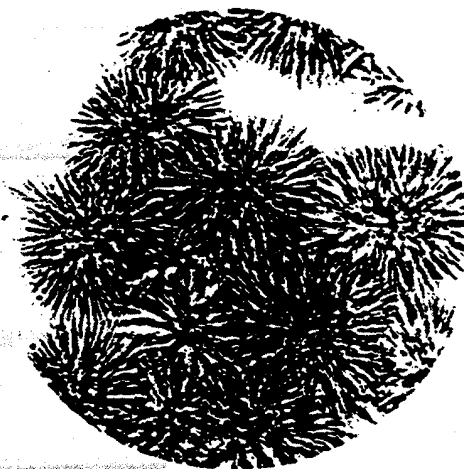
* Anatase type permitted.

† About 10% silica may be used to replace barytes and/or magnesium silicate to control gloss.

‡ The 10.6 lbs. litharge may be replaced by 40.8 lbs. (4.3 gals.) of lead naphthenate (24%) and compensation made by adjusting the mineral spirits content.

** This formula approximates Fed. Spec. TT-P-25a.

Photomicrograph illustrating the meshing effect of spiney lead soap crystals formed by the reaction of white lead with fatty acids in the paint film.



Experimental paint films with varying lead pigmentation, after stripping, soaking and drying. As the lead content increases disintegration is materially reduced.

Lead

Non-lead

Lead

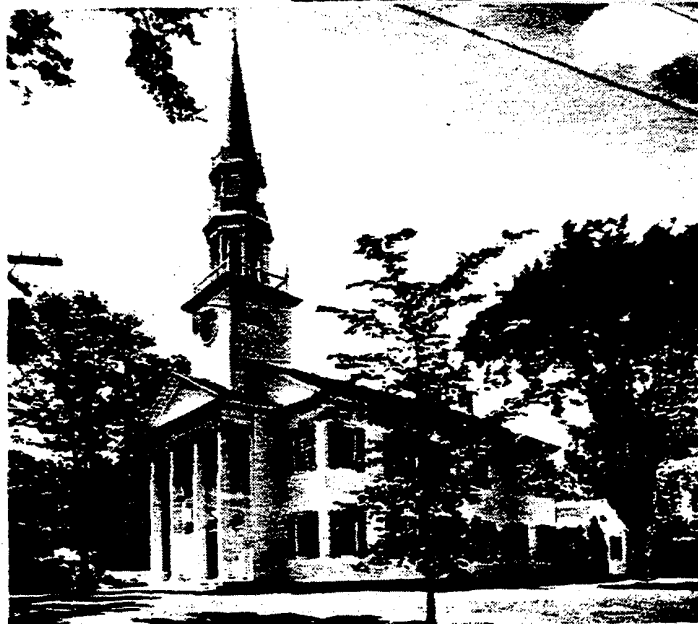
Non-lead

Photographs of test panels exposed 30 months in Florida (left) and 36 months in Chicago (right) show how properly lead-pigmented house paints retain their elasticity, toughness, staying power and appearance.



A typical private home protected and beautified by lead base exterior mixed pigment white paint.

Historic Baron Von Steuben headquarters erected in 1700 at South Bound Brook, N. J., is preserved both inside and out with pure white lead paint.



A typical New England landmark, the Congregational Church at Litchfield, Conn., is painted with white lead.

HOUSE PAINTS

The following are white and tint base formulations stabilized with substantial proportions of white lead. Carefully balanced formulas of this type provide long term protection, maintain excellent appearance and offer excellent surfaces for eventual re-painting.

HOUSE PAINT B₃—WHITE

	Pounds Non-Vol.	Total Pounds	Gallons
White Lead .....	....	296.0	5.5
Zinc Oxide .....	....	262.0	5.6
Anatase Free-Chalking Titanium Dioxide * .....	....	140.0	4.3
Magnesium Silicate .....	....	225.0	9.5
Raw or Refined Linseed Oil.....	282.0	282.0	36.5
Bodied Linseed Oil (Z-2 to Z-3).....	124.0	124.0	15.5
Lead Naphthenate (24%).....	....	6.7	0.7
Manganese Naphthenate (6%).....	....	1.2	0.2
Mineral Spirits .....	....	158.0	24.2
		1494.9	102.0

Pigment = 61.7%
P.V.C. = 32.4

Vehicle = 38.3%
Fig./Gal. Paint = 9.2 lbs.

Consistency †

Pigment Analysis

	Percent
White Lead	32.1
Zinc Oxide	28.3
Anatase Free-Chalking Titanium Dioxide.....	15.2
Magnesium Silicate	24.4
	100.0

Vehicle Analysis

	Percent
Raw or Refined Linseed Oil	49.3
Bodied Linseed Oil (Z-2 to Z-3)	21.7
Thinner and Drier.....	29.0
	100.0

* The free-chalking anatase titanium dioxide may be replaced in whole or in part by semi-non-chalking anatase to reduce chalking and erosion with some increase in dirt collection.

† The consistency of this paint will vary depending upon the raw materials used. The oil content may be altered slightly to improve working properties.

HOUSE PAINT B₄—TINT BASE

	Pounds Non-Vol.	Total Pounds	Gallons
White Lead		296.0	5.5
Zinc Oxide		262.0	5.6
Rutile Non-Chalking Titanium Dioxide....		112.0	3.2
Magnesium Silicate		251.0	10.6

LEAD IN MODERN INDUSTRY

Raw Linseed Oil.....	282.0	282.0	36.5
Bodied Linseed Oil (Z-2 to Z-3).....	124.0	124.0	15.5
Lead Naphthenate (24%).....		6.7	0.7
Manganese Naphthenate (6%).....		1.2	0.2
Mineral Spirits		158.0	24.2
		1492.9	102.0

Pigment = 61.7%

Vehicle = 38.3%

P.V.C. = 32.3

Fig./Gal. Paint = 9.2 lbs.

Consistency *

Pigment Analysis

	Percent
White Lead	32.1
Zinc Oxide	28.4
Rutile Non-Chalking Titanium Dioxide	12.2
Magnesium Silicate	27.3

100.0*Vehicle Analysis*

	Percent
Raw Linseed Oil.....	49.3
Bodied Linseed Oil (Z-2 to Z-3)	21.7
Thinner and Drier.....	29.0

100.0

* The consistency of this paint will vary depending upon the raw materials used. The oil content may be altered slightly to improve working properties.

HOUSE PAINT B5—WHITE

	Pounds Non-Vol.	Total Pounds	Gallons
White Lead		243.0	4.5
Zinc Oxide		302.0	6.5
Anatase Free-Chalking Titanium Dioxide *		130.0	4.0
Magnesium Silicate		300.0	12.6
Raw or Refined Linseed Oil.....	320.0	320.0	41.4
Bodied Linseed Oil (Z-2 to Z-3).....	105.0	105.0	13.1
Lead Naphthenate (24%).....		6.9	0.7
Manganese Naphthenate (6%).....		1.2	0.2
Mineral Spirits		124.0	19.0
		1532.1	102.0

Pigment = 63.5%

Vehicle = 36.5%

P.V.C. = 33.8

Fig./Gal. Paint = 9.6 lbs.

Consistency †

Pigment Analysis

	Percent
White Lead	24.9
Zinc Oxide	31.0
Anatase Free-Chalking Titanium Dioxide	13.3
Magnesium Silicate	30.8

100.0*Vehicle Analysis*

	Percent
Raw or Refined Linseed Oil	57.4
Bodied Linseed Oil (Z-2 to Z-3)	18.8
Thinner and Drier.....	23.8

100.0

* The free-chalking anatase titanium dioxide may be replaced in whole or in part by semi-non-chalking anatase to reduce chalking and erosion with some increase in dirt collection.

† The consistency of this paint will vary depending upon the raw materials used. The oil content may be altered slightly to improve working properties.

WHITE LEAD PAINTS

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HOUSE PAINT B6—TINT BASE

	Pounds Non-Vol.	Total Pounds	Gallons
White Lead		243.0	4.5
Zinc Oxide .....	.....	302.0	6.5
Rutile Non-Chalking Titanium Dioxide....	.....	105.0	3.0
Magnesium Silicate .....	.....	325.0	13.6
Raw Linseed Oil.....	320.0	320.0	41.4
Bodied Linseed Oil (Z-2 to Z-3).....	105.0	105.0	13.1
Lead Naphthenate (24%).....	.....	6.9	0.7
Manganese Naphthenate (6%).....	.....	1.2	0.2
Mineral Spirits .....	.....	124.0	19.0
		1532.1	102.0

Pigment = 63.5%

P.V.C. = 33.8

Vehicle = 36.5%

Pig./Gal. Paint = 9.7 lbs.

Consistency *

Pigment Analysis

White Lead	24.9
Zinc Oxide	31.0
Rutile Non-Chalking Ti-	
tanium Dioxide	10.8
Magnesium Silicate	33.3

100.0

Vehicle Analysis

Raw Linseed Oil.....	57.4
Bodied Linseed Oil.....	18.8
Thinner and Drier.....	23.8

100.0

* The consistency of this paint will vary depending upon the raw materials used.
The oil content may be altered slightly to improve working properties.

CHAPTER TWENTY-FOUR

Metal Protective Lead Paints

RED LEAD PAINTS

RED LEAD has long been the most important pigment in the production of metal protective paints, particularly metal primers. In fact for more than a century pure red lead paint has been considered the standard priming coat for the protection of iron and steel against corrosion and rust.

However, modern research has not only brought about improvements in red lead pigment and pure red lead paint, but also has developed a variety of multiple pigment paints, containing red lead as the principal pigment, which are designed to meet specific conditions. While pure red lead and linseed oil paint gives outstanding service where there is ample time for drying, it is now possible to formulate red lead paints which will meet exacting requirements for quick drying, low cost, light weight, salt or fresh water exposure, or other conditions as the formulator or specifier may desire.

Properly formulated multiple pigment or pure red lead paints adhere tenaciously and form impervious films resistant to water, many corrosive gases, and air. Red lead has a strong affinity for linseed oil, forming lead soaps in the paint. These strengthen the film, which is tough and elastic when dry, so that it can expand and contract as the surface expands and contracts with temperature changes. Furthermore, red lead effectively inhibits the anodic solution of steel through its oxidizing character and buffering action. The basic character of red lead also minimizes the destructive action of low molecular weight organic acids resulting from the breakdown of oleoresinous vehicles after prolonged exposure to weathering and adverse environmental conditions.

Both in impartial competitive tests and in actual performance, red lead paint has proved its worth. For instance, the Corrosion Committee of the Iron and Steel Institute of Great Britain in its 1943 report stated, "As regards to the paints themselves, the priming coat should be of an inhibitive character. So far no paint tested by the committee has proved superior to red lead for this purpose."

In May, 1949 a report was published by the American Iron and Steel Institute on a study of paints for enclosed structural members in steel housing construction. This comprehensive research project was carried out at the Battelle Memorial Institute. The following was among the conclusions reached after exposing thirty-four different paint systems to continuous immersion in water, contact with air at high humidity and alternate wet-dry conditions: "Considering all factors in rating the various coatings, System C (red lead) appears to be outstanding. It has a good blister rating, affords excellent protection to the base metal, as evidenced by low weight loss and slight visual evidence of attack on the steel and, as previously mentioned, penetration and undercutting at the damaged zone are either negligible or slight."

But even more conclusive than such statements are the protective jobs red lead is actually performing. It is the priming coat of paint on such bridges as the San Francisco-Oakland Bay, Brooklyn, and George Washington Bridges; the majority of state highway departments use red lead primers on steel; by far the majority of railroads use red lead for priming steel structures; millions of tons of ships including the U. S. Navy have been primed with red lead paint; and far more than any other paint it has been depended upon for the first coat on steel structures of all kinds.

The use of red lead paints is included in the latest recommendations of the American Water Works Association for both the exterior and interior of steel water tanks. *Recommended Practices* include the following statement: "The outside prime coat or patch coat shall comply with Federal Specifications TT-P-86a, Type I, which require the use of red lead in linseed oil weighing not less than 25 lb. per gallon." With reference to steel tank interiors this same bulletin says, "All interior surfaces of the

tank shall be painted with (or touched up with) paint complying with Federal Specifications TT-P-86a, Type IV, with all subsequent amendments, if any." This specification calls for a red lead base paint containing a highly water impervious and chemically resistant spar varnish vehicle.

Red lead is available as a dry powder, as a paste, or as ready-mixed paint in which the pigment is all red lead or a mixture of red lead and other pigments. The following formula is typical of pure red lead and linseed oil paint made from paste red lead:

Paste red lead.....	100 lb.
Raw linseed oil.....	1½ gal.
Turpentine	1½ pt.
Liquid drier	1½ pt.
Total paint	4½ gal.

Pure red lead and multiple pigment red lead paints are available in ready-mixed form, either untinted or tinted to offer contrast between coats.

Red lead paint specifications based on practical experience are available to meet a wide variety of drying requirements, surface conditions and exposure environments. Red lead has proven adaptable to successful formulation with a wide variety of fast drying, durable synthetic resins developed in recent years. These include alkyd, phenolic and vinyl type vehicles.

Extensive research work is being continued by the Lead Industries Association, government agencies and others toward the development of improved red lead paints to meet a diversity of requirements. The Lead Industries Association is prepared to give technical assistance to formulators, specifiers and users of metal protective paints.

White lead base paints, tinted as desired, are frequently used as finish coat paints over red lead primers. Where a metallic finish is desired, aluminum finish paints containing alkyd or phenolic type synthetic vehicles, have been used very successfully over red lead paints for steel structures exposed to the atmosphere.

A number of typical formulas for straight red lead and multiple pigment red lead base paints follow, together with the type of exposures for which they are recommended and other comments pertinent to their proper usage.

ATMOSPHERIC EXPOSURE

Primers based on the following formulas are indicated for use on bridges, similar structural steel and other ferrous metal surfaces. They are suitable for priming and body, either in the shop or field, where good resistance to the corrosive effects of the usual atmospheric environment is required. The vehicle solids, consisting entirely of linseed oil offer the best means of wetting the metal and obtaining an intimate bond between the paint and the surface, despite the presence of limited amounts of corrosion products found impractical to remove.

PAINT B7 (Federal Specification TT-P-86a, Type I)

	Percent	Pounds	Gallons
PIGMENT: Red Lead (97% Grade).....	99.7	1860.0	25.96
Aluminum Stearate	0.3	5.5	0.66
	100.0		
VEHICLE: Raw Linseed Oil.....	49.0	262.0	34.80
Pale Heat Bodied Linseed Oil (Z-2 Viscosity)	17.0	90.8	11.60
Mineral Spirits	29.0	154.5	23.80
Drier *	5.0	26.4	3.18
	100.0	2399.2	100.00

Pigment = 77.8%

Wt./Gal. = 24 lbs.

Vehicle = 22.2%

PV = 36%

* Federal Specification TT-D-651a, Type I.

The following primer formulas were designed for the priming and general maintenance of structural steel where work schedules call for an overnight dry and complete removal of rust and mill scale is not feasible. A vehicle composed of a blend of linseed oil and synthetic resin has proven to be a successful compromise under these conditions. Since the vehicle is a compromise, its wetting and penetrating characteristics are limited. Consequently it should only be applied to surfaces freed of loose mill scale and corrosion products.

PAINT B8 (Federal Specification TT-P-86a, Type II)

	Percent	Pounds	Gallons
PIGMENT: Red Lead (97% Grade).....	65.0	746.0	10.30
Iron Oxide (85% Fe ₂ O ₃).....	16.0	184.0	4.96
Magnesium Silicate	14.5	168.0	7.13
Mica	4.2	46.0	1.95
Aluminum Stearate	0.3	3.5	0.42
	100.0		
VEHICLE: Alkyd Resin *	57.0	327.0	40.96
Raw Linseed Oil.....	28.0	163.0	20.90
Mineral Spirits	14.1	83.5	12.80
Lead Naphthenate Drier (24% Pb) .	0.6	4.2	0.44
Cobalt Naphthenate Drier (6% Co) .	0.3	1.7	0.20
	100.0	1726.9	100.00

Pigment = 66.4%

Vehicle = 33.6%

Wt./Gal. = 17 lbs.

PV = 38%

* Medium oil length linseed modified glyceryl phthalate alkyd (34% phthalic anhydride), 50% solution in mineral spirits.

PAINT B9

	Percent	Pounds	Gallons
PIGMENT: Read Lead (Fed. Spec. TT-R-191a, Type I, Grade C).....	75.0	1240.0	16.80
Iron Oxide	24.7	407.0	11.70
Aluminum Stearate	0.3	5.0	0.70
	100.0		
VEHICLE: Raw Linseed Oil.....	65.3	358.0	46.30
Alkyd Resin *	33.6	184.0	23.80
Lead Naphthenate Drier (24% Pb) .	0.8	4.6	0.50
Cobalt Naphthenate Drier (6% Co) .	0.3	1.8	0.20
	100.0	2200.4	100.00

Pigment = 75%

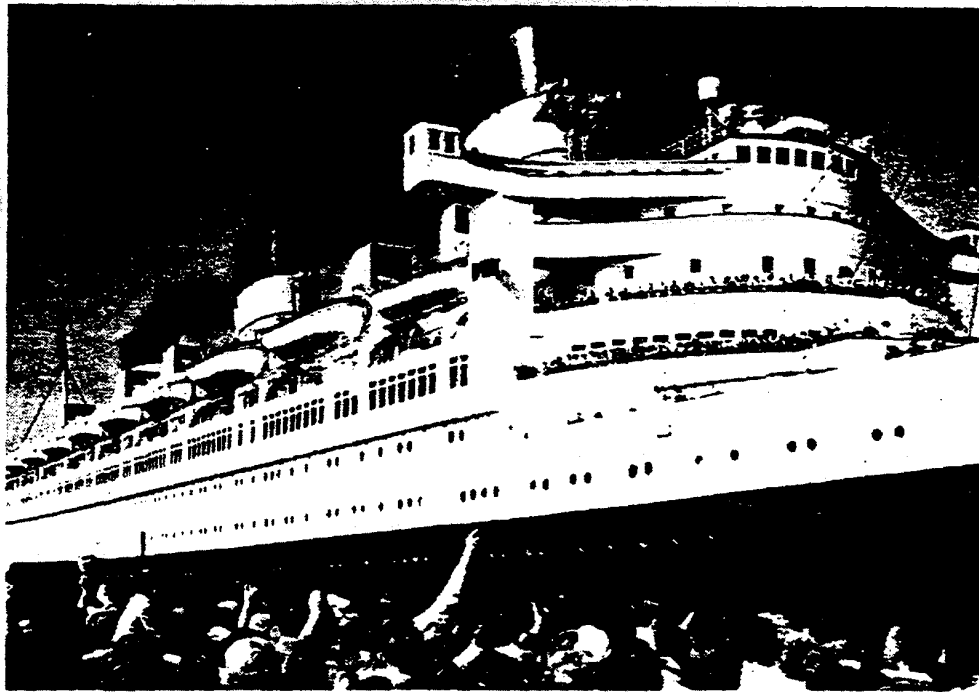
Vehicle = 25%

Wt./Gal. = 22 lbs.

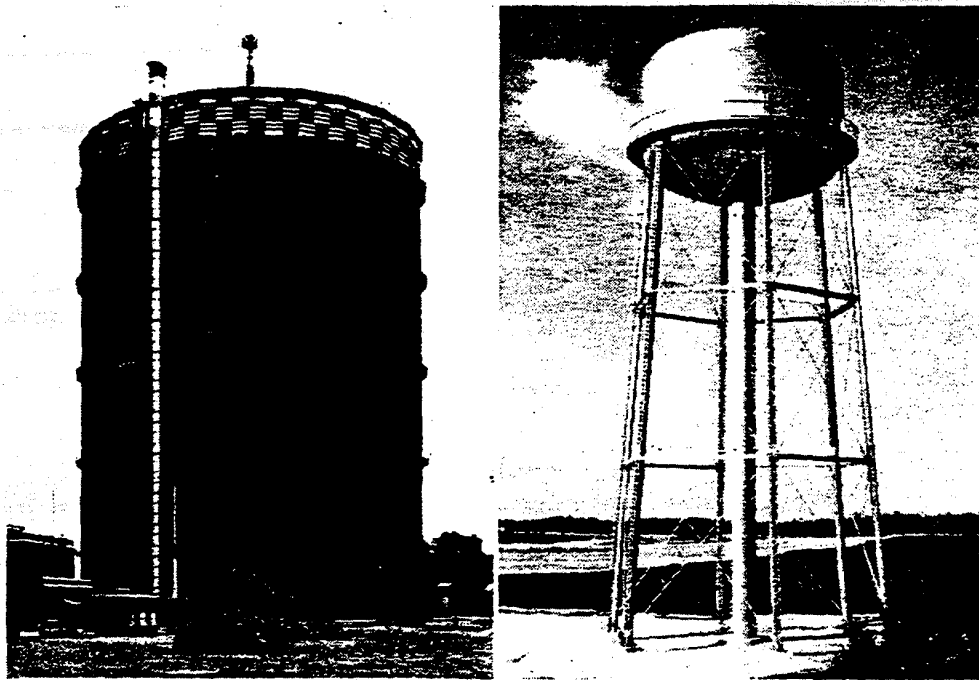
PV = 32%

* U. S. Maritime Commission Specification 52-MC-501, Type II.

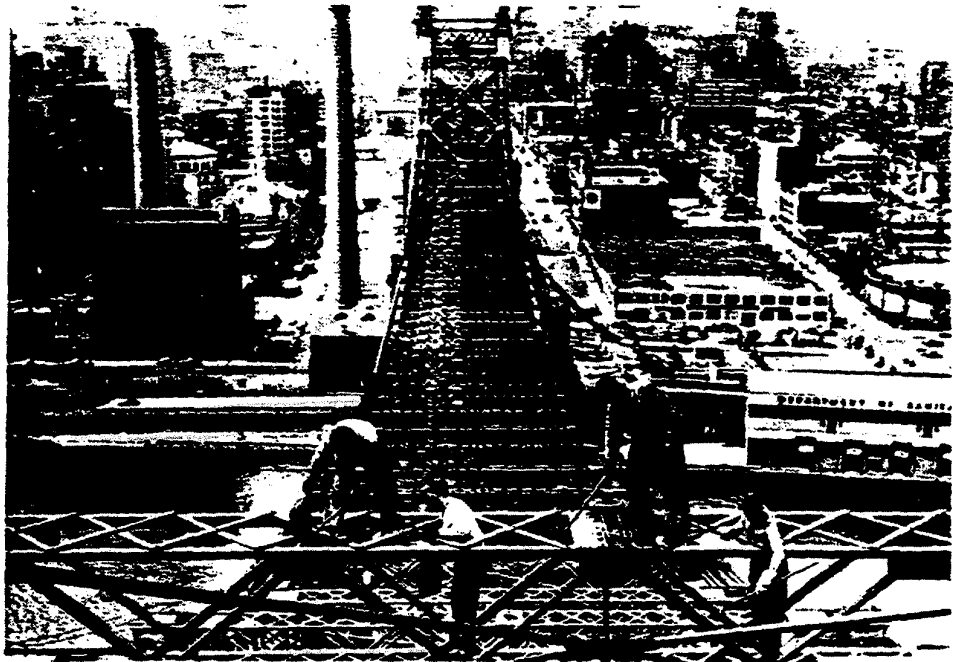
The following synthetic vehicle paint was formulated for thoroughly cleaned iron and steel surfaces and for touch-up work where drying within a six-hour period is desired. It is intended for use on smooth steel, particularly as an industrial primer for articles fabricated at the factory, such as railroad cars, window sash, air conditioning conduits, etc. It is also well



Practically all metal surfaces, interior and exterior, of ships such as the *Queen Mary* are primed and maintained with red lead base paint.

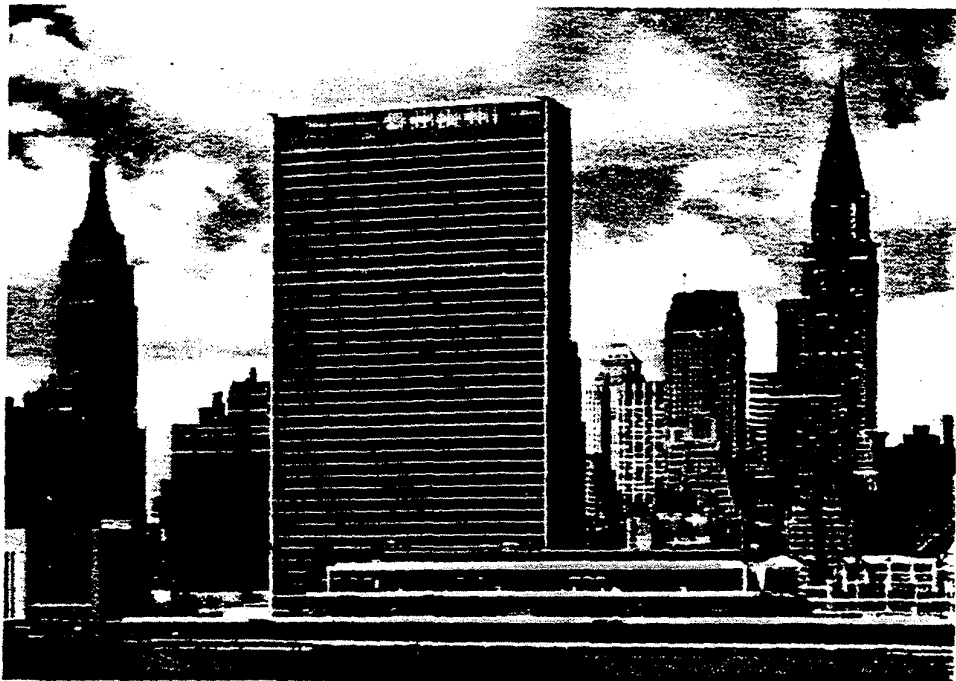


The exteriors of gas holders and water tanks are customarily primed with red lead paint. Water tank interiors are protected with a special red lead base paint.



Wide World

Painters applying red lead to New York's Queensboro Bridge. Most of the world's steel bridges are primed with red lead base paint.



United Nations

The United Nations Building flanked by the Empire State and the Chrysler Buildings each have their steel framework protected by red lead base paint.

suited as a fast drying general maintenance primer for touch-up work on thoroughly cleaned steel.

PAINT B10 (Federal Specification TT-P-86a, Type III)

	Percent	Pounds	Gallons
PIGMENT: Red Lead (97% Grade).....	99.7	1275.0	17.20
Aluminum Stearate	0.3	3.5	0.46
	100.0		
VEHICLE: Alkyd Resin *	84.0	522.5	67.50
Aromatic Petroleum Spirits.....	14.5	90.0	13.70
Cobalt Naphthenate (6% Co).....	0.3	1.9	0.20
Antioxidants and Wetting Agents..	1.2	7.6	0.94
	100.0	1900.5	100.00
Pigment = 67.3%		Wt./Gal. = 19 lbs.	
Vehicle = 32.7%		PV = 38%	

* Medium oil length linseed modified glyceryl phthalate alkyd conforming to the requirements of Federal Specification TT-R-266, Type III.

MARINE ATMOSPHERIC EXPOSURE AND INTERMITTENT SEA WATER IMMERSION

Paints made according to the following formulas are suitable for priming iron and steel surfaces on the topsides of ships, bridges situated along the seacoast or over tidewaters, dock structures and other atmospherically exposed marine installations. These primers dry fast enough to permit recoating in six hours under normal drying conditions. Since these paints contain synthetic vehicles they should be applied only over thoroughly cleaned surfaces.

PAINT B11 (Bureau of Ships Paint Formula No. 116, Primer, Exterior, Maintenance, June 1, 1949)

	Percent	Pounds	Gallons
PIGMENT: Red Lead (Fed. Spec. TT-R-191, Type I, Grade B).....	55.0	380	5.13
Zinc Yellow (Fed. Spec. TT-Z-415)	10.1	70	2.33
Mica (Navy Dept. Spec. 52M3) ..	9.4	65	2.77
Indian Red (Fed. Spec. TT-I-511, Type I)	1.5	10	0.23
Magnesium Silicate (Navy Dept. Spec. 52M2, Type A)	23.1	160	6.70
Aluminum Stearate (Navy Dept. Spec. 52A12)	0.9	6	0.71
	100.0		

VEHICLE: Alkyd Resin Solution (Fed. Spec. TT-R-266, Type I, Class A)*.			
	64.9	415 (290.5)	52.00
Dipentine (Fed. Spec. TT-D-376)	3.9	25.0	3.52
Paint Thinner (Fed. Spec. TT-T-291, Grade I).....	29.6	190.0	29.20
Lead Drier (Fed. Spec. TT-D-643, Type I).....	0.8	4.7	0.49
Cobalt Drier (Fed. Spec. TT-D-643, Type II).....	0.8	4.7	0.59
	100.0	1330.4	103.67

* Alkyd Resin Solution (Federal Specification TT-R-266, Type I, Class A) :

A solution of a soy oil-modified alkyd resin containing not less than 23% phthalic anhydride and a fatty acid content of 60-75%. The specification calls for the following characteristics :

Non-Volatile = 69-71% Viscosity (Gardner-Holdt) = Y-Z2 Acid Number = 5-10 (on solids)

The following anticorrosive red lead formulations are intended especially for paints for priming and undercoats on ship boat-topping areas and on parts of marine structures undergoing intermittent sea water immersion by tidal action. These formulas are also well adapted for surfaces exposed to marine atmospheric environments. These quick drying paints contain straight synthetic vehicles and should be applied only to thoroughly cleaned surfaces.

PAINT B12

	Percent	Pounds	Gallons
PIGMENT: Red Lead (97% Grade).....	52.8	330.0	4.50
Zinc Yellow	10.0	62.8	2.15
Zinc Oxide, Lead Free.....	7.9	49.8	1.07
Mica, Graphitic	15.1	94.3	3.88
Raw Sienna	3.9	24.9	0.93
Magnesium Silicate	10.0	62.8	2.65
Aluminum Stearate	0.3	1.9	0.23
	100.0		

VEHICLE: Oleoresinous Varnish Vehicle*....	61.9	391.3	52.32
Aromatic Mineral Spirits.....	37.1	234.5	81.50
Lead Naphthenate (24% Pb).....	0.7	4.3	0.44
Cobalt Naphthenate (6% Co).....	0.1	0.7	0.08
Manganese Naphthenate (6% Mn).	0.1	0.7	0.08
Anti-Skinning Agent †	0.1	1.0	0.17
	100.0	1259.0	100.00

Pigment = 49.8%
Vehicle = 50.2%

Wt./Gal. = 12.6 lbs.
PV = 35%

* Description of Oleoresinous Varnish Vehicle :

A long oil modified phenolic varnish formulated as follows :

Modified Phenolic Resin.....	100 lbs.
China Wood Oil.....	34 gallons
Alkali Refined Linseed Oil.....	16 gallons
Mineral Spirits	45 gallons
V. M. and P. Naphtha.....	15 gallons
Dipentene	5 gallons

Cooking Procedure: Run resin, china wood oil and 10 gallons of alkali refined linseed oil to 500°F. Hold for body (40 minutes for laboratory batch) : Add 6 gallons of alkali refined linseed oil and all of the heavy bodied linseed and heat to 475°F. Hold for 10 to 15 minutes. Take off fire, cool and reduce to viscosity of G-H (Gardner-Holdt).

Properties: Non-Volatile = 60% by weight
 Viscosity = G-H (Gardner-Holdt)
 Color = 6 L-6
 Acid Number = 7.3

† An anti-skinning agent of the aliphatic oxime type.

CONTINUOUS IMMERSION IN SEA WATER

The following formulation has been designed for use with antifouling paints for the protection of steel ship bottoms and continuously immersed marine structures. This primer can be used with a variety of antifouling paints.

One example of a high quality bottom paint system is this red lead-coumarone anticorrosive primer applied over clean steel in multiple coats to a dry film thickness of 3 mils and followed by the application of 6 mils of antifouling paint such as Navy Cold Plastic 105, Maritime Commission Specification 52-MC-403 or Military Specification MIL-P-15931. If desired the anticorrosive paint can be applied on phosphate treated steel surfaces. The anti-corrosive paint may be applied by brushing or spraying. A minimum drying period of six hours should be allowed between coats and before application of the antifouling paint.

PAINT B13

	Percent	Pounds	Gallons
PIGMENT: Red Lead (97% Grade).....	47.0	332.0	4.51
Zinc Oxide	8.3	58.1	1.24
Zinc Yellow	8.8	62.2	2.08
Mica (325 Mesh).....	8.3	58.1	2.46
Magnesium Silicate	0.4	192.0	0.37
Aluminum Stearate	0.4	3.1	0.37
	100.0		
VEHICLE:* Coumarone-Indene Resin (M. R. 127-137°C.) †	25.4	166.0	18.12
Coumarone-Indene Resin (M. R. 5-15°C.) ‡	8.7	57.0	6.22

(Continued next page)

VEHICLE * (con't):

	Percent	Pounds	Gallons
Liquid Coal Tar (Navy Dept. Spec. 52T5a)	8.9	58.1	5.87
Zinc Resinate	3.2	20.8	2.17
Chlorinated Rubber	6.3	41.5	3.03
Hi-Flash Naphtha	31.7	208.0	28.50
Aliphatic Petroleum Spirits (Boiling Range 105°-260°F.)	15.0	98.5	16.69
Pine Oil	0.8	5.2	0.67
	100.0	1360.6	100.00
Pigment = 51.9%	Wt./Gal. = 13.6 lbs.		
Vehicle = 48.1%	PV = 35%		

* This vehicle may be prepared by heating the coumarone resins and liquid coal tar together to a temperature of 445°F., adding the zinc resinate and holding temperature until it is all melted in. All of the petroleum spirits and 80 gallons of the required Hi-Flash naphtha may then be added. The chlorinated rubber can then be dissolved into the remaining Hi-Flash naphtha at room temperature. The chlorinated rubber should be blended in with the remainder of the ingredients only after the coumarone-coal tar-resinate mixture has cooled to 140°F. or less. To avoid decomposition, the chlorinated rubber should never be heated above 140°F.

Although the above method is preferred, the vehicle may also be prepared by cold cutting the indicated ingredients.

† A coumarone-indene resin with a melting range of 127-137°C.

‡ A coumarone-indene resin with a melting range of 5-15°C.

Note: Only dark colored finishes should be applied over this primer since bleeding through of the coal tar may occur. However this does not affect its protective performance.

The following anticorrosive paint consists of a red lead pigmentation incorporated into a vinyl chloride-acetate copolymer resin binder. The well known corrosion inhibitive characteristics of red lead and the excellent water impermeability and high abrasion resistance of vinyl resins are combined in this paint. The inherent heat and light stabilizing effect of lead compounds makes red lead an especially valuable pigment for use in vinyl type vehicles.

The red lead-vinyl anticorrosive paint, applied as part of a conventional vinyl anticorrosive-antifouling system, is particularly well suited for the protection of metal surfaces immersed in or exposed to sea water. This vinyl anticorrosive paint also offers long term protection for ferrous surfaces exposed to fresh water and highly corrosive atmospheric environments.

A suggested basis for an outstanding system for marine service or for highly corrosive atmospheres consists of 0.3-0.5 mil of a metal conditioner ¹ followed by a total of 4 mils of a red lead-

¹ As the name implies the metal conditioner is intended primarily to provide a firm bond between the metal surface and subsequent coats and assure good adhesion. It is necessary to follow the metal conditioning treatment

vinyl anticorrosive paint applied in three sprayed coats (double pass for each coat). This should be followed with suitable top-coats. For details regarding the composition and uses of vinyl antifouling paint reference can be made to Military Specification MIL-P-15931 or U. S. Coast Guard Specification CGS-59P-3a. Other types of finish coat paints can also be used depending upon color preference and exposure environment. For maximum service the metal surface should be freed of surface contaminants by sandblasting or other equally effective means.

PAINT B14 (This formula conforms with the requirements of Military Specification MIL-P-15929 or U. S. Coast Guard Specification CGS-52P-4a)

	Percent	Pounds	Gallons
PIGMENT: Red Lead (Fed. Spec. TT-R-191, Type I, Grade C)	100.0	213.53	2.92
	100.0		
VEHICLE: Vinyl Resin *	19.36	142.35	12.29
Tricresyl Phosphate	1.94	14.24	1.44
Toluene †	39.35	289.45	43.41
Methyl Isobutyl Ketone †	39.35	289.45	39.94
	100.00	949.02	100.00
Pigment = 22.5% Wt./Gal. = 9.5 lb.			
Vehicle = 77.5% PV = 17.5%			

* A copolymerized vinyl chloride-acetate resin meeting the following composition requirements: 89.5 to 91.5% (by weight) of vinyl chloride, 5.3 to 7.0% (by weight) of vinyl alcohol and 2.0 to 5.5% (by weight) of vinyl acetate. Such a resin is typified by Carbide and Carbon Corporation's VAGH.

† For application in extremely hot weather 6.0 to 8.0% of the methyl isobutyl ketone may be replaced with cyclohexanone and 6.0 to 8.0% of the toluene may be replaced with xylene to reduce the volatility.

Note: For the purpose of differentiating between coats or to minimize contrast the above formula can be modified to a brown color by including 0.25% lampblack by weight of the total pigment.

CONTINUOUS IMMERSION IN FRESH WATER

The following formulation was designed primarily as an anti-corrosive paint for total immersion in fresh water. It is a fast, hard drying red lead base paint incorporating a highly water impermeable and chemically resistant spar varnish vehicle. This paint is included in the recommended practice of the American

with priming anticorrosive paints which are essential to the satisfactory performance of metal protective paint systems. For details regarding the composition and use of the metal conditioner reference can be made to Military Specification MIL-P-15328 (SHIPS) or U. S. Coast Guard Specification CGS-52P-7.

Water Works Association¹ for the priming of water tank interiors. A dry film thickness of approximately 6 mils (3-4 coats) is suggested for this type of application.

This paint is also suitable on iron and steel surfaces exposed to the atmosphere, particularly under conditions of high humidity. In addition to its excellent water impermeability, this paint also has good resistance to alkaline environments.

Water storage tanks, structural work on dams, equipment in bottling plants, laundries and mines are typical of steel surfaces on which this paint is effective as a protective coating. This paint dries to a tack free film in 4 hours under normal conditions.

Clean steel surfaces, free from rust and mill scale, are required to insure the best performance of this paint.

PAINT B15 (Fed. Spec. TT-P-86a, Type IV)

	Percent	Pounds	Gallons
PIGMENT: Red Lead (97% Grade).....	85.0	950.0	12.85
Diatomaceous Silica	8.0	89.6	5.36
Magnesium Silicate	6.6	74.0	3.10
Aluminum Stearate	0.40	4.4	0.53
	100.00		
VEHICLE: Phenolic Varnish *	74.0	432.0	57.70
Aromatic Petroleum Spirits.....	22.4	129.7	17.70
Dipentene	2.75	16.0	2.26
Antioxidants	0.5	2.2	0.27
Lead Naphthenate (24% Pb).....	0.23	1.4	0.15
Cobalt Naphthenate (6% Co).....	0.06	0.3	0.04
Manganese Naphthenate (6% Mn) ..	0.06	0.3	0.04
	100.00	1699.9	100.00
Pigment = 65.9%	Wt./Gal. = 17 lbs.		
Vehicle = 34.1%	PV = 41%		

* Phenolic Varnish :

Phenolic Resin (100% para tertiary amyl phenol-formaldehyde resin) ..	20.25%
Tung Oil (F. S. JJJ-O-353).....	39.75
Mineral Spirits (F. S. TTT-T-291a, Grade 1).....	40.00
	100.00%

Cooking Procedure: Heat all the resin and oil to 465°F. in 40 minutes. Hold the batch at this temperature long enough (35-40 minutes) to obtain the desired viscosity when thinned to the specified solids content. Water-cool and thin with mineral spirits.

Oil Length 25 gallons	Color (Hellige). 9	Drying Time:
Non-Volatile 59-61%	Wt./Gal. 7.5 lbs.	Set to Touch. 2 hrs.
Viscosity (G-H). F-H		Print Free .. 8 hrs.

¹ Tentative Recommended Practice for Inspecting, Repairing and Repainting Elevated Steel Water Storage Tanks, Standpipes and Reservoirs, A.W.W.A. 7H.2-T, 1949.

BLUE LEAD PAINTS

Blue lead, also referred to as basic lead sulphate-blue, is a pigment which consists of basic lead sulphate and small amounts of lead sulphite, lead sulphide, zinc oxide plus a very small amount of carbon. The principal use of blue lead is in the manufacture of paint for the protection of iron and steel surfaces. Its pleasing blue-grey color, extreme fineness and unusual hiding power, in combination with excellent rust inhibitive qualities, make blue lead an excellent pigment for use in paints intended for rust prevention.

Blue lead is marketed in dry form and in paste form, that is, ground in linseed oil. The paste-in-oil and the dry pigment meet Federal Specification TT-B-486 and ASTM Standard D405-41. In ready-mixed paint as a primer for iron and steel, it is covered by Federal Specification TT-P-20 and in many State Highway and other specifications.

Blue lead exhibits the same affinity for linseed oil and constituents of vehicles used in paints as shown by other lead pigments. It has excellent paint film forming properties, giving a film which retains its flexibility over a long period of time. It imparts this characteristic to mixed pigment paints containing, for example, zinc chromate, basic silicate white lead, zinc oxide and certain inert materials such as magnesium silicate and diatomaceous earth.

While blue lead shows good performance in atmospheric exposure it excels in combination with basic silicate white lead in damp and humid exposures and in fresh and salt water exposures. The following formula is typical of pure blue lead and linseed oil paint made from blue lead oil paste.

Blue lead in oil.....	100 lb.
Raw linseed oil.....	2½ gal.
Turpentine (or equivalent).....	1½ pt.
Liquid drier	2 pt.
Total paint	6¼ gal.

A number of typical formulas for straight blue lead and multiple pigment blue lead base pigments follow together with the type of exposure for which they are recommended.

READY-MIXED BLUE LEAD BASE PAINT FOR ATMOSPHERIC EXPOSURE

PAINT B16 (Fed. Spec. TT-P-20)

	Percent	Pounds	Gallons
PIGMENT: Blue Lead	100.0	1475.51	26.12
VEHICLE: Raw Linseed Oil.....	90.20	512.55	66.01
Mineral Spirits	7.32	41.49	6.33
Pb Naphthenate 24%.....	1.88	10.63	1.11
Co Naphthenate 6%.....	0.60	3.47	0.43
	100.00	2043.65	100.00

Pigment = 72.2%

Wt./Gal. = 20.44 lbs.

Vehicle = 27.8%

PV = 28.35%

Note: This formulation is a standard linseed oil, rust inhibitive, ready-mixed paint, conforming to Federal Specification TT-P-20.

For a dry film thickness of 1.5 mils, the spreading rate is 980 sq. ft. per gallon. Drying time, 15 hours, dust-free; 18 hours, re-coat.

BLUE LEAD PRIMER FOR ATMOSPHERIC EXPOSURE

PAINT B17 (Fed. Spec. TT-R-266, Type III)

	Percent	Pounds	Gallons
PIGMENT: Blue Lead	54.0	463.3	8.20
Zinc Chromate	18.0	154.5	5.36
Lead Free Zinc Oxide.....	8.0	68.9	1.46
Magnesium Silicate	15.0	128.5	5.41
Diatomaceous Silica	5.0	42.9	2.21
	100.0		
VEHICLE: Raw Linseed Oil.....	30.3	177.1	22.81
*Alkyd Resin Solution.....	60.4	354.1	46.60
Mineral Spirits	7.5	44.2	6.79
Pb Naphthenate 24% Pb.....	1.3	7.3	0.78
Co Naphthenate 6% Co.....	0.5	3.0	0.38
	100.0	1443.8	100.00

Pigment = 59.4%

Wt./Gal. = 14.44 lbs.

Vehicle = 40.6%

PV = 35.0%

Note: For a dry film thickness of 1.5 mils, the spreading rate is 690 sq. ft. per gallon. Drying time, 4 hours, dust free; 8 hours, re-coat.

BLUE LEAD PRIMER FOR FRESH WATER IMMERSION

PAINT B18

	Percent	Pounds	Gallons
PIGMENT: Blue Lead	80	927.97	16.43
Basic Silicate White Lead.....	20	231.99	4.80
	100		

METAL PROTECTIVE LEAD PAINTS

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VEHICLE: Varnish *	99	578.41	78.14
Guaiacol	1	5.93	0.63
	100	1744.30	100.00

Pigment = 66.5%

Wt./Gal. = 17.44 lbs.

Vehicle = 33.5%

PV = 35.0%

Note: For a dry film thickness of 1.5 mils, the spreading rate is 640 sq. ft. per gallon. Drying time, 2 hours, dust-free; 4 hours, re-coat.

* Varnish is a 33 gallon china wood oil phenolic (100% para tertiary amyl phenol-formaldehyde resin) 55% solids by wt. Body B-C. Weighs 7.4 lbs./gal.

BLUE LEAD PRIMER FOR INTERMITTENT OR TIDE LEVEL SEA WATER IMMERSION

PAINT B19

	Percent	Pounds	Gallons
PIGMENT: Blue Lead	60.0	441.42	7.81
Basic Silicate White Lead	15.0	110.42	2.29
Lead Free Zinc Oxide	10.0	73.57	1.57
Magnesium Silicate	7.5	55.14	2.32
Diatomaceous Silica	7.5	55.14	2.84
	100.0		

VEHICLE: Varnish *	89.5	545.25	73.66
Mineral Spirits	9.6	58.51	8.92
Guaiacol	0.9	5.51	0.59
	100.0	1344.96	100.00

Pigment = 54.7%

Wt./Gal. = 13.45 lbs.

Vehicle = 45.3%

PV = 31.2%

Note: For a dry film thickness of 1.5 mils, the spreading rate is 570 sq. ft. per gallon. Drying time, 2 hours, dust-free; 3 hours, re-coat.

* Varnish is a 25 gal. china wood oil phenolic (100% para tertiary amyl phenol-formaldehyde resin) 55% solids by wt. Body At. Wt. 7.40 lbs. per gal.

BLUE LEAD PRIMER FOR CONTINUOUS SEA WATER EXPOSURE

PAINT B20

	Percent	Pounds	Gallons
PIGMENT: Blue Lead	60.0	510.24	9.03
Basic Silicate White Lead	15.0	127.56	2.64
Lead Free Zinc Oxide	10.0	85.04	1.81
Magnesium Silicate	7.5	63.78	2.69
Diatomaceous Silica	7.5	63.78	3.29
	100.0		

VEHICLE: Varnish *	90.9	541.62	72.52
Mineral Spirits	8.2	48.88	7.45
Guaiacol	0.9	5.35	0.57
	100.0	1446.25	100.00

Pigment = 58.8%

Wt./Gal. = 14.46 lbs.

Vehicle = 41.2%

PV = 34.9%

Note: For a dry film thickness of 1.5 mils, the spreading rate is 590 sq. ft. per gallon. Drying time, 1 hour, dust-free; 2 hours, re-coat.

* Varnish is a 15 gal. phenolic (100% para tertiary amyl phenol-formaldehyde resin) 55% solids by wt. Body A. Weighs 7.47 lbs. per gal.

CHAPTER TWENTY-FIVE

The Safe Handling of Lead and Its Products

WHILE, like nearly everything we use in modern living, lead if improperly used and handled may be a health hazard, its properties have been recognized for so many years, its use has been so widespread and its toxicology has been studied so extensively that methods for handling lead and its products with complete safety are well understood. In spite of all this, however, erroneous and alarming statements are still made from time to time and unfounded prejudices still persist.

To result in lead intoxication (lead poisoning), the lead must gain entrance into the human system in measurable quantity, usually by one or both of two means: (1) inhalation of vapors, fumes or dust or (2) ingestion of lead compounds introduced into the mouth on the fingers or with food, tobacco, etc., or swallowed as a result of being trapped in the upper respiratory tract.

Of the two, ingestion is by far the less important and is most often associated with children chewing on objects coated with paints containing lead. However, since most inside paints and paints used by manufacturers on children's furniture and toys contain no lead, a hazard usually exists only if children are allowed to chew outside painted surfaces, like porch railings, or if parents inadvertently repaint furniture with outside house paint. Pica (abnormal appetite in children) or teething may cause them to chew on painted surfaces and also on many other substances which may be injurious to health.

The average healthy adult normally ingests with his food and drink minute quantities of lead. He inhales air containing a small quantity. But only a fractional portion of ingested lead is actually absorbed into the body, most of it being eliminated by normal body processes. The human system can tolerate lead to this extent without disturbing the individual's sense of well-

being. To produce lead *intoxication* or poisoning, an abnormal and extended exposure to lead must take place.

As it is not practical in all industrial operations to eliminate completely the possibility of lead exposure, a maximum allowable atmospheric limit has been established: a concentration of 1.5 mg. of lead per 10 cubic meters of air. In other words, when the air of workrooms regularly contains not more than 1.5 mg. of lead per 10 cubic meters of air, no cases of disabling lead intoxication can be expected to occur among the men who regularly work there.

Certain principles have been laid down which are helping immeasurably in the prevention of lead intoxication in industrial operations where lead is used. Probably the one factor which has contributed most is the adoption of good housekeeping methods. These should include encouraging personal cleanliness on the part of the workmen, providing showers and clean lunch rooms, keeping floors well swept and preventing careless handling of materials. Processes have been revamped in many instances to reduce the duration of exposure. Newer equipment is being constructed with exhaust devices as integral parts. Lead fumes are being suppressed and collected by a variety of fume scrubbers and similar devices to prevent atmospheric pollution. Exposures which are necessarily hazardous are being localized in specific areas where they can be controlled.

Many large companies manufacturing lead products maintain qualified physicians, industrial hygienists and nurses on their staffs. Regular inspections are made of all departments where lead or its products are handled to check the lead content of the air as well as the functioning of special equipment such as respirators, exhaust fans, hoods, fume scrubbers, etc. They also check periodically the lead absorption of all workmen exposed to such conditions. Many small plants retain a hygienist or medical man on a part-time basis for this purpose, often in conjunction with other companies in the same area.

Lead intoxication can be cured and recovery is usually complete, leaving no disability. In all cases treatment for lead intoxication must be undertaken by a properly qualified physician and should be administered only after it has been determined

beyond doubt that the illness is actually due to excessive lead absorption. This point cannot be stressed too highly in view of the fact that most symptoms of lead intoxication are very similar to those of other illnesses, such as appendicitis or simple colic, and are oftentimes confused by individuals not fully acquainted with the characteristics of true lead intoxication. A complete history should be taken in each case, in order to certify the cause, nature, degree and duration of the exposure and a complete diagnosis, including analyses, is necessary. Detection of lead absorption may be by such methods as examination or analysis of the blood or analysis of the feces or urine for the presence of lead. But no one of these alone can be relied upon as a sure means of detection. Two or more methods should always be used in combination to check the findings. The treatment is seldom complicated and many excellent published works are available on both diagnosis and treatment, for example, the publication "Occupational Lead Exposure and Lead Poisoning," obtainable from the American Public Health Association, 1790 Broadway, New York 19, N. Y. at 75¢ per copy.

Detailed information on this subject is available from the office of the Lead Industries Association.

CHAPTER TWENTY-SIX

Specifications for Lead, Lead Alloys and Lead Products

THIS chapter contains a tabulation of many government, commercial, and other standard specifications for lead, its alloys and products. Abbreviations used in this chapter refer to standards or specifications as identified below:

- A.A.S.H.O. American Association of State Highway Officials, 1220, National Press Building, Washington 4, D. C.
- A.S. Army Specifications obtainable from Office of Chief Engineer, Washington 25, D. C.
- A.S.A. Standards approved by the American Standards Association, 70 East 45th St., New York 17, N. Y.
- A.S.T.M. Standards and Tentative Standards published by the American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.
- A.W.W.A. Standards and Tentative Standards published by the American Water Works Association, 500 Fifth Ave., New York 18, N. Y.
- C.S. Commercial Standards representing voluntary standards of the trade, prepared under the procedure of the National Bureau of Standards and published by the United States Department of Commerce. Obtainable from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
- F.S. Federal Specifications published by the Federal Specifications Board and obtainable from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

- L.I.A. Standards published by the Lead Industries Association, 420 Lexington Ave., New York 17, N. Y.
- M.C. Maritime Commission Specifications set up for U. S. Maritime Commission, Washington 25, D. C.
- M.S.S. Standards published by the Manufacturers Standardization Society of the Valve and Fittings Industry, 420 Lexington Ave., New York 17, N. Y.
- N.S. Navy Specifications obtainable from Bureau of Supplies and Accounts, Navy Department, Washington 25, D. C.
- S.A.E. Specifications prepared by the Society of Automotive Engineers, 29 West 39th St., New York 18, N. Y.
- T.D. Treasury Department Specifications obtainable from the Procurement Division, Treasury Department, Washington 25, D. C.
- T.V.A. Specifications established by Tennessee Valley Authority, Knoxville, Tenn.

American Society for Testing Materials Standards are issued under fixed designations; "T" indicates Tentative. All specifications and standards are subject to revision from time to time, hence, when ordering it is important to request the latest date of issue.

SUBJECT	F.S.	A.S.A.	A.S.T.M.	OTHER
METALLIC LEAD				
Calking lead	QQ-L-156			L.I.A.; A.W.W.A., C.S., 94
Hard lead fittings				L.I.A.
Lead pipe	WW-P-325			L.I.A.; C.S., 95
Lead traps	WW-P-325			L.I.A.; C.S., 96
Pig lead	QQ-L-171		B29	
Sheet lead	QQ-L-201			
LEAD ALLOYS				
Bearing alloys	QQ-M-161		B23	S.A.E. 10, 110, 11, 15
Car and tender journal bearings, lined			B67	
Copper-lead bearings				S.A.E. 48, 480, 481
Lead- and tin-base alloy die castings			B102	
Soft solder	QQ-S-571a		B32	S.A.E. 1A-6A
Wiping solder				S.A.E. 1b to 6b
CHEMICAL ANALYSIS				
Bismuth in pig lead			E58	
Iron in lead- and tin-base alloys			E67	
Lead alloys, spectro			E49	
Lead- and tin-base solder			E46	
Pig lead			E37	
Pig lead, spectro			E25	
Red lead, dry		K16.1	D49	
White metal bearing alloys			E57	

SUBJECT	F.S.	A.S.A.	A.S.T.M.	OTHER
LEAD PAINTS				
Blue lead	TT-P-20			
Chrome green, exterior	TT-P-71b			
Chrome yellow	TT-P-53			
Exterior, titanium-lead-zinc	TT-P-102			
Exterior, white lead and oil	TT-P-104			
Internat'l orange	TT-P-59			
Olive drab enamel	TT-E-485b			
Paint, marine ext., basic lead chromate				T.D., 356
Paint, marine ext. red lead				T.D., 358
Primer, shop for underwater metal surfaces				T.V.A., C-44
Primer, exterior (undercoat for wood)	TT-P-25a			
Protective painting for metals				A.S., C.E.-11
Red lead base paints	TT-P-86a			M.C. 52-M.C.-18
				A.A.S.H.O., M7
				Bu. Ships 116
				M.C. 52-M.C.-20
				M.C. 52-M.C.-20
				A.A.S.H.O., M7
Repainting elevated steel tanks (red lead)				A.W.W.A., 7H.2
White and tinted (lead and zinc base)				A.A.S.H.O., M7
LEAD COMPOUNDS				
Aviation gasolines			D910	
Litharge				N.S., 52-L-10b
Tests for lead in gasoline			D810	
Tests for tetraethyl lead in gasoline			D526	

SUBJECT	F.S.	A.S.A.	A.S.T.M.	OTHER
LEAD PIGMENTS				
Basic carbonate white lead	TT-W-251b	K23.1	D81	
Basic sulphate white lead	TT-W-261a	K47.1	D82	
Blue lead; basic sulphate	TT-B-486	K48	D405	
Chrome green, dry	TT-C-235			
Enamel; drum coating exterior	TT-E-485a			
Enamel, O.D. rust inhib.				A.S. 3-181A
Lead chromate (yellow and orange)	TT-C-290			
Lead titanate			D606	
Leaded zinc oxide	TT-Z-321		D80	
Red lead	TT-R-191a	K24	D83	
LEAD COATINGS				
Lead-alloy coated iron or steel			A267	
Lead-coated copper sheets			B101	
Lead- and lead-alloy-coated copper wire			B189	
Lead on steel, electrodepos.			B200	
Terne-plate (long)	QQ-T-191			
Terne-plate (roofing)	QQ-T-201			
MISCELLANEOUS				
Allow. conc. of lead and certain inorg. compds.		Z37.11		
Batteries, storage	W-B-131b			

SUBJECT	F.S.	A.S.A.	A.S.T.M.	OTHER
MISCELLANEOUS (cont'd)				
Cable, armored and lead-covered-armored	J-C-71			
Corrosion, alt. imm.			B192	
Corrosion, total imm.			B185	
Die castings			B102	
Leaded-rubber (Roentgen opaque)	ZZ-L-151			
Packing, metallic, flexible	HH-P-126a			
Packing, metallic and non-metallic, plastic	HH-P-131a			
Packing, metallic, flexible, condenser tube	HH-P-128			
Prep. of metallographic spec.			E3	
Treads; safety, metallic	RR-T-661			

CHAPTER TWENTY-SEVEN

Properties of Lead and Lead Alloys

IN ONE form or another lead is associated with nearly every phase of our daily life. Its practically innumerable applications depend not upon one single property or characteristic but upon many different properties inherent in the element. It is employed in some instances primarily for its weight, in others because of its resistance to corrosion or its softness and malleability or its atomic structure or its ability to alloy readily with other metals to change or modify its properties. The various properties, comparative figures and other pertinent data that apply to lead and lead alloys are consolidated in this chapter to serve as a handy source of reference and as a guide to the proper use of the metal.

General Properties

Color	Bluish gray
Patina	On atmospheric exposure lead takes on a silvery gray patina except in industrial atmospheres where it changes to dark gray to black
Atomic number	82
Atomic arrangement	Cubic face-centered
Length of lattice edge.....	4.9389 Å
Atomic weight	207.21

Specimens of lead are known having atomic weights differing considerably from that given above. Such varieties are derived from radioactive ores or produced in atomic pile reactions. Lead isotopes vary in atomic weights from 201 to 216.

Atomic volume18.27

ValenceUsually 2, sometimes 4 or 1

Weight and Density**Density:**

Cast lead, 20° C.....11.34 g. per c.c.

Rolled, 20° C.....11.35 to 11.37 g. per c.c.

Just solid, 327.4° C.....11.005 g. per c.c.

Just liquid, 327.4° C.....10.686 g. per c.c.

Density of molten lead in g. per c.c.:

Temp. °C.	Density	Temp. °C.	Density	Temp. °C.	Density	Temp. °C.	Density
327.4	10.686	411	10.583	529	10.423	650	10.265
331	10.663	416	10.558	555	10.382	694	10.219
345	10.642	459	10.507	577	10.360	717	10.200
356	10.632	486	10.475	580	10.354	731	10.188

Density, vapor (Hydrogen 1), calculated103.6

Weight:

Cast lead, 20° C., calculated.....0.4092 lb. per cu. in.

equivalent to707 lb. per cu. ft.

Rolled, 20° C. (density 11.37), calculated

.....0.4103 lb. per cu. in.

equivalent to709 lb. per cu. ft.

Liquid, 327.4° C., calculated.....0.3854 lb. per cu. in.

equivalent to666 lb. per cu. ft.

Sheet lead, 1 ft. square by $\frac{1}{8}$ in.

thickapproximately 1 lb.

Volume of 1 lb. cast lead, 20° C.,

calculated2.44 cu. in.

Thermal Properties

Melting point, common lead.....327.4° C. (621° F.)

Melting point, chemical lead.....325.6° C. (618° F.)

Elevation of melting point for each

150 atm. increase in pressure.....1.2° C. (2.16° F.)

Recrystallization temperaturebelow 0° C. for 99.999% Pb

125° C. for chemical lead

Casting temperature790 to 830° F.

THERMAL DATA *

	Antimony	Lead	Tin	Babbitt 75-10-15 Pb-Sn-Sb	Babbitt 80-10-10 Pb-Sn-Sb	Type metal 86-3-11 Pb-Sn-Sb
Composition						
Mean specific heat, 60° F. to melting point, point, B.t.u./lb./°F.	0.054	0.032	0.069	0.039	0.038	0.036
Heat in solid at melting point, B.t.u./lb.....	59.7	18.0	26.9	15.8	20.5	15.3
Latent heat of fusion, B.t.u./lb.....	70.0	9.9	24.9	26.2	17.4	21.5
Total heat in liquid at melting point, B.t.u./ lb.	129.7	27.9	51.8	42.0	37.9	36.8
Mean specific heat of liquid, B.t.u./lb./°F...	0.054	0.032	0.060	0.038	0.037	0.036
Average pouring temperature, °F.....	1,320	720	650	625	820	620
Total heat in liquid at pouring temperature, B.t.u./lb.	138.0	31.1	63.8	48.2	46.0	41.6

* Mostly based on data taken from Industrial Gas Series, "Combustion," American Gas Ass'n, 1932.

Boiling point at different pressures:

Pressure, in atmospheres.	0.14	0.35	1.0	6.3	11.7
Boiling point, °C.....	1325	1410	1525	1873	2100
Boiling point, °F.....	2417	2570	2777	3403	3812

Vapor pressure:

Temperature, °C.	808	1000	1200	1365	1525	1870	2100
Pressure, mm.Hg.	0.08	1.77	23.29	166.	760.	6.3 atm.	11.7 atm.

Specific heat (cal. per g.):

Temp., °C.	Specific heat	Temp., °C.	Specific heat	Temp., °C.	Specific heat
-150	0.02805	50	0.0309	liquid 327.4	0.0333
-100	0.02880	100	0.0315	378	0.0338
		200	0.0325		
- 50	0.0298	300	0.0338	418	0.0335
0	0.0303	(solid) 327.4	0.0340	459	0.0335

Latent heat of fusion.....6.26 cal. per g. or 11.27 B.t.u. per lb.

To melt 1 lb. of lead heating

from 20° C. requires.....7100 g. cal. or 28.2 B.t.u.

Latent heat of vaporization..202 cal. per g.

Relative thermal conductivity

(silver 100)8.2

Thermal conductivity (cal./cm.²/cm./°C./sec.):

Temp., °C		Temp., °C		Temp., °C	
-247.1	0.117	100	0.081	400	0.038
-160	0.092	200	0.077	500	0.037
0	0.083	300	0.074	600	0.036

Heat contents of lead in B.t.u. at various temperatures up to 1700° F. appear on page 134.

Coefficient of expansion:

Linear (-190 to 19° C. mean).....0.0000265 per deg. C.

Linear (17 to 100° C. mean).....0.0000293 per deg. C.

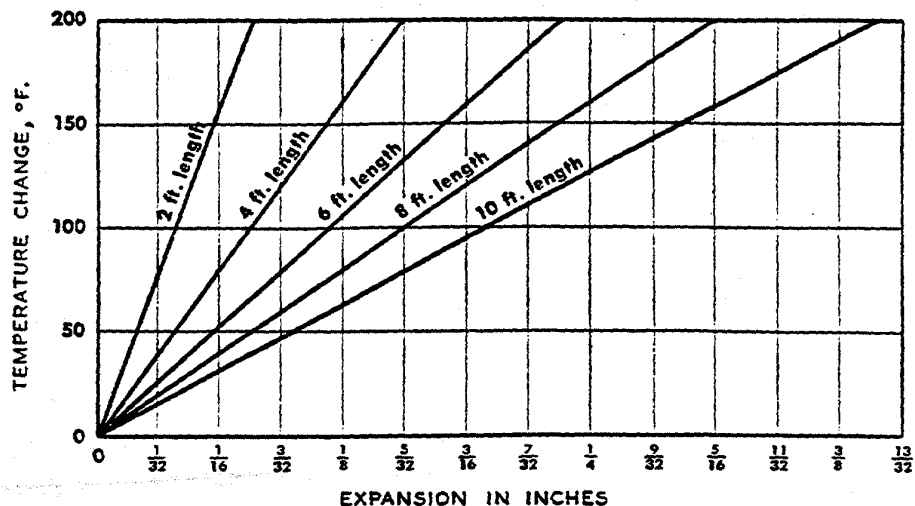
or 0.0000163 per deg. F.

Cubical (liquid at melting point to

357° C.)0.000129 per deg. C.

Cubical (17 to 100° C.).....0.0000879 per deg. C.

Expansion of sheet lead:



(A graph showing the expansion of antimonial or "hard" sheet lead appears on page 88.)

Increase in volume from 20° C. to liquid

at melting point.....6.1 percent

Decrease in volume from liquid at melting

point to 20° C., calculated.....5.8 percent

Increase in volume on melting.....4.01 percent

Decrease in volume on solidification.....3.85 percent

Shrinkage on casting taken in practice as $\frac{7}{64}$ to $\frac{5}{16}$ in. per ft.

Coefficient of heat transfer (theoretical overall value) for bonded lead covered copper pipe:

$$U = \frac{1}{\frac{X}{K} + \frac{1}{h_1} + \frac{1}{h_2} + \frac{Y}{K_1}}$$

where:

U = theoretical overall coefficient of heat transfer,
B.t.u./hr./sq. ft./°F.,

K = conductivity of lead wall per inch (use 240),

K₁ = conductivity of copper wall per inch (use 2680),

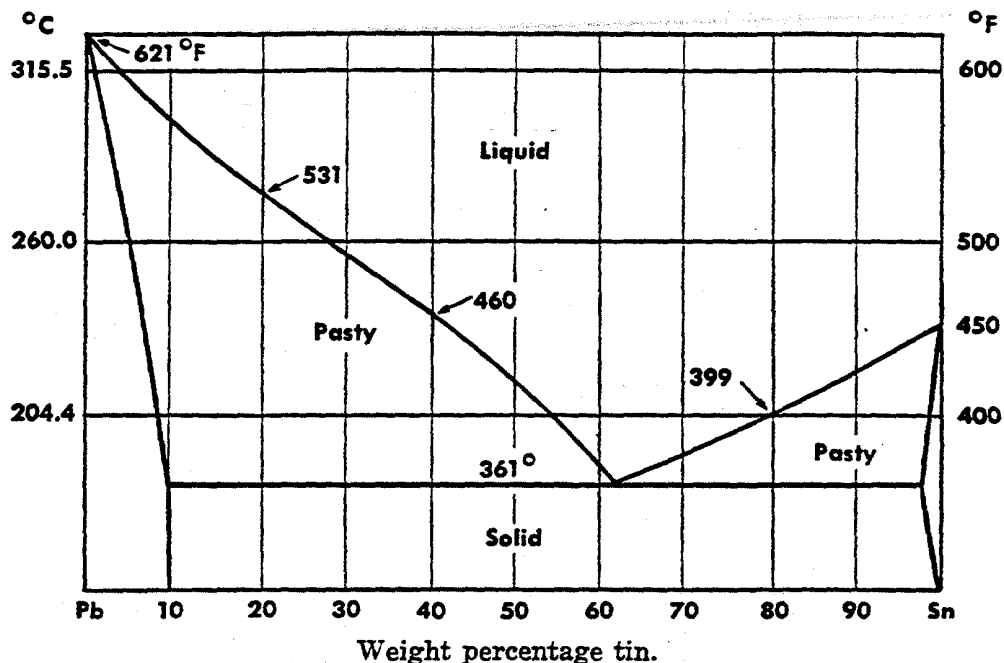
X = thickness of lead wall in inches,

Y = thickness of copper wall in inches,

h₁ = steam film (use 1000), and,

h₂ = liquid film (film 300).

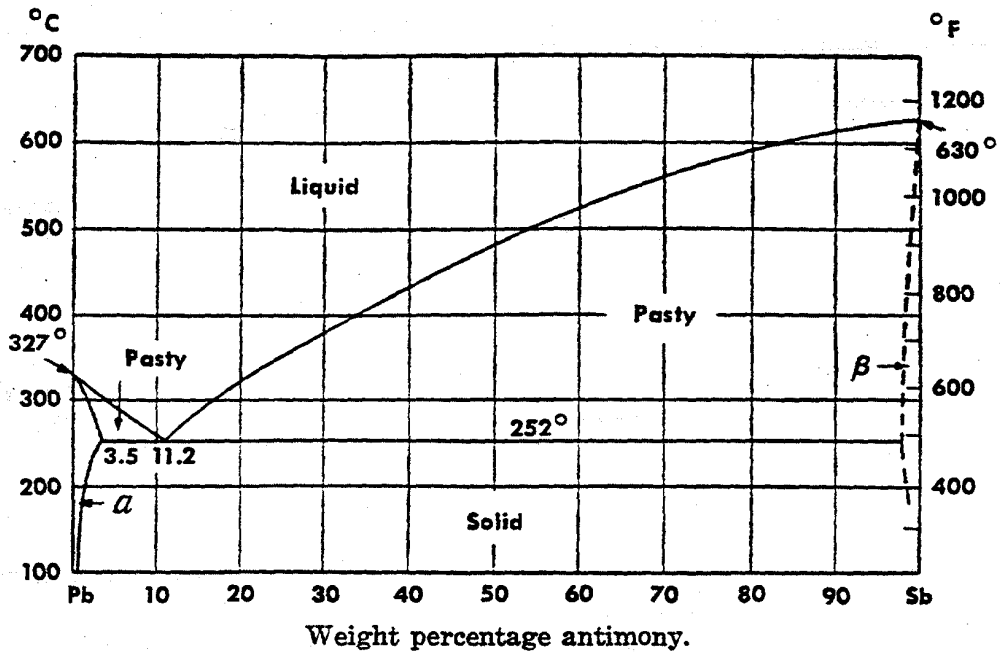
Tin-lead phase diagram:



Tin. percent	Lead, percent	A Solidus, °F	B Liquidus, °F	(B-A) Pasty range, °F
0	100.0	621	621	0
5.0	95.0	518 *	594	76 *
10.0	90.0	361 *	570	209 *
15.0	85.0	361 *	550	189 *
20.0	80.0	361 *	531	170
25.0	75.0	"	511	150
30.0	70.0	"	491	130
35.0	65.0	"	477	116
40.0	60.0	"	460	99
45.0	55.0	"	441	80
50.0	50.0	"	421	60
55.0	45.0	"	399	38
60.0	40.0	"	374	13
62.0	38.0	"	361	0
65.0	35.0	"	367	6
70.0	30.0	"	378	17
75.0	25.0	"	387	26
80.0	20.0	"	399	38
85.0	15.0	"	410	49
90.0	10.0	"	423	62
95.0	5.0	"	435	74
100.0	0	450	450	0

* These are preferred values for engineering purposes but are not equilibrium values. At equilibrium the eutectic limits are 19.5—98 percent tin.

Antimony-lead phase diagram:



Eutectics of lead:

Melting point of eutectics of lead with other metals:

Other metal	Percent by weight	Temp., °C.
Silver .....Ag	2.3	304
Arsenic .....As	2.8	292
Gold .....Au	15	215
Barium .....Ba	4.5	291
Bismuth .....Bi	56.5	125
Cadmium .....Cd	17.4	248
Magnesium .....Mg	3	250
Palladium .....Pd	5	265
Platinum .....Pt	5	290
Antimony .....Sb	12.5	251
Tin .....Sn	62	183
Zinc .....Zn	.5	318

Low Temperature Properties

At low temperatures soft solders that contain a high percentage of lead retain their ductility and increase in impact strength. When the percentage of tin reaches 50 percent, serious embrittlement and decrease in impact strength occur. Tin contents up to 15 percent have no serious embrittling effect. The tensile strength of solder alloys and the breaking load of soldered joints increases proportionally as the temperature is lowered. The solder containing the most tin (50 percent) shows the greatest increase in strength and the solder with the most lead (97.5 percent) shows the least increase in strength.

Unalloyed lead shows no visible or otherwise detectable effects at temperatures in the range of those to be encountered in the Arctic, for example, therefore no special care is required for the maintenance of lead or high lead base alloys. Lead base bearing alloys could be expected to behave in a manner similar to that of the various solder alloys.

The Bureau of Standards has reported the following results from some of their investigations, all based on pure lead.

CAST LEAD

Temperature, °F.	Tensile strength, psi	Elongation, percent	Brinell	Impact
Room	3000	33	4.3	2.3
-300	6200	40	9.0	3.8

ROLLED LEAD

59	3600	52	—	—
- 4	7200	40	—	—
- 40	13300	31	—	—
-103	15200	24	—	—

Mechanical Properties

Hardness, Moh's scale.....1.5

Brinell number, 1 cm. ball, 30 sec., 100 kg. load:

Common lead3.2 to 4.5

Chemical lead4.5 to 6.0

Influence of temperature on Brinell hardness (chemical lead) :

Temperature, °C.	25	100	150
Hardness	5.3	3.6	2.6

Ultimate tensile strength:

Common lead	1400 to 1700 lb. per sq. in.
Chemical lead	2300 to 2800 lb. per sq. in.

Effect of temperature on tensile properties (lead annealed at 100° C.) :

Temperature		Tensile strength, lb. per sq. in.	Elongation, percent	Reduction in area, percent
°C.	°F.			
20	68	1920	31	100
82	180	1140	24	100
150	302	710	33	100
195	383	570	20	100
265	509	280	20	100

Tensile strength and elongation:

(Laboratory rolled specimens, room temperature, pulling speed $\frac{1}{4}$ in. per min. per in. of test section)

Grade of lead	Tensile strength, lb. per sq. in.	Elongation, percent
Common (99.85+0.13 Bi)	1931	34.4
Corroding (99.99+0.006 Bi)	1904	37.7
Common (99.98+no Bi)	2093	43.0
Chemical (99.92+0.06 Cu)	2961	42.2
Chemical (Commercial sheet)	2454	57.0
Chemical (Extruded)	2200	48.0

Resistance to bending:

(Extruded strips under 200 lb. per sq. in. stress subjected to alternate 90° reverse bends over 5-in. rolls, 11 cycles per min.)

Grade of lead	Cycles to failure	Elongation, percent
Common	72	49
Chemical	103	52
Corroding	54	35

Maximum allowable fibre stress in extruded pipe:

Temperature		Equivalent steam gage pressure lb. per sq. in.	Maximum allowable fibre stress, lb. per sq. in.	
°C.	°F.		Chemical lead	6 percent antimonial lead
20	68		200	400
30	86		190	370
40	104		180	340
50	122		172	310
60	140		162	280
70	158		153	254
80	176		144	222
90	194		136	195
100	212	0	127	165
110	230	6	118	137
120	248	14	110	110
130	266	24	100	80
140	284	37	90	50
150	302	54	80	—
247	477	535	—	0
327	621	—	0	—

To calculate safe working pressure of lead pipe, use formula

$$P = \frac{2ST}{D} \text{ or } T = \frac{PD}{2S}$$

where P=safe working pressure in lb. per sq. in.

S=maximum allowable fibre stress from above table.

T=thickness of pipe wall in inches.

D=inside diameter of pipe in inches.

For mechanical or structural reasons, it is sometimes wise to allow additional wall thickness above that derived from this formula. Likewise in chemical installations where considerable corrosion may be anticipated, extra allowance should be made.

For calculating the safe working pressure of circular ends of thin-walled cylinders use

$$T = \frac{PD}{4S}$$

Elastic limit 200 lb. per sq. in.

Young's modulus 2,000,000 lb. per sq. in.

Bulk modulus 0.44×10^{12} dynes per sq in.

Poisson's ratio of transverse contraction to longitudinal extension under tensile strength 0.4 to 0.45
Compressibility, 20° C., per unit volume per megabar..... 2.2 to 2.5 x 10⁻⁶

CREEP

Creep, room temperature:

Stress, lb. per sq. in.	Creep, percent per hour	
	Common lead	Chemical or copper lead
200	5 x 10 ⁻⁵	0.4 x 10 ⁻⁵
300	3.5 x 10 ⁻⁴	1.5 x 10 ⁻⁵
400	11 x 10 ⁻⁴	3 x 10 ⁻⁵

Creep, 150 deg. F., chemical or copper lead:

Stress, lb. per sq. in.	Creep, percent per hour
200	6 x 10 ⁻⁴
300	50 x 10 ⁻⁴
400	230 x 10 ⁻⁵

Tensile stress, lb. per sq. in.	Creep, percent in one year			
	Lead	Lead +2.0 tin	Lead +0.75 antimony	Lead +0.04 calcium
100	0.2	—	—	—
200	0.8	0.6	0.4	0.2
300	1.7	1.1	0.6	0.3
400	4.0	2.0	1.0	0.5
500	—	3.3	1.4	0.7
600	—	—	1.9	1.0
700	—	—	2.5	1.3
800	—	—	—	1.7

FATIGUE

Fatigue limit (50,000,000 cycles) extruded.... 215 lb. per sq. in.

Metal	Endurance limit at 5 x 10 ⁷ cycles, lb. per sq. in.	Endurance limit at 10 ⁷ cycles, lb. per sq. in.
Lead	215- 400	470
Lead+0.026 percent calcium		1038
Lead+0.038 percent calcium	685- 840	
Lead+0.04 percent calcium	820-1500	
Lead+0.041 percent calcium		1180
Lead+0.06 percent calcium	1120	
Lead+1 percent antimony	300-1000	
Lead+2 percent tin	800	
Lead+0.06 percent copper	600	725
Lead+ { 0.045 percent tellurium		1000
0.06 percent copper		

Electrical Properties

Electrical resistivity:

Temp., °C.	Resistivity, micro-ohms per c.c.	Temp., °C.	Resistivity, micro-ohms per c.c.	Temp., °C.	Resistivity, micro-ohms per c.c.
20	20.648	180	34.413	330	96.735
40	22.084	200	36.478	340	97.867
60	23.645	220	38.542	360	99.000
80	25.285	240	40.697	380	100.255
100	27.021	260	42.791	400	101.418
120	28.787	280	44.946	420	102.563
140	30.582	300	47.938	440	103.716
160	32.468	320	54.761	460	104.878

Temperature coefficient of electrical resistivity:

Temp., °C.	Temp. coef. of elec. resist.	Temp., °C.	Temp. coef. of elec. resist.	Temp., °C.	Temp. coef. of elec. resist.
20-40	0.00336	180-200	0.00291	330-340	0.00116
40-60	0.00341	200-220	0.00275	340-360	0.000576
60-80	0.00335	220-240	0.00273	360-380	0.000570
80-100	0.00332	240-260	0.00251	380-400	0.000577
100-120	0.00311	260-280	0.00246	400-420	0.000561
120-140	0.00302	280-300	0.00322	420-440	0.000559
140-160	0.00299	300-320	0.00665	440-460	0.000558
160-180	0.00293	320-330	0.0554		

Specific electrical conductance:

at 0° C. 5.05×10^4 cm.⁻¹ ohms.⁻¹
 18° C. 4.83
 melting point 1.06

Atomic electrical conductance, calculated. 1.139×10^6

Relative electrical conductance (copper
 100) 7.82

Relative electrical resistance (copper
 100) 1280

Lead is diamagnetic

Magnetic susceptibility, per g.,

18-330° C. -0.12×10^{-6}
 300-600° C. -0.08×10^{-6}

Electrolytic solution pressure:

ions of Pb ++ 6.3×10^{-5} atm.
 ions of Pb ++++ 3.0×10^{-74} atm.

Electrochemical equivalents:

Valence	Mg. per coulomb	Coulombs per mg.	G. per amp. hr.
2	1.0736	0.9314	3.8651
4	0.5368	1.8628	1.9326

Electrodeposition, to deposit 1 lb. of lead requires117 amp. hr.

Electrode potential of lead at 25° C.:

with normal calomel electrode.....0.403 v.

with normal hydrogen electrode.....0.122 v.

Thermoelectric strength against platinum.... +0.44 mv. per °C.

Galvanic or electrochemical series:

In the following list, each metal is electropositive to all that precede it, i.e., two metals in contact in the presence of an electrolyte form a galvanic couple which tends to cause the more electropositive to be dissolved by electrolysis:

Column headed "cobalt" follows column ending "Indium."

CORRODED END (Anodic, or least noble)

Caesium
Lithium
Rubidium
Potassium
Calcium
Sodium
Magnesium
Magnesium alloys
Beryllium
Aluminum
Manganese
Zinc
Aluminum 2S
Chromium
Gallium
Aluminum 17 ST
Iron or steel
Cast iron
Chromium—iron (Active)
18—8 Stainless (Active)
18—8—3 Stainless (Active)
Cadmium
Indium

Cobalt
Nickel (Active)
Inconel (Active)
Tin
Lead-tin
Lead-antimony
Lead
Brasses
Hydrogen
Antimony
Bismuth
Arsenic
Copper
Mercury
Bronzes
Copper-nickel
Monel
Silver solder
Silver
Graphite
Palladium
Platinum
Gold
PROTECTED END (Cathodic,
or most noble)

Miscellaneous Properties

Optical constants, solid lead, for λ of 0.589μ (yellow) :

Refractive index	2.01
Absorption	3.48
Reflection	62 percent

Stopping power, s , for alpha rays is approximately proportional to the square root of atomic weight, w :

s (air 1)	4.27
$\sqrt{w}$ (air 1)	3.78

Coefficient of absorption of beta or gamma rays is approximately proportional to the density.

For thickness of lead for radiation protection see page 100.

Velocity of sound in lead	122,700 cm. per sec.
equivalent to	4,026 ft. per sec.

Surface tension:

at melting point 327.4°C	444 dynes per cm.
350°C	442 dynes per cm.
400°C	438 dynes per cm.
500°C	431 dynes per cm.

Comparative Data

Metal	Atomic weight	Specific gravity	Melting point		Hardness, Moh's scale
			$^\circ \text{C}$.	$^\circ \text{F}$.	
Aluminum	26.97	2.70	659.7	1214.6	2.0
Antimony	121.76	6.62	630.5	1166.9	3.3
Arsenic	74.91	5.73	850.0	1562.0	3.5
Bismuth	209.0	9.80	271.0	519.8	2-2.5
Cadmium	112.41	8.65	320.9	609.6	2.0
Calcium	40.08	1.55	810.0	1564.0	1.5
Copper	63.57	8.94	1083.0	1981.4	2.5-3
Iron	55.84	7.70	1535.0	2795.0	4-5
Lead	207.21	11.35	327.4	621.2	1.5
Nickel	58.69	8.85	1452.0	2640.0	4-4.5
Silver	107.88	10.5	960.5	1760.9	2.5-3
Tin	118.70	7.30	232.0	449.6	1.5
Zinc	65.38	7.14	419.45	787.0	2.5

PROPERTIES OF EXTRUDED ANTIMONIAL LEAD ROD

Antimony, percent	Tensile strength, lb. per sq. in.	Elongation, percent	Brinell hardness
0	1740	110	4.0
1	2920	58	5.1
2	3200	56	6.5
3	3100	55	7.7
4	3100	58	8.9
5	3150	59	9.9
6	3300	65	10.7
7	3240	68	11.4
8	3330	75	12.4
9	3400	76	12.8
10	3700	64	13.7
11	3800	74	13.7
12	3800	65	14.3
13	4000	57	14.6
14	3930	48	14.6

Note: These properties may vary considerably depending upon temperature of extrusion, rate of cooling and time of aging.

PROPERTIES OF COLD ROLLED ANTIMONIAL LEAD SHEET

(95 percent reduction)

Antimony, percent	Tensile strength, lb. per sq. in.		Elongation, percent	
	As cold rolled	1 day after heat treatment *	As cold rolled	1 day after heat treatment *
4	4020	11670	48.5	6.3
6	4100	12650	47.0	3.2
8	4650	12350	31.3	4.7

Antimony, percent	Brinell hardness					
	Aged without heat treatment			Heat treated * and aged		
	1 day	104 days	7½ years	1 day	104 days	7½ years
4	8.1	8.6	8.3	24.3	22.8	18.4
6	8.6	9.0	9.0	23.5	21.2	17.4
8	9.5	10.1	10.0	26.3	24.0	19.9

* Heat treated at 235° C., quenched and aged at room temperature.

TENSILE STRENGTH OF LEAD-CALCIUM ALLOYS

Percent	Tensile strength, lb. per sq. in.		
	Cast and aged	Quenched and aged	Quenched
0.	—	2250	2000
0.04	5250	5150	3000
0.08	7500	7250	3750
0.12	8200	8000	4600
0.16	7750	7000	5100
0.20	7350	6200	5400
0.24	6900	5800	4500

PROPERTIES OF CAST LEAD-ANTIMONY ALLOYS

Anti- mony, percent	Density	Liquidus, °F.	Solidus, °F.	Tensile strength, lb. per sq. in.	Elongation, percent	Brinell hardness	Expansivity coefficient
0	11.35	621	—	2500	45	4.0	0.0000293
1	11.26	612	603	3400	16	7.0	0.0000288
2	11.18	602	559	4200	16	8.0	0.0000284
3	11.10	590	516	4700	15	9.1	0.0000281
4	11.03	578	495	5660	22	10.1	0.0000278
5	10.95	565	"	6360	29	11.0	0.0000275
6	10.88	552	"	6840	24	11.8	0.0000272
7	10.81	539	"	7180	21	12.5	0.0000270
8	10.74	527	"	7420	19	13.3	0.0000267
9	10.66	515	"	7580	17	14.0	0.0000264
10	10.59	505	"	7670	15	14.6	0.0000261
11	10.52	496	"	7620	13	14.8	0.0000258
12	10.52	489	"	7480	12	15.0	0.0000256
12.5	10.42	485	"	7380	11	15.1	0.0000254
13	10.38	492	"	7280	10	15.2	0.0000253
14	10.30	506	"	7000	9	15.3	0.0000251

PROPERTIES OF LEAD-TIN ALLOYS

Percent tin	Density at 20° C., g. per c.c.	Tensile strength, lb. per sq. in.		Elongation, percent		Reduction of area, percent		Brinell hardness, chill castings at 20° C.	Thermal conductivity, watts per cm. per °C.	Electrical resistivity, microhms per cm.
		at 25° C.	at 150° C.	at 25° C.	at 150° C.	at 25° C.	at 150° C.			
5	11.0	3200	1500	55	65	75	90	8.0	0.35	19.5
10	10.7	4100	2100	45	35	50	70	11.5	0.36	18.9
15	10.4	4900	2000	15	20	25	30	12.0	0.37	18.2
20	10.1	5400	1900	25	70	50	60	11.7	0.38	17.8
30	9.7	6200	1900	40	120	75	90	12.4	0.39	17.0
40	9.3	6600	1900	60	140	75	95	13.0	0.41	16.2
50	8.9	7000	1900	60	145	60	95	14.3	0.45	15.5
60	8.6	7200	1800	50	140	40	100	10.7	0.49	15.0

* Balance lead.

LEAD-TIN-ANTIMONY ALLOYS

Mechanical Properties ¹

Lead (by dif.), percent	Tin, percent	Antimony, percent	Yield point, lb. per sq. in.	Tensile strength, lb. per sq. in.	Elongation, percent	Compression load required to compress to half length
88.0	4.1	7.9	4,800	5,400	1.5	28,448
86.5	8.6	4.9	4,800	7,220	3.0	N.O.
81.8	13.1	5.1	6,010	7,500	2.0	N.O.
76.8	14.8	8.4	6,300	6,900	1.0	N.O.
72.6	22.1	5.3	N.O.	5,400	—	19,920
65.7	28.7	5.6	6,610	8,400	1.5	N.O.
85.2	4.6	10.2	8,990	13,820	10.5	28,200
82.0	8.9	9.1	8,660	14,400	13.0	24,640
75.1	14.7	10.2	8,400	14,400	5.5	N.O.
71.0	18.6	10.4	8,990	11,400	1.5	20,150 C.
66.8	23.0	10.2	8,400	12,000	1.0	N.O.
79.6	4.5	15.9	6,900	11,690	4.0	N.O.
77.1	8.6	14.3	Broken in machining			26,000
66.4	19.0	14.6	7,800	12,000	—	23,980 S.C.
66.0	18.9	15.1	7,800	12,000	1.5	21,720 S.C.
70.1	4.6	25.3	Broken in machining			28,000 S.C.
68.8	9.1	22.1	10,180	10,180	—	21,950 *
64.1	13.9	22.0	9,600	11,400	—	22,400 *
72.2	4.5	23.3	7,800	—	—	19,700 *
65.0	10.0	25.0	Broken in machining			18,590 *
64.2	5.9	29.9	8,400	12,580	1.0	14,500 *

N.O.—Not observed; C.—Cracks in compression test piece; S.C.—Slight cracks in compression test piece; *—Failure in compression test piece.

¹ O. W. Ellis, Note on Lead-Tin-Antimony Alloys, J. Inst. Metals, 1918, v. 10, No. 1, p. 151.

COMPOSITION AND PHYSICAL PROPERTIES^a OF WHITE METAL BEARING ALLOYS

Alloy grade ^b	Specified nominal composition of alloys				Specific gravity ^c	Compositions of alloys tested				Yield point, psi. ^e		Johnson's apparent elastic limit, psi. ^f		Ultimate strength in compression, psi. ^g		Brinell hardness ^h		Melting point		Temperature of complete liquefaction	
	Tin, percent	Antimony, percent	Lead, percent	Copper, percent		Tin, percent	Antimony, percent	Lead, percent	Copper, percent	20 C.	100 C.	20 C.	100 C.	20 C.	100 C.	20 C.	100 C.	Deg. Fahr.	Deg. Cent.	Deg. Fahr.	Deg. Cent.
No. 1..	91.0	4.5	....	4.5	7.34	90.0	4.52	none	4.50	4400	2050	2450	1050	12850	6950	17.0	8.0	433	223	700	371
No. 2..	89.0	7.5	....	8.5	7.30	89.2	7.4	0.03	3.1	6100	3000	3350	1100	14900	8700	24.5	12.0	460	241	669	354
No. 3..	83.33	8.33	....	8.33	7.40	83.4	8.2	0.03	8.3	6000	3150	5350	1300	17600	9900	27.0	14.5	464	240	702	434
No. 4..	75.0	12.0	10.0	3.0	7.52	75.0	11.0	10.2	3.0	5550	2150	3200	1550	10150	6900	24.5	12.0	363	184	583	306
No. 5..	65.0	15.0	18.0	2.0	7.75	65.5	14.1	18.2	2.0	5050	2150	3750	1500	15050	6750	22.5	10.0	358	181	505	268
No. 6..	20.0	15.0	63.5	1.5	9.33	19.8	14.0	63.7	1.5	3800	2050	3550	1800	14550	8050	21.0	10.5	358	181	531	278
No. 7..	10.0	15.0	75.0	....	9.73	10.0	14.5	75.0	0.11	3550	1600	2500	1350	15050	6150	22.5	10.5	404	210	614	207
No. 8..	5.0	15.0	80.0	....	10.04	5.2	14.0	79.4	0.14	8400	1750	2050	1200	15000	6150	20.0	9.5	459	237	522	273
No. 10..	2.0	15.0	83.0	....	10.07	2.05	15.7	82.0	0.12	3350	1850	2250	1200	15450	5750	17.5	9.0	408	242	507	265
No. 11..	....	15.0	85.0	....	10.28	0.09	14.8	84.7	0.19	3050	1400	2750	1100	12800	5100	15.0	7.0	471	244	504	262
No. 12..	....	10.0	90.0	....	10.67	0.11	9.9	89.4	0.12	2800	1250	2250	950	12900	5100	14.5	6.5	473	245	498	260
No. 15 ^c .	1.0	15.0	82.5	0.5	10.05	....	....	....	....	....	....	....	....	....	....	....	....	470	248	538	283
No. 16..	10.0	12.5	77.0	0.5	9.88	....	....	....	....	....	....	....	....	....	....	27.5	13.6	471	244	495	265
No. 19..	5.0	9.0	86.0	....	10.50	....	....	....	....	....	....	....	....	15000	6100	17.7	8.0	402	230	495	265

^a The compression test specimens were cylinders 1.5 in. in length and 0.5 in. in diameter, machined from chill castings 2 in. in length and 1 in. in diameter. The Brinell tests were made on the bottom face of parallel machined specimens cast in a 2-in. diameter by 0.025-in. deep steel mold at room temperature.

^b Alloy grade No. 9 was discontinued in 1910.

^c Also nominal arsenic 1.0 percent.

^d The specific gravity multiplied by 0.0301 equals the density in pounds per cubic inch.

^e The values for yield point were taken from stress-strain curves at a deformation of 0.125 percent reduction of gage length.

^f Johnson's apparent elastic limit is taken as the unit stress at the point where the slope of the tangent to the curve is $\frac{1}{2}$ times its slope.

^g The ultimate strength values were taken as the unit load necessary to produce a deformation of 25 percent of the length of the specimen.

^h These values are the average Brinell number of three impressions on each alloy using a 10-mm. ball and a 500-kg. load applied for 30 sec.

From A.S.T.M. Standards, Designation B 28-48T. Appendix.

COMPOSITION AND PROPERTIES OF LEAD ALLOYS FOR DIE CASTING

ASTM Designation	No. 4	No. 5	Bearing Alloy	"C.T." Metal
COMPOSITION %				
Lead	79 to 81	89 to 91	80	85 to 87
Tin	4 to 6	—	5	0.65
Antimony	14 to 16	9.25 to 10.75	15	12.50
Copper, max.	0.50	0.50	—	—
Arsenic, max.	0.15	0.15	—	0.65
Zinc, max.	0.01	0.01	—	—
Aluminum, max.	0.01	0.01	—	—
PROPERTIES AND CONSTANTS				
Tensile Strength, p.s.i.....	13,800	12,500	9,100	9,800
Impact Strength, Izod, ft. lb.....	0.6	0.4	0.8	0.2
Elongation, % in 2 in.....	10.5	2.0	3.8	5.5
Brinell Hardness	23.2	24.1	23.2	18.0
Specific Gravity	10.24	9.73	10.12	10.38
Weight, lb./cu. in.....	0.370	0.351	0.365	0.379
Melting Range, F.....	459-493	464-514	462-500	473-504
Solidification Shrinkage in./in.....	0.002	—	—	—
Corrosion Resistance	Good	Good	Good	Good
Bearing Qualities	Good	Good	Good	Fair

CHAPTER TWENTY-EIGHT

Physical Constants of Lead Compounds

THERE are literally hundreds of compounds of lead, both inorganic and organic, many of which are important contributors to modern living. The manufacture, use, and physical constants of some of the more familiar lead compounds have been described in detail in earlier chapters of this book; the rest of them will be covered here.

The available data for practically all inorganic lead compounds, lead salts of organic acids and organic lead compounds are presented in the following tables. Molecular weights are rounded off to the nearest hundredth. Specific gravity is given at 20° C. referred to water at 4° C. with other temperatures indicated by superior and inferior figures. The normal specific gravity is numerically equivalent to density in grams per milliliter. The boiling point is stated at normal atmospheric pressure (760 mm. of Hg) unless otherwise indicated by a superscript. The tables begin with the inorganic compounds of lead and lead salts of organic acids and on page 217 take up the organic compounds of lead.

PHYSICAL CONSTANTS OF LEAD COMPOUNDS INORGANIC COMPOUNDS OF LEAD

Name	Formula	Molecular weight	Crystalline form color index of refraction	Specific gravity	Melting point °C	Boiling point °C	Solubility in 100 ml. of		
							Cold water	Hot water	Alcohol, acid, etc.
Lead	Pb	207.21	Cubical. Silvery blue-white soft metal.	11.3437 ¹⁶ 11.2884 ⁸ RaPb 11.206 ¹⁶ UPb.	327.43 to 327.5	1525	Insol.	Insol.	Sol. in HNO ₃ , hot conc. H ₂ SO ₄ and acetic acid.
Lead orthoantimonate	Pb ₃ (SbO ₄) ₂	993.15	Orange yellow powder.	6.58 ³⁷	....	....	Insol.	....	Insol. in dil. acids.
Lead pyroantimonate	Pb ₂ Sb ₂ O ₇	769.94	Dark yellow powder.	6.72	....	....	Insol.	Insol.	Very slightly sol. in HCl.
Lead arsenate, basic	10PbO·3As ₂ O ₅ ·3H ₂ O	2975.81	Hexagonal crystals.	6.86	....	....	....	....	.....
Lead arsenate, basic	Pb ₅ (PbPH) ₂ (AsO ₄) ₄	2461.62	....	7.08	....	....	....	....	.....
Lead arsenate, basic	2Pb ₃ (AsO ₄) ₂ ·2Pb(OH) ₂ ·10H ₂ O	2461.62	White solid.	7.1	....	....	....	....	.....
Lead diarsenate (Schultenite)	PbHAsO ₄	347.13	Monoclinic leaf 1.90 1.97.	5.79	Decompd. at 720.	Loses H ₂ O at 220.	Insol.	Slightly sol.	Sol. in HNO ₃ and caustic alkalis.

Lead meta-arsenate	$\text{Pb}(\text{AsO}_3)_2$	453.03	Hexagonal tablets.	6.42 ¹⁵	....	....	Decompd.	Decompd.	Sol. in acids and fixed alkalis.
Lead monoarsenate	$\text{Pb}(\text{H}_2\text{AsO}_4)_2$	489.06	Triclinic crystals 1.74 to 1.82.	4.46 ¹⁵	Decompd. at 140.	....	Decompd.	....	Sol. in HNO_3 and caustic alkalis.
Lead orthoarsenate	$\text{Pb}_2(\text{AsO}_4)_3$	899.45	White crystals.	7.80	1042 slightly decompd. at 1200.	....	Very slightly sol.	....	Sol. in HNO_3 and caustic.
Lead orthoarsenate	$\text{Pb}_2(\text{AsO}_4)_3 \cdot 0.5\text{H}_2\text{O}$	908.53	White solid.	7.00	....	....	....	....	.....
Lead orthoarsenate, basic	$5\text{PbO} \cdot \text{Pb}_2(\text{AsO}_4)_3$	2015.52	White solid.	....	862	....	....	....	.....
Lead orthoarsenate, basic	$5\text{PbO} \cdot \text{Pb}_2(\text{AsO}_4)_3 \cdot 0.5\text{H}_2\text{O}$	2024.53	White rhombic crystals.	8.04	....	....	....	....	.....
Lead pyroarsenate	$\text{Pb}_2\text{As}_2\text{O}_7$	676.24	Rhombic crystals BO. 203.	6.8518	802	....	Insol.	Decompd.	Sol. in HCl or HNO_3 . Insol. in acetic acid.
Lead orthoarsenite	$\text{Pb}_2(\text{AsO}_2)_3 \cdot x\text{H}_2\text{O}$	872.45 X18	White powder, bulky.	5.85	....	....	Insol.	....	Sol. in HNO_3 and fixed alkalis.

PHYSICAL CONSTANTS OF LEAD COMPOUNDS—Continued INORGANIC COMPOUNDS OF LEAD—Continued

Name	Formula	Molecular weight	Crystalline form color index of refraction	Specific gravity	Melting point °C	Boiling point °C	Solubility in 100 ml. of		
							Cold water	Hot water	Alcohol, acid, etc.
Lead azide	$\text{Pb}(\text{N}_3)_2$	291.26	Colorless needles.	....	Explodes at 350.	....	0.023 ¹⁸	0.09 ⁷⁰	Very sol. in acetic acid. Insol. in NH_4OH .
Lead metaborate	$\text{Pb}(\text{BO}_2)_2 \cdot \text{H}_2\text{O}$	310.87	White cryst. powder.	5.598 anhydrous.	....	Loses water at 160.	Insol.	Insol.	Sol. in acids. Insol. in alkalis or alc.
Lead borofluoride	$\text{Pb}(\text{BF}_4)_2$	380.85	Prismatic crystals.	....	....	....	Partially decompd.	....	Partially decomposed by alc.
Lead bromate	$\text{Pb}(\text{BrO}_3)_2 \cdot \text{H}_2\text{O}$	481.00	Colorless monoclinic crystals.	5.53	Decompd. at 180.	....	1.38 ²⁰	Sol.	.....
Lead bromide	PbBr_2	367.04	White rhombic crystals.	6.06	373	916 to 918.	0.4554 ⁰ 0.8441 ²⁰	4.71 ¹⁰⁰	Sol. in acids and KBr. Slightly sol. in NH_3 . Insol. in alc.
Lead bromide, basic	$\text{PbO} \cdot \text{PbBr}_2 \cdot \text{H}_2\text{O}$	608.24	Rhombic crystals.	6.22 ²⁰	....	....	....	....	.....
Lead sub-bromide	PbBr	287.13	.....	....	....	....	....	....	.....
Lead carbonate (Cerussite)	PbCO_3	267.22	Colorless rhombic crystals. 1.804: 2.076: 2.078.	6.6	Decompd. at 315.	....	0.00011 ²⁰	Decompd.	Sol. in acids and alkalis. Insol. in NH_3 and alc.
Lead carbonate, basic (White lead) (Hydrocerussite)	$2\text{PbCO}_3 \cdot \text{Pb}(\text{OH})_2$	775.07	White hexagonal crystals of amorphous powder. 2.09: 1.91.	6.14	Decompd.	....	Insol.	Insol.	Sol. in acids and fixed alkalis. Slightly sol. in aqueous CO_2 . Insol. in alc.

Lead carbonate, basic	$4\text{PbCO}_3 \cdot 2\text{Pb(OH)}_2 \cdot \text{PbO}$	1774.55	White.	....	Decompd.	....	Insol.	Insol.	Sol. in acids and fixed alkalis. Insol. in alc.
Lead chlorate, anhydrous	$\text{Pb(ClO}_3)_2$	374.12	White monoclinic crystals.	374.12	Decompd.	....	Very sol.	....	Sol. in alc.
Lead chlorate	$\text{Pb(ClO}_3)_2 \cdot \text{H}_2\text{O}$	392.14	Deliquescent white monoclinic crystals.	4.037	Decompd. at 110.	....	151.3	171	Sol. in alc.
Lead perchlorate	$\text{Pb(ClO}_4)_2 \cdot 3\text{H}_2\text{O}$	460.17	Rhombic crystals.	2.6	Decompd. at 110.	....	499.7 ²⁵	....	Sol. in alc.
Lead chloride (Plumbous chloride) (Cotunnite)	PbCl_2	278.12	White rhombic crystals. 2.100: 2.217: 2.260.	5.80 to 5.85	5.01	954 ^{700mm}	0.673 ^o	3.34 ¹⁰⁰	Slightly sol. in dilute HCl or NH_4a . Insol. in alc.
Lead subchloride	PbCl	242.67	.....	....	....	....	....	....	.....
Lead oxychloride (Matlockite)	$\text{PbCl}_2 \cdot \text{PbO}$ or Pb_2OCl_2	501.33	Tetragonal white crystals. 2.04: 2.15.	7.21	Decompd. at 524.	....	0.0005 ¹⁰	Insol.	Sol. in alkalis or boiling concd. HCl.
Lead oxychloride (Laurionite)	Pb(OH)Cl	519.35	Rhombic crystals.	6.24	Decompd. at 142.	....	....	....	.....
Lead oxychloride (Paralaurionite)	$\text{PbCl}_2 \cdot \text{PbO} \cdot \text{H}_2\text{O}$	519.35	Colorless to white monoclinic prisms. 2.140.	6.05 ¹⁸	Decompd. at 150.	....	....	....	.....
Lead oxychloride (Mendipite)	$\text{PbCl}_2 \cdot 2\text{PbO}$	724.54	Rhombic yellow crystals. 2.24: 2.27: 2.31.	7.08	603	....	Insol.	Insol.	Sol. in alkalis and concd. HCl.
Lead oxychloride	$\text{PbCl}_2 \cdot 3\text{PbO}$	947.75	Yellow solid.	....	....	....	0.0056 ¹⁸	0.07 ⁷⁴	.....
Lead oxychloride	$\text{PbCl}_2 \cdot 4\text{PbO}$	1170.96	Yellow solid.	....	....	....	....	....	.....

PHYSICAL CONSTANTS OF LEAD COMPOUNDS—Continued INORGANIC COMPOUNDS OF LEAD—Continued

Name	Formula	Molecular weight	Crystalline form color index of refraction	Specific gravity	Melting point °C	Boiling point °C	Solubility in 100 ml. of		
							Cold water	Hot water	Alcohol, acid, etc.
Lead oxychloride	$\text{PbCl}_2 \cdot 7\text{PbO}$	1840.59	Yellow crystalline solid or powder.	....	....	....	Insol.	....	.....
Lead oxychloride (Penfieldite)	$\text{PbO} \cdot 2\text{PbCl}_2$	779.42	Hexagonal crystals.	....	....	....	....	....	.....
Lead oxychloride (Lorettoite)	$6\text{PbO} \cdot \text{PbCl}_2$	1517.33	Tetragonal.	7.0 ²⁰	....	....	....	....	.....
Lead oxychloride (Fiedlerite)	$2\text{PbCl}_2 \cdot \text{PbO} \cdot \text{H}_2\text{O}$	797.447	Monoclinic crystals.	5.88 ²⁰	Decompd. at 150.	....	....	....	.....
Lead tetrachloride (Plumbic chloride)	PbCl_4	349.04	Yellow oily liquid.	3-18 ¹	-15	Explodes at 105.	Decompd. evolving Cl_2 .	Same as for cold water.	Sol. in concd. HCl .
Lead chloride sulphide (Lead sulphochloride)	$\text{PbCl}_2 \cdot 3\text{PbS}$	995.93	Red.	....	....	....	Insol.	Decompd.	Decompd. by acid or alkali. Insol. in dil. acid.
Lead chlorite	$\text{Pb}(\text{ClO}_2)_2$	342.12	Yellow monoclinic crystals.	....	Explodes at 126.	....	0.005 ²⁰	0.42 ¹⁰⁰	Sol. in alkali hydroxides.
Lead chlorobromide	PbClBr	322.57	.....	5.74 ²⁰	....	....	....	....	.....
Lead chromate (Chrome yellow) (Crocoite)	PbCrO_4	323.22	Yellow monoclinic crystals. 2.31:2.37.	6.12 ¹⁵	844	Decompd.	0.000058 ²³	Insol.	Sol. in acids and alkalis. Insol. in acetic acid or NH_3 .
Lead chromate, basic	$\text{Pb}_2(\text{OH})_2\text{CrO}_4$	564.45	Red amorphous or cryst., solid. May be orange.	6.63 to 6.86	920	....	Insol.	....	1.019 g. in 100 ml. of 2N KOH. Sol. in acids and alkalis.

Lead chromate, basic (Chrome red)	$\text{PbO} \cdot \text{PbCrO}_4$	546.43	Red cryst. powder.	6.63 to 6.86	....	....	Insol.	Insol.	Sol. in acids and alkalies.	Bo wh of
Lead dichromate	PbCr_2O_7	423.23	Red crystals.	....	....	....	Decompd.	....	Sol. in acids and alkalies.	
Lead cyanate	$\text{Pb}(\text{OCN})_2$	291.25	White cryst. needles.	....	Decompd.	....	Insol.	Slightly sol.	.....	Tr nat tra fro of
Lead cyanide	$\text{Pb}(\text{CN})_2$	259.25	Yellowish white powder.	....	....	....	Slightly sol.	Sol.	Sol. in HCN.	Ac alk nit
Lead cyanide, basic	$\text{Pb}_3\text{O}_2(\text{CN})_2$	705.67	White solid.	....	....	....	....	....	Sparsingly sol. in KCN.	Tr sol nit
Lead cyanimide	PbCN_2	.....	Green amorphous compound.	....	....	....	Insol.	....	Insol. in oil.	
Lead ferricyanide	$\text{Pb}_3\text{Fe}(\text{CN})_{12} \cdot 6\text{H}_2\text{O}$	1153.62	Black-brown to reddish mono- clinic crystals.	1.037 satd. soln.	Decompd. at 120.	....	Slightly sol.	Slightly decompd. at 100.	Sol. in HNO_3 or alkalies.	Tr sol ric
Lead ferrite	$\text{Pb}(\text{FeO}_2)_2$	882.89	Hexagonal.	....	1530 decompd. at 750.	....	....	....	.....	
Lead ferrocyanide	$\text{Pb}_2\text{Fe}(\text{CN})_6 \cdot 8\text{H}_2\text{O}$	680.48	Yellowish-white powder.	....	Decompd. at 100.	....	Insol.	....	Slightly sol. in H_2SO_4 . Decompd. by alkalies. Insol. in dil. acids.	Tr sol ro
Lead fluoride	PbF_2	245.21	White rhombic crystals.	8.24	855	1200	0.064 ²⁰	....	Sol. in HNO_3 or H_2SO_4 . Insol. in acetic acid, NH_3 or HF.	Tr sol rid
Lead tetrafluoride	PbF_4	289.21	.....	....	....	....	....	....	.....	Fu an HF
Lead fluorochloride	PbFCl	261.651	Tetragonal crystals.	....	601	....	....	....	.....	
Lead fluosilicate	$\text{PbSiF}_6 \cdot 2\text{H}_2\text{O}$	885.30	Colorless mono- clinic crystals.	....	Decompd.	....	Sol.	Very sol.	.....	Tr hy an

PHYSICAL CONSTANTS OF LEAD COMPOUNDS—Continued INORGANIC COMPOUNDS OF LEAD—Continued

Name	Formula	Molecular weight	Crystalline form color index of refraction	Specific gravity	Melting point °C	Boiling point °C	Solubility in 100 ml. of			
							Cold water	Hot water	Alcohol, acid, etc.	
Lead fluosilicate	$\text{PbSiF}_6 \cdot 4\text{H}_2\text{O}$	421.33	Monoclinic crystals.	....	Decompd. at 100.	....	....	....	.....	Cry- dil Ph
Lead dihydride	PbH_2	209.23	Gray powder.	....	Decompd.	....	....	....	Attacked by fused KNO_3 under conditions where finely divided lead is only attacked.	Ac- fol ph
Lead tetrahydride	PbH_4	211.24	Gaseous compound liquefied by liquid air.	....	Decompd. by heat.	....	....	....	.....	He in hy
Lead hydroxide	$\text{Pb}(\text{OH})_2$	241.23	White amorphous solid.	....	Decompd. at 145 into PbO and H_2O}.	....	0.0155 ²⁰	Slightly sol.	Sol. in acids and alkalies. Insol. in acetic acid.	Sm by lit
Lead hydroxide	$\text{Pb}_2\text{O}(\text{OH})_2$ or $2\text{PbO} \cdot \text{H}_2\text{O}$	464.44	Cubical crystals or white amorphous powder.	7.592	Decompd. at 145 into PbO and H_2O}.	....	0.014	Slightly sol.	Sol. in HNO_3 , alkalies or acetic acid.	Ad ide
Lead hydroxide	$3\text{PbO} \cdot \text{H}_2\text{O}$	687.65	Cubical crystals.	7.592	Decompd. at 130.	....	0.014	....	Sol. in acids and alkalies.	Se un co dit
Lead iodate	$\text{Pb}(\text{IO}_3)_2$	557.08	White solid.	....	Decompd. at 300.	....	0.0012 ²	0.003 ²⁰	Slightly sol. in HNO_3 . Insol. in NH_3 or acetic acid.	Ac loc sol
Lead paraperiodate	PbHIO_6	415.14	Crystals.	....	Decompd. at 130.	....	Insol.	Insol.	Sol. in dil. HNO_3 .	Ac ac ide of
Lead paraperiodate	$\text{PbHIO}_6 \cdot \text{H}_2\text{O}$	433.15	Amorphous.	....	Loses water at 100.	....	Insol.	Insol.	Sol. in dil. HNO_3 .	Ac rie lea
Lead mono-iodide	PbI	334.13	Pale yellow solid.	....	Decompd. at 300.	....	0.01	....	.....	Ac dil

Lead di-iodide	PbI_2	481.05	Yellow hexagonal powder.	6.16	402 (393)	854 (900)	0.044 ⁰	0.41 ¹⁰⁰	Sol. in KI or alkalies. Insol. in alc.	
Lead iodide, basic	$\text{PbO} \cdot \text{PbI}_2$	684.26	.....	....	....	....	....	....	.....	
Lead iodide, basic	$\text{PbI}_2 \cdot \text{PbO} \cdot \text{H}_2\text{O}$	702.28	Rhombic crystals.	6.83 ²⁰	Decompd. at 100.	....	....	....	.....	
Lead iodide	PbNH	222.23	Reddish-brown substance.	....	....	....	....	....	.....	
Lead molybdate (Wulfenite)	PbMoO_4	367.16	Yellow-white powder or octahedral plates.	6.7	1008	....	Insol.	....	Decompd. by concd. H_2SO_4 . Sol. in acids or KOH. Insol. in alc.	
Lead nitrate	$\text{Pb}(\text{NO}_3)_2$	331.23	Colorless cubical or monoclinic crystals. 1.782.	4.53	Decompd. at 470.	....	38.8 ⁰	138.8 ¹⁰⁰	8.77 ²² in 43% alc. Sol. in NH_3 or alkalies.	
Lead nitrate	$2\text{PbO} \cdot \text{N}_2\text{O}_5 \cdot 1.5\text{H}_2\text{O}$	581.44	White monoclinic crystals.	....	Decompd. at 100.	....	....	....	.....	
Lead nitrate	$4\text{PbO} \cdot \text{N}_2\text{O}_5 \cdot \text{N}_2\text{O}_5 \cdot 2\text{H}_2\text{O}$	1112.86	White rhombic crystals.	....	Decompd. at 100.	....	....	....	.....	
Lead nitrate	$2\text{PbO} \cdot \text{N}_2\text{O}_5 \cdot \text{H}_2\text{O}$ or $\text{Pb}(\text{OH})\text{NO}_3$	572.43	White rhombic crystals.	5.83	Decompd.	....	....	Fairly sol.	Sol. in acetic acid, alkali hydroxides, HCl and HNO_3 .	
Lead nitrate, basic	$\text{Pb}(\text{OH})\text{NO}_3$	286.23	Rhombic crystals.	5.93	Decompd. at 180.	....	19.4 ^{10.2}	Sol.	Sol. in acids.	

PHYSICAL CONSTANTS OF LEAD COMPOUNDS—Continued INORGANIC COMPOUNDS OF LEAD—Continued

Name	Formula	Molecular weight	Crystalline form color index of refraction	Specific gravity	Melting point °C	Boiling point °C	Solubility in 100 ml. of			
							Cold water	Hot water	Alcohol, acid, etc.	
Lead nitrite (Lead subnitrite)	$3\text{PbO} \cdot \text{N}_2\text{O}_5 \cdot \text{H}_2\text{O}$ A variable compound.	763.66	Light yellow powder.	....	....	....	Very sol.	....	Sol. in dil. HNO_3 .	Dec. tri-rid. in
Lead monoxide (Litharge)	PbO	223.21	Yellow tetragonal crystals. 2.665; 2.535.	9.53	888	....	0.0017 ²⁰	....	Sol. in alkalies, lead acetate, NH_4Cl , CaCl_2 , SrCl_2 .	He-ber-nac-air
Lead monoxide (Massicot) (Massicotite)	PbO	223.21	Yellow rhombic crystals. 2.51; 2.61; 2.71.	8.0	....	....	0.0023 ²²	Insol.	Sol. in alkalies.	Mo-at-air
Lead dioxide (Lead peroxide) (Plattnerite)	PbO_2	239.21	Brown tetragonal crystals. W 2.3.	9.875	Decompd. at 280.	....	Insol.	Insol.	Sol. in dil. HCl and HNO_3 . H_2O_2 . Slightly sol. in acetic acid. Insol. in alc.	Ac-dix-H ₂ or-pre-Al-the-phu-ser-lea
Lead sesquioxide (Metaplumbate)	Pb_2O_3 or $\text{PbO} \cdot \text{PbO}_2$	462.42	Red-yellow amorphous powder.	....	Decompd. at 360.	....	Insol.	Decompd.	Sol. in acids or alkalies.	Ad-chi-sol-tic
Lead oxide (Red lead) (Minium) (Orthoplumbate)	Pb_3O_4	685.63	Cryst. scales or red amorphous powder. 2.4 n.	9.1 (4.6)	Decompd. at 500.	....	Insol. 5.3 10 ⁻⁵¹ .	Insol.	Sol. in acetic acid, hot HCl or HNO_3 . H_2O_2 . Insol. in alc.	He-com
Lead suboxide	Pb_2O	430.42	Black amorphous powder.	8.842	Decompd. into Pb and PbO}.	....	Insol.	Insol.	Sol. in acids or alkalies.	Fe-pu-du-at

Lead phosphate, basic	$\text{PbO} \cdot \text{Pb}_3(\text{PO}_4)_2$	1034.85	White solid.	....	982	....	....	....	.....	
Lead phosphate, basic	$2\text{PbO} \cdot \text{Pb}_3(\text{PO}_4)_2$	1400.0	White solid.	....	946	....	....	....	.....	
Lead phosphate, basic	$5\text{PbO} \cdot \text{Pb}_3(\text{PO}_4)_2$	1927.65	White solid.	....	860	....	....	....	.....	
Lead hypophosphate	PbPO_3	318.23	.....	....	....	....	Insol.	Insol.	.....	
Lead orthophosphate	$\text{Pb}_3(\text{PO}_4)_2$	811.67	Colorless hexagonal crystals or white powder 1.970: 1.930.	6.9 to 7.3	1014	....	0.000014 ²⁰	Insol.	Sol. in HNO_3 or alkali hydroxides. Insol. in acetic acid or alc.	
Lead diorthophosphate	PbHPO_4	303.24	Rhombic or monoclinic cryst. solid.	5.661 ¹⁸	Decompd.	....	....	....	Sol. in HNO_3 , KOH , NaOH or NH_4Cl .	
Lead mono-orthophosphate	$\text{Pb}(\text{H}_2\text{PO}_4)_2$	461.28	Cryst. needles.	....	....	....	Decompd. to $\text{Pb}_3(\text{PO}_4)_2$	Decompd. to $\text{Pb}_3(\text{PO}_4)_2$	Sol. in KOH , NaOH , HNO_3 or hot concd. HCl . Insol. in 50% acetic acid.	
Lead pyrophosphate	$\text{Pb}_2\text{P}_2\text{O}_7$	588.46	White rhombic crystals or amorphous.	5.8 ²⁰	824	....	Insol.	Decompd.	Sol. in HNO_3 or KOH . Insol. in acetic acid.	
Lead pyrophosphate	$\text{Pb}_2\text{P}_2\text{O}_7 \cdot \text{H}_2\text{O}$	606.48	Rhombic solid.	....	806 anhydrous.	....	Insol.	Decompd.	Sol. in HNO_3 , KOH or $\text{Na}_2\text{P}_2\text{O}_7$.	
Lead metaphosphate	$\text{Pb}(\text{PO}_3)_2$	365.25	Colorless crystals or white powder.	....	700 to 800	....	Very slightly sol.	....	Readily decompd. by acid.	
Lead phosphide	PbP_6	362.31	Black unstable solid.	....	Heated in vacuo to 400 decomposes.	....	Attached by water.	....	Decompd. by dil. acids.	
Lead hypophosphite	$\text{Pb}(\text{H}_2\text{PO}_2)_2$	337.31	White cryst. powder.	....	....	....	Slightly sol.	....	.....	

PHYSICAL CONSTANTS OF LEAD COMPOUNDS—Continued
INORGANIC COMPOUNDS OF LEAD—Continued

Name	Formula	Molecular weight	Crystalline form color index of refraction	Specific gravity	Melting point °C	Boiling point °C	Solubility in 100 ml. of			
							Cold water	Hot water	Alcohol, acid, etc.	
Lead orthophosphite	PbHPO_3	287.24	White powder.	....	Decompd.	....	Insol.	Insol.	Sol. in HNO_3 .	Pp sol of sol
Lead platincyanoide	$\text{PbPt}(\text{CN})_4$	506.45	Yellowish white cryst. powder.	....	....	....	....	....	.....	Act len sel sal
Lead selenate	PbSeO_4	350.17	White rhombic crystals.	0.372 ^o	Decompd.	....	Insol.	Insol.	Sol. in concd. acids.	Act len sel sal
Lead selenide (Clausenthalite)	PbSe	286.17	Lead grey cubical crystals.	8.10	1065	....	Insol.	....	Sol. in HNO_3 or hot concd. HCl .	Act alk sol
Lead silicate or Lead metasilicate (Alamosite)	PbSiO_3	283.27	Colorless or white monoclinic crystals.	0.49	760	....	Insol.	....	Decompd. by acids. Insol. in alc.	Ma lit by tat cat
Lead orthodisilicate (Barysilite)	$\text{Pb}_2\text{Si}_2\text{O}_7$	582.54	Trigonal white solid. 2.070: 2.050.	0.53 to 6.707	....	....	Insol.	Insol.	.....	A
Lead silicofluoride	$\text{PbSiF}_6 \cdot 2\text{H}_2\text{O}$	385.83	Colorless crystals.	....	....	....	Sol.	....	.....	He con dro bel the add
Lead sulfate (Anglesite) (Plumbous)	PbSO_4	303.27	White monoclinic or rhombic crystals. 1.877: 1.882: 1.894.	6.2	1170	....	0.0028 ^o	0.0056 ⁴⁰	Sol. in concd. acids, tartaric acid or ammo- nium salts. Insol. in acetic acid.	Act fate on nit
Lead sulfate, basic (Lanarkite)	$\text{PbSO}_4 \cdot \text{PbO}$	526.48	White monoclinic crystals. 1.93: 1.99: 2.02.	6.92	977	....	0.0044 ¹⁶	Very slightly sol.	Slightly sol. in H_2SO_4 .	Act air

Lead sulfate, basic	$\text{PbSO}_4 \cdot 3\text{PbO}$	972.90	Yellowish white solid.	....	....	....	....	....	.....	Treat- stoc- tion
Lead sulfate, basic	$\text{Pb}(\text{HSO}_4)_2 \cdot \text{H}_2\text{O}$	419.36	Cryst. solid.	....	Decompd.	....	0.0001 ¹⁸	....	Slightly sol. in H_2SO_4 .	Boll- sulfur
Lead persulfate (Lead peroxydisulfate)	$\text{PbS}_2\text{O}_8 \cdot 3\text{H}_2\text{O}$	453.38	Deliquescent cryst. solid.	....	....	....	Very sol.	Very sol.	Decompd. by alkalies.	Elect- H_2SO_4 cell v with C. M high- PbO_2
Lead sulfide (Galena)	PbS	239.27	Cubical blue gray metallic crystals. 3.012.	7.5	1114	....	$4.4 \cdot 10^{-13}$	....	Sol. in acids or hot dil. HCl . In- sol. in KOH or alc.	Bubb- lead is a lead, will or bl
Lead sulfite	PbSO_3	287.27	White powder.	....	Decompd.	....	Insol. Less sol. than sul- fate.	Insol.	Decompd. by HNO_3 , HCl , H_2SO_4 . Slightly sol. in H_2SO_3 . Insol. in acetic acid.	Pptd alkali sol.
Lead ammonium sulfate	$\text{Pb}(\text{NH}_4)_2(\text{SO}_4)_2$	435.41	.....	....	....	....	....	Decompd. at 100.	.....	Add prop- mon- sol.
Lead potassium sulfate	$\text{PbK}_2(\text{SO}_4)_2$	477.52	.....	....	....	....	....	Decompd. at 100.	.....	Add prop- alum- lead
Lead telluride (Atollite)	PbTe	334.82	Tin-white cubical crystals.	8.16	917	....	....	....	.....	Acti- kali of s
Lead thiocyanate	$\text{Pb}(\text{CNS})_2$	323.37	Colorless mono- clinic crystals.	3.82	Decompd. at 190.	....	0.05 ²⁰	Sol.	Sol. in KCNS . HNO_3 or alkali hydroxides.	Pptd lead mon-
Lead dithionate	$\text{PbS}_2\text{O}_6 \cdot 4\text{H}_2\text{O}$	439.39	Trigonal solid. 1.035: 1.653.	3.22	Decompd.	....	115.0 ^{20.5}	....	.....	Diss- Na_2S of w
Lead thiosulfate	PbS_2O_3	319.33	White crystals or powder.	5.18	Decompd.	....	0.03	....	Sol. in acids or $\text{Na}_2\text{S}_2\text{O}_3$.	Pptd tate thios

PHYSICAL CONSTANTS OF LEAD COMPOUNDS—Continued
INORGANIC COMPOUNDS OF LEAD—Continued

Name	Formula	Molecular weight	Crystalline form color Index of refraction	Specific gravity	Melting point °C	Boiling point °C	Solubility in 100 ml. of		
							Cold water	Hot water	Alcohol, acid, etc.
Lead-sodium thiosulfate	$\text{PbS}_2\text{O}_4 \cdot 2\text{Na}_2\text{S}_2\text{O}_3$	635.56	Small white heavy crystals.	....	....	....	....	....	Sol. in thiosulfate solns.
Lead metatitanate	PbTiO_3	303.11	Yellow to white rhombic prisms.	7.52	....	....	Insol.	Insol.	Decompd. by HCl into PbCl_2 and TiO_2 .
Lead tungstate (Raspite)	PbWO_4	455.13	Monoclinic crystals.	8.46	1123	....	Insol.	Insol.	Decompd. by hot HNO_3 . Insol. in NH_4OH .
Lead tungstate (Stolzite)	PbWO_4	455.13	Colorless tetragonal crystals. 2.269; 2.182.	8.32	....	....	Insol.	....	Sol. in KOH. Insol. in HNO_3 .
216 Lead metavanadate	$\text{Pb}(\text{VO}_3)_2$	405.11	Yellow powder	....	....	....	Slightly sol.	....	Decompd. by HCl. Sol. in dil. HNO_3 .
Ammonium chloroplumbate	$(\text{NH}_4)_2\text{PbCl}_6$	456.03	Yellow cubical cryst. solid.	....	Decompd. at 120.	....	....	....	Decompd. by cold concd. H_2SO_4 , yielding PbCl_4 .
Calcium plumbate	$\text{Ca}_2\text{PbO}_4 \cdot 4\text{H}_2\text{O}$	423.43	Colorless crystals.	....	....	....	Sol.	....	.....
Hydrochloroplumbic acid	H_2PbCl_6	421.97	Dark brown soln. in concd. HCl.	....	Free acid decomposes with PbCl_4 and HCl.	....	....	....	.....
Potassium plumbate	$\text{K}_2\text{PbO}_3 \cdot 3\text{H}_2\text{O}$ or $\text{K}_2\text{Pb}(\text{OH})_6$	387.45	.....	....	....	....	Sol.	....	.....
Pyromorphite	$\text{PbCl}_2 \cdot 3\text{Pb}_3(\text{PO}_4)_2$	2713.06	Hexagonal cryst. solid.	6.6	1156				

Sodium plumbite	Na_2PbO_2	285.20					Sol.		
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ORGANIC COMPOUNDS OF LEAD

Lead acetate	$\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$	810.03	Brown, lustrous translucent lumps or fine yellowish white powder.				Insol.		Insol. in most solvents. Sparingly sol. in linseed oil.
Lead acetate, anhydrous, normal	$\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$	325.80	White triclinic crystals.	3.251 ²⁴	280	....	44.3 ²⁰	221.20 ⁶⁰	.....
Lead acetate, normal (Sugar of lead)	$\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 3\text{H}_2\text{O}$	370.35	White monoclinic crystals. M. 576.	2.55	Loses $3\text{H}_2\text{O}$ at 75. Anhydrous at 280.	....	45.64 ¹⁵	200 ¹⁰⁰	Slightly sol. in alc.
Lead acetate	$\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 10\text{H}_2\text{O}$	505.46	Rhombic crystals.	1.680	22	....	Sol.	Sol.	Insol. in alc.
Lead acetate, basic	$\text{Pb}_2(\text{C}_2\text{H}_3\text{O}_2)_3\text{OH}$	608.56	White.	....	....	....	Very sol.	....	Slightly sol. in alc.
Lead acetate, monobasic	$\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot \text{Pb}(\text{OH})_2 \cdot \text{H}_2\text{O}$	584.54	White monoclinic crystals.	....	....	....	Very sol.	....	Sol. in alc.
Lead acetate, dibasic	$\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 2\text{Pb}(\text{OH})_2$	807.75	White microscopic needles.	....	....	....	5.55	18.2	Sol. in alc.
Lead acetate, tribasic	$\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 3\text{PbO} \cdot \text{H}_2\text{O}$	1012.90	White powder.	....	....	....	....	....	.....

PHYSICAL CONSTANTS OF LEAD COMPOUNDS—Continued
ORGANIC COMPOUNDS OF LEAD—Continued

Name	Formula	Molecular weight	Crystalline form color index of refraction	Specific gravity	Melting point °C	Boiling point °C	Solubility in 100 ml. of			
							Cold water	Hot water	Alcohol, acid, etc.	
Lead tetra-acetate	$\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_4$	443.30	Colorless mono- cellinic crystals.	2.228	175	....	Decomposes into PbO_2 and acetic acid.	....	Decompd. by alc. Sol. in chloro- form. Sol. in hot acetic acid.	Add acid to cool.
Lead benzoate	$\text{Pb}(\text{C}_7\text{H}_5\text{O}_2)_2 \cdot \text{H}_2\text{O}$	467.45	White cryst. powder.	....	Loses water at 100.	....	0.16 ²⁰	0.31 ^{100.5}	.....	Action benzo- solin.
Lead butyrate	$\text{Pb}(\text{C}_4\text{H}_7\text{O}_2)_2$	381.85	White viscous mass.	....	....	....	Insol.	....	Sol. in HNO_3 .	Inter- acid salt vent.
Lead isobutyrate	$\text{Pb}(\text{C}_4\text{H}_7\text{O}_2)_2$	381.40	White prisms.	....	100	....	9.1 ¹⁶	....	.....	Action acid ide.
Lead caprate	$\text{Pb}(\text{C}_{10}\text{H}_{19}\text{O}_2)_2$	549.72	.....	....	103 to 104	....	Insol.	Insol.	0.0029 ²⁰ in ether.	Treat solin. with capric
Lead caproate	$\text{Pb}(\text{C}_8\text{H}_{17}\text{O}_2)_2$	487.51	.....	....	78 to 74	....	....	....	1.09 ²⁰ in ether.	Treat lead alc. acid.
Lead caprylate (Lead octoate)	$\text{Pb}(\text{C}_8\text{H}_{15}\text{O}_2)_2$	493.61	White leafs.	....	83.5 to 84.5	....	Insol.	Insol.	Sol. in alc. 0.0938 ²⁰ in ether.	Treat of lead an capryl
Lead cerotate	$\text{Pb}(\text{C}_{26}\text{H}_{51}\text{O}_2)_2$	998.56	White needles from benzene.	....	112.5 to 113.5	....	Insol.	....	Insol. in alc. or ether.	Treat lead alc. acid.
Lead citrate	$\text{Pb}_3(\text{C}_6\text{H}_5\text{O}_7)_2 \cdot 3\text{H}_2\text{O}$	1053.88	White cryst. powder.	....	....	....	Sol.	....	.....	Action trate of lead

Lead enanthate	$\text{Pb}(\text{C}_7\text{H}_{15}\text{O}_2)_2$	465.56	White leafs.	....	01.5	....	....	Slightly sol.	Insol. in alc.	Heat excc. acic
Lead ethoxide	$\text{Pb}(\text{OC}_2\text{H}_5)_2$	297.33	Light yellow friable powder.	....	....	....	Hydrolyzed by water.	....	.....	Sus. of alc. stre. pas. with vacu. acic
Lead ethylsulfate	$\text{Pb}(\text{C}_2\text{H}_5\text{SO}_4)_2 \cdot 2\text{H}_2\text{O}$	493.45	Colorless liquid.	....	....	....	Sol.	....	.....	Int. eth. hyd.
Lead tetraethyl	$\text{Pb}(\text{C}_2\text{H}_5)_4$	323.45	Colorless liquid 1.5218 ¹⁹ .	1.059	-130	198 to 202 or 152 ^{21mm.}	Insol.	....	In ether. Sol. in all organic solvents. Insol. in dil. alc. or dil. alkali.	Act. did. all. lead alk.
Lead hexaethyl di (Hexaethyldiplumbane) (Diplumble hexaethyl) (Lead triethide)	$\text{Pb}_2(\text{C}_2\text{H}_5)_6$	588.78	Liquid.	1.471	....	Decompd.	Insol.	....	.....	
Lead diethyldipropyl	$\text{Pb}(\text{C}_2\text{H}_5)_2(\text{C}_3\text{H}_7)_2$	351.38	Liquid.	1.520 ^{25.4}	....	....	....	....	.....	Tre. loy. pro.
Lead diethyl di-isobutyl	$\text{Pb}(\text{C}_2\text{H}_5)_2(\text{isoC}_4\text{H}_9)_2$	379.42	Liquid.	1.456 ²⁷	....	....	....	....	.....	Tre. loy. iso.
Lead triethylmonomethyl	$\text{Pb}(\text{C}_2\text{H}_5)_3(\text{CH}_3)$	309.40	Liquid.	1.712 ²⁴	....	....	....	....	.....	Ac. me. lea.
Lead triethylmonopropyl	$\text{Pb}(\text{C}_2\text{H}_5)_3(\text{C}_3\text{H}_7)$	337.37	Liquid.	1.505 ^{22.5}	....	....	....	....	.....	Tre. loy. pro.
Lead triethylmonoisobutyl	$\text{Pb}(\text{C}_2\text{H}_5)_3(\text{isoC}_4\text{H}_9)$	351.38	Liquid.	1.530 ^{22.6}	....	....	....	....	.....	Tre. loy. iso.
Lead triethylmonoamyl	$\text{Pb}(\text{C}_2\text{H}_5)_3(\text{C}_6\text{H}_{11})$	365.4	Liquid.	1.482 ²⁰	....	....	....	....	.....	Tre. loy. am.
Lead triethylmonoisoamyl	$\text{Pb}(\text{C}_2\text{H}_5)_3(\text{isoC}_6\text{H}_{11})$	365.4	Liquid.	1.506 ^{21.6}	....	....	....	....	.....	Tre. loy. iso.

PHYSICAL CONSTANTS OF LEAD COMPOUNDS—Continued
ORGANIC COMPOUNDS OF LEAD—Continued

Name	Formula	Molecular weight	Crystalline form color index of refraction	Specific gravity	Melting point °C	Boiling point °C	Solubility in 100 ml. of			Action or other notes
							Cold water	Hot water	Alcohol, acid, etc.	
Lead formate	$\text{Pb}(\text{CHO}_2)_2$	207.25	White lustrous rhombic crystals. 1.789; 1.852; 1.877.	4.56 to 4.03	Decompd.	....	1.6 ¹⁶	20 ¹⁰⁰ decompd.	Insol. in alc.	Boil in formic
Lead lactate	$\text{Pb}(\text{C}_3\text{H}_5\text{O}_2)_2$	385.31	Heavy white cryst. powder.	....	....	....	Sol.	....	Sol. in hot alc.	Action or sol. in alc.
Lead laurate	$\text{Pb}(\text{C}_{12}\text{H}_{23}\text{O}_2)_2$	605.82	Chalky white powder.	....	104.7	....	0.009 ³⁵	....	0.007 ^{14.5} in ether.	Action rate or alc. on tate so
Lead lignocerate	$\text{Pb}(\text{C}_{24}\text{H}_{47}\text{O}_2)_2$	942.45	White powder.	....	117	....	Insol.	....	Very sol. in boiling benzene. Slightly sol. in alc. Insol. in ether.	Action of lead solns. acid o nocerate
Lead linoleate	Approximate $\text{Pb}(\text{C}_{18}\text{H}_{31}\text{O}_2)_2$	766.07	Yellowish-brown plastic-like mass.	....	....	....	Insol.	Insol.	Sol. in hot linseed oil or hot turpentine.	Treat in alc salt of
Lead malate	$\text{Pb}(\text{C}_4\text{H}_4\text{O}_6) \cdot 3\text{H}_2\text{O}$	303.33	White powder.	....	....	....	Slightly sol.	....	.....	Action ate on salt.
Lead mellissate	$\text{Pb}(\text{C}_{17}\text{H}_{31}\text{O}_2)_2$	1138.82	White powder.	....	115 to 116	....	Insol.	Insol.	Sol. in boiling toluene, acetic acid. Slightly sol. in hot benzene or chloroform. Insol. in alc., ether.	Action of mell. alc. s acetate
Lead tetramethyl	$\text{Pb}(\text{CH}_3)_4$	207.35	Colorless liquid 1.5128.	1.0051 ²⁴	-27.5	110.7 ¹⁰⁰	Insol.	....	In ether.	Action dide o alloy, lead ch alkyl.
Lead dimethyldiethyl	$\text{Pb}(\text{CH}_3)_2(\text{C}_2\text{H}_5)_2$	295.22	Liquid.	1.790	....	....	....	....	.....	Action methyl lead-so

Lead dimethyldipropyl	$\text{Pb}(\text{CH}_3)_2(\text{C}_3\text{H}_7)_2$	823.35	Liquid.	$1.623^{21.7}_4$	....	....	....	....	.....	Treat 1 loy wi propyl
Lead dimethyldi-isobutyl	$\text{Pb}(\text{CH}_3)_2(\text{IsoC}_4\text{H}_9)_2$	851.38	Liquid.	$1.504^{20.6}$	....	....	....	....	.....	Treat 1 loy wi isobuty
Lead dimethyldi-isoamyl	$\text{Pb}(\text{CH}_3)_2(\text{IsoC}_5\text{H}_{11})_2$	879.42	Liquid.	1.430^{20}	....	....	....	....	.....	Treat 1 loy wi isoamyl
Lead trimethylmonorthyl	$\text{Pb}(\text{CH}_3)_3(\text{C}_3\text{H}_7)$	281.308	Liquid.	1.880	....	....	....	....	.....	Action methyl lead so
Lead trimethylmonopropyl	$\text{Pb}(\text{CH}_3)_3(\text{C}_3\text{H}_7)$	295.32	Liquid.	1.760^{21}	....	....	....	....	.....	Action propyl lead-so
Lead trimethylmonobutyl	$\text{Pb}(\text{CH}_3)_3(\text{C}_4\text{H}_9)$	309.40	Liquid.	1.664^{21}	....	....	....	....	.....	Action butyl sodium
Lead trimethylmonoisobutyl	$\text{Pb}(\text{CH}_3)_3(\text{IsoC}_4\text{H}_9)$	309.40	Liquid.	1.668^{21}	....	....	....	....	.....	Action isobutyl lead-so
Lead trimethylmonoisamyl	$\text{Pb}(\text{CH}_3)_3(\text{IsoC}_5\text{H}_{11})$	323.54	Liquid.	$1.524^{21.4}_4$	....	....	....	....	.....	Treat 1 loy wi isoamy
Lead myristate	$\text{Pb}(\text{C}_{14}\text{H}_{27}\text{O}_2)_2$	601.93	White powder.	....	107	....	0.005^{25}	0.006^{20}	0.004^{25} in alc. $0.010^{14.5}$ in ether.	Treat hot alc soln. acid.
Lead 2-naphthalene-sulfonate	$\text{Pb}(\text{C}_{10}\text{H}_7\text{SO}_3)_2$	621.64	White cryst. powder.	....	....	....	Insol.	....	Sol. in alc.	Interac lead dium sulfon
Lead naphthanate	$\text{Pb}(\text{C}_{12}\text{H}_9\text{O}_4)$	421.38	.....	....	....	....	Insol.	....	Sol. in vegetable oil, turpentine, mineral spirits.	Patent
Lead nonylate	$\text{Pb}(\text{C}_9\text{H}_{17}\text{O}_2)_2$	521.416	Solid.	....	05	....	....	....	.....	Interac acid nonylate lead s
Lead oleate	$\text{Pb}(\text{C}_{18}\text{H}_{33}\text{O}_2)_2$	770.10	White powder.	....	....	....	Insol.	....	6.46^{20} in ether. Sol. in petroleum ether, slightly sol. in alc.	Pptd. lead soln. c

PHYSICAL CONSTANTS OF LEAD COMPOUNDS—Continued
ORGANIC COMPOUNDS OF LEAD—Continued

Name	Formula	Molecular weight	Crystalline form color index of refraction	Specific gravity	Melting point °C	Boiling point °C	Solubility in 100 ml. of			
							Cold water	Hot water	Alcohol, acid, etc.	
Lead oxalate	PbC_2O_4	205.23	Heavy white powder.	5.28	Decompd. at 300.	....	0.00016 ¹⁸	....	Sol. in HNO_3 , fixed alkalies. Insol. in alc. Sparingly sol. in acetic acid.	Pptd. soln. of ammoni
Lead palmitate	$\text{Pb}(\text{C}_{16}\text{H}_{31}\text{O}_2)_2$	718.03	Chalky white powder.	....	112.3	....	0.005 ²⁰	0.007 ²⁰	Sol. in alc. 0.148 ²⁰ in ether.	Boil. a palmitic soln. w acetate
Lead phenolate (Lead phenate) (Lead carbolate)	$\text{Pb}(\text{OH})\text{OC}_6\text{H}_5$	317.82	Yellowish to gray-white powder.	....	....	....	Insol.	....	.....	Boil ph arge.
Lead pentachlorophenate	$\text{Pb}(\text{OC}_6\text{Cl}_5)_2$	738.80	White solid.	....	....	....	Relatively insol.	....	.....	..
222 Lead tetrachlorophenate	$\text{Pb}(\text{OC}_6\text{H}_2\text{Cl}_4)_2$	668.89	White solid.	....	....	....	Relatively insol.	....	.....	..
Lead 2-chlor-6-phenylphenate	$\text{Pb}(\text{OC}_6\text{H}_3\text{Cl}-\text{C}_6\text{H}_5)_2$	614.25	White solid.	....	....	....	Relatively insol.	....	.....	..
Lead phenol-sulfonate (Lead sulfocarbolate)	$\text{Pb}(\text{C}_6\text{H}_4(\text{OH})\text{SO}_3)_2 \cdot 5\text{H}_2\text{O}$	643.61	White lustrous needles.	....	....	....	Sol.	....	Sol. in alc.	Treat t of acid w salt an
Lead tetraphenyl	$(\text{C}_6\text{H}_5)_4\text{Pb}$	515.61	White needles.	....	227.7	....	....	....	Sol. in benzene.	Action monolo sodium
Lead phthalate	$\text{Pb}(\text{OOC}_6\text{H}_4)_2$	.....	.....	....	....	....	....	....	.....	Reaction carbon water s anhydr
Lead phthalocyanine	$\text{Pb}(\text{C}_8\text{H}_4\text{C}_2\text{N}_2)_4$		Green.				Insol.		Insol. in oil.	Heat and me ocyanl inorgan pound.

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