ALUMINIUM AND ITS ALLOYS

Wm. L. Fink

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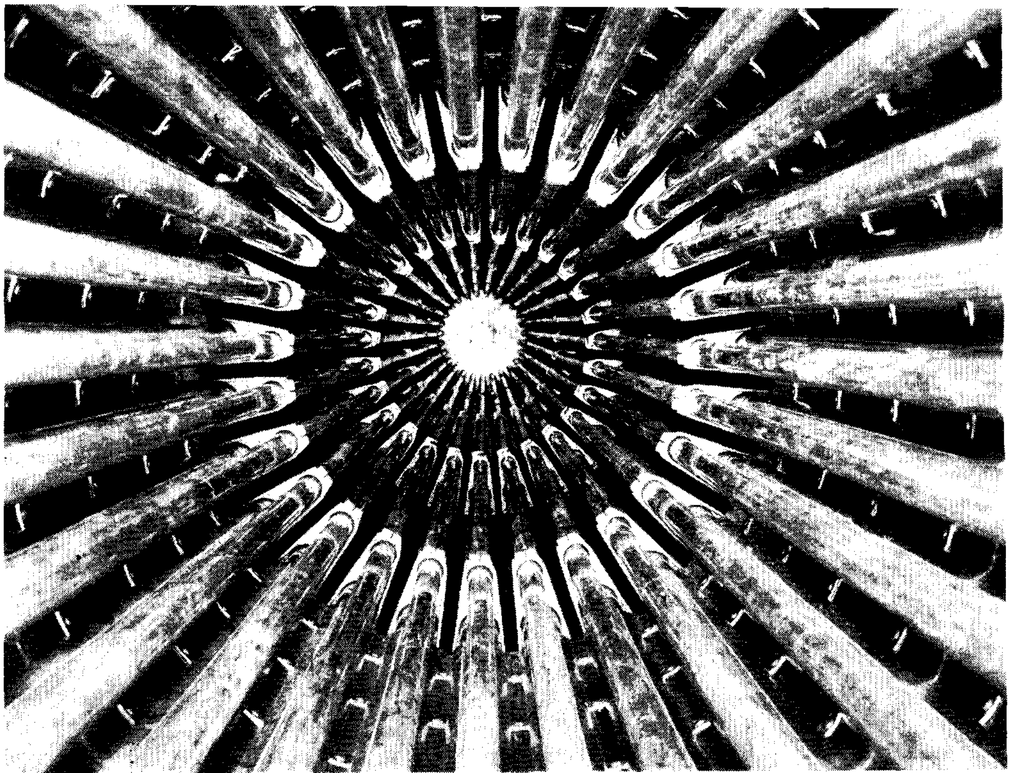
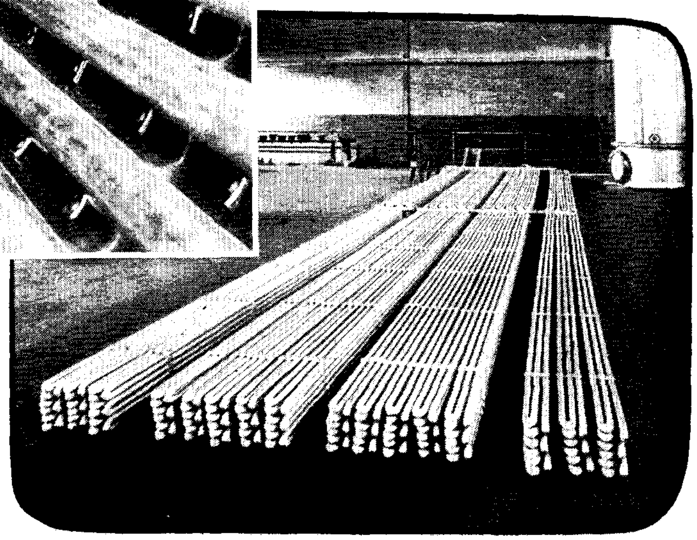




(*Left*) INSIDE VIEW OF PIGMENT DRYING APPARATUS USED IN THE PAINT INDUSTRY

Inside lining and steam coils are of 3S aluminum alloy. The length of an apparatus of this type ranges from 25 to 60 feet.

(*Below*) HEATING COILS OF 2S ALUMINUM ALLOY FOR A TURPENTINE RETORT

ALUMINUM AND ITS ALLOYS

WM. L. FINK
Aluminum Company of America, New Kensington, Pa.

ALUMINUM and its alloys are being used in the chemical and allied industries to a constantly increasing extent. Tanks, pipe and fittings, valves, shipping containers, tank cars, tank trucks, centrifugal drying apparatus, heat exchangers, stills, condensers, filter presses, and numerous other pieces of equipment are now being made of aluminum on account of its fortunate combination of chemical and physical properties.

Chemical Properties

Many materials are substantially inert towards aluminum. Distilled water, steam, hydrogen peroxide, concentrated nitric acid, sulfur, hydrogen sulfide, organic sulfur compounds, anhydrous sulfur dioxide, acetic acid, fruit acids, fatty acids, sodium soap, ammonia, aldehydes, turpentine, alcohol, varnish, rosin, many dye solutions, beer, and milk are among the products which have been handled advantageously in aluminum equipment.

This remarkable stability of an element which stands so high in the electromotive series is attributable to a very thin, adherent, protective coating of aluminum oxide which forms spontaneously on the surfaces which are exposed to air or even to liquids containing dissolved oxygen or water. It is a corollary that it may be hazardous to use aluminum in environments where breaks in the oxide film cannot heal spontaneously (i. e., under strictly anhydrous, oxygen-free conditions). For example, alcohol and some other organic liquids, which will not react with aluminum if they contain a small portion of water, will pit aluminum readily under strictly anhydrous conditions. Amalgamation also prevents the formation of a protective film and permits rapid oxidation of the aluminum, so that the breakage of mercury thermometers or mercury vapor lights in or above aluminum equipment may cause much trouble. Also, erosion or abrasion (e. g., solid particles impinging on fan blades or a stirrer scraping a tank wall), which constantly removes the surface film and exposes the underlying reactive metal, will greatly decrease the life of the apparatus. A thicker, more protective, much more abrasion-resistant film may be formed on aluminum by suitable anodic oxidation processes.

Aluminum is anodic to most other structural metals and will, therefore, suffer electrolytic attack if exposed to an electrolyte while in contact with heavy metals such as copper, tin, and lead. This direct electrolytic attack is generally understood and can be prevented by suitably insulating the various parts. However, there is another type of electrolytic attack which is not generally recognized. Small quantities of heavy metal salts in the solution being handled are reduced by the aluminum at certain points over the surface, thus forming small metallic deposits and inducing localized electrolytic attack which may result in relatively deep pits. Appreciably less than one part per million of copper or tin in an electrolyte is ample to accelerate greatly the pitting of aluminum. Lead, manganese, cobalt, nickel, and iron are less detrimental but definitely injurious.

In many cases the reaction of aluminum with various chemicals can be prevented, or at least the rate of the reaction can be greatly decreased, by the use of suitable inhibitors (for example, sodium dichromate, sodium silicate, and certain colloids). Consequently, aluminum may be used in certain applications where pitting would normally be unduly accelerated by chlorides or heavy metal salts, provided it is possible to add a suitable inhibitor without interfering with the chemical process or the purity of the product.

The salts of aluminum are colorless so that slight corrosion does not discolor or stain the materials being handled or the final products which may be made from these materials. This is one of the important reasons for using aluminum so extensively in the manufacture of acetic acid, cellulose acetate, stearic acid, organic solvents, varnishes, rosin, etc.

The corrosion products of aluminum are nontoxic to men, animals, and yeasts. For this reason aluminum is widely used in the fermentation industries, in dairies, and in the preparation of pharmaceutical supplies and foods.

Caustic alkalies and most salts which hydrolyze to give a pH greater than 9 readily attack aluminum. For this reason aluminum should not, in general, be used to handle solutions which are alkaline to phenolphthalein unless a suitable inhibitor can be found. Ammonia solutions are exceptions to the above rule since no inhibitor is necessary if the solution is free from heavy metals and chlorides. Ammonia does react initially, but the aluminum is soon coated with a relatively thick, impervious film which effectively prevents further reaction. The action of alkali carbonates and phosphates, certain alkaline dye baths, alkaline soaps, and similar materials can usually be inhibited by the use of small amounts of certain grades of sodium silicate. The Philadelphia Quartz Company's G. C. grade is of the type which seems to give the best results. No satisfactory inhibitor is known for caustic alkali solutions (sodium, potassium, and calcium hydroxides).

Physical Properties

One of the outstanding properties of aluminum is its low density (approximately 2.7). This means that a given piece of equipment will be much lighter when made of aluminum. The advantages of light weight are obvious. The use of aluminum for shipping containers and tank cars substantially reduces shipping costs. Aluminum centrifugal extractors can be brought up to speed quicker or with the expenditure of less energy than if made of heavier metals. Covers which must be removed by hand or apparatus which must be frequently disassembled for cleaning are more easily and more quickly handled if made of aluminum.

Aluminum and its alloys possess high thermal and electrical conductivity. For this reason they may be used advantageously for heat exchangers, cooling coil fins, and in any equipment where efficient heat transfer, uniform distribution of heat, and the avoidance of local overheating are important. The high electrical conductivity makes aluminum well suited for the construction of bus bars, cables, and other electrical conductors which are required in electrochemical operations.

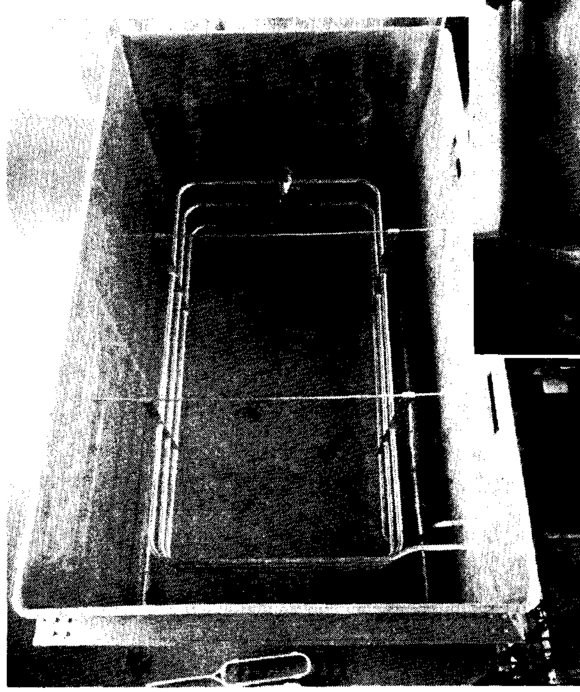
The low modulus of elasticity and the high plasticity enable aluminum equipment to withstand excessive accidental overloads by extensive deformation, whereas a less ductile material would suffer local failure. For example, aluminum drums for shipping nitric acid, acetic acid, hydrogen peroxide, etc., were tested by dropping the full drums from a considerable height. The drums did not burst even when they fell on a rail or I-beam. Likewise, aluminum tank cars and tank trucks have been involved in wrecks without loss of their valuable and sometimes dangerous liquid contents.

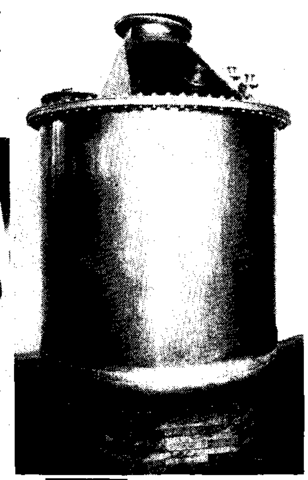
Aluminum possesses a combination of chemical and physical properties which fit it admirably for service in contact with many chemicals. Higher efficiency, higher quality of product, and lower operating or transportation costs are among the advantages to be gained by the intelligent use of aluminum. Its suitability should be carefully determined for each new type of application and approved cleaners and sterilizers should be used, to assure long service.

The high thermal reflectivity of aluminum gives rise to an interesting application. A few layers of aluminum foil separated by air spaces act as an efficient thermal insulation (the patented Alfol insulation). This insulation has been used on milk storage tanks, milk trucks, refrigerators, steam lines, and various other items of both refrigerated and heated equipment. This type of insulation is noncombustible, light in weight, and vermin-proof. Obviously it cannot corrode the container to which it is applied as do some of the porous or fibrous insulating materials.

(*Below*) Five-Hundred Barrel Fermenter of High-Purity Aluminum with 53S Stay Bars, and Attemperator Coils of High-Purity Aluminum

Inhibited calcium chloride brine is circulated through the coils.





(*Above*) Direct-Fired Varnish Kettle of 52S Alloy

Temperature of varnish, 400° to 500° F.

(Reading from top to bottom)

TANKS OF HIGH-PURITY ALUMINUM FOR STORING BEER UNDER 25 POUNDS PER SQUARE INCH PRESSURE

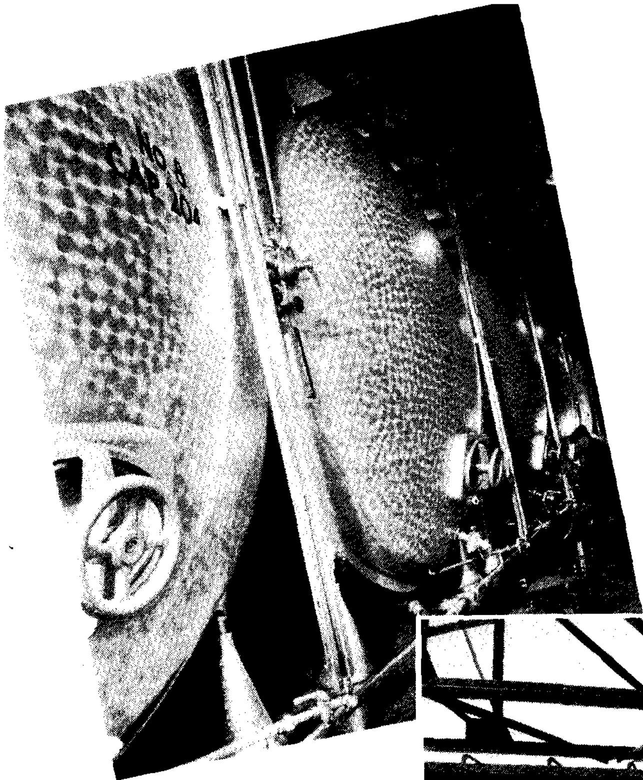
ALUMINUM SLUDGE REMOVER AT THE MILWAUKEE SEWAGE PLANT

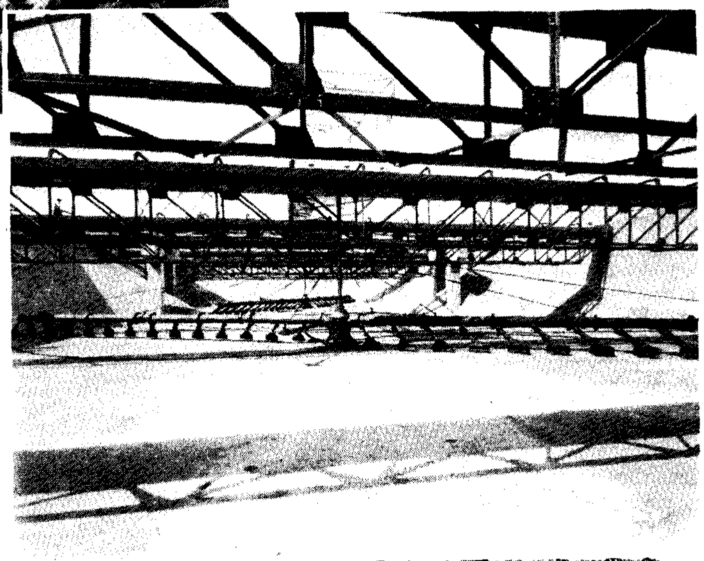
Castings of 214 alloy, tubing of 3S, and stay bars of 53S

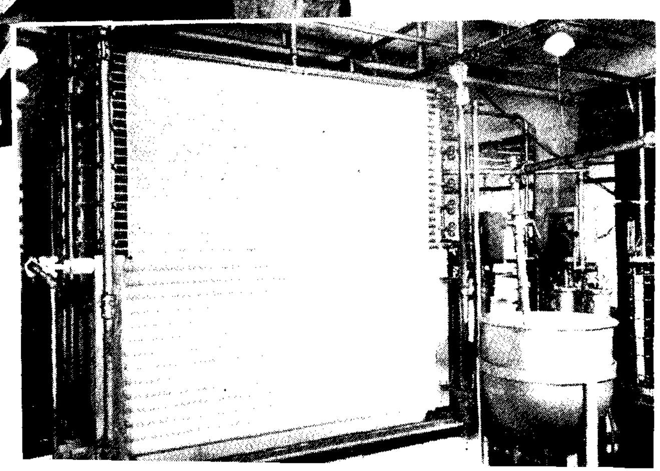
STEARIC ACID SOLIDIFYING TRAYS MADE OF 3S ALUMINUM ALLOY

ALUMINUM REGENERATIVE COOLER WHICH COOLS 500 TO 600 GALLONS OF MILK PER HOUR FROM 145° TO 110° F.

Such coolers are made preferably of 53S alloy.







Choice of Alloys

The alloys most generally used for chemical equipment are 2S (commercially pure aluminum) and 3S (aluminum plus 1.25 per cent manganese). These materials are readily formed and welded, and there is a large background of experience, both in fabrication and in use. However, for many applications other aluminum alloys are more satisfactory. The resistance of aluminum to attack by chemicals generally increases as the purity of the aluminum increases. For this reason an appreciable increase in the life of the equipment may sometimes be obtained by the use of high-purity aluminum. Moreover, 2S and 3S are alloys of only moderate strength and may be inadequate to carry the loads. In such cases 52S and 53S alloys may be used. These alloys compare favorably with high-purity aluminum in their resistance to most chemicals. The alloys mentioned are all wrought materials. For some parts it may be necessary or advantageous to use castings. In this case, alloys 13, 43, 214, 216, 220, 356, and 406 are suitable.

Table I lists the mechanical properties of these alloys in various tempers, at room temperature. Table II gives the factors for design stresses at elevated temperatures. Alloy 52S retains its strength to a greater extent than other wrought-aluminum alloys; therefore it is used to a considerable extent in apparatus which operates at elevated temperatures. For example, varnish kettles are now regularly made from 52S. Alloy 53S-T has a good combination of mechanical properties, and for this reason it is used to a considerable extent for structural shapes, pressure apparatus, centrifugal extractors, etc.

It should not be assumed that these alloys are always equivalent chemically. In a given application one of these materials may be distinctly superior to the others in resisting chemical attack. Alloys containing magnesium (e. g., 52S, 214, and 220) are more resistant to weak alkalies than is pure aluminum. Aluminum-silicon alloys (e. g., 43) are relatively less resistant to chloride solutions. Such generalizations as these are valuable guides in the selection of alloys for new applications. However, most service conditions involve innumerable variables which can usually be evaluated accurately only by tests under service conditions. If actual parts of the apparatus cannot be constructed of aluminum for test purposes small panels may be exposed in existing apparatus. Care should be exercised in running such tests. Obviously it would be unsatisfactory to test an aluminum panel in a piece of apparatus made from copper.

Certain chemical materials react with aluminum at isolated points (where there are weak points in the protective oxide film) and thus produce relatively deep pits while most of the surface is substantially unattacked. If the extent of corrosion were evaluated by loss in weight methods the material would appear to be satisfactory. However, in actual use some of these pits might perforate the sheet and produce a leak before the material had given long enough service to justify its cost. An Alclad material seems to be suitable for handling electrolytes of this type. Alclad products are made by coating an aluminum alloy with another and more anodic aluminum alloy. After a pit has penetrated the coating, a local electrolytic cell is set up which protects the underlying metal in much the same way that zinc coating protects the iron in galvanized iron. In other words, the pitting type of attack is converted into general surface attack which does not impair the serviceability of the equipment. Alclad materials, principally Alclad 17S-T and Alclad 24S-T, have been used in increasing amounts for several years. When thin sections of aluminum alloys must be used under severely corrosive conditions, the selection of Alclad products is the best assurance of prolonged structural integrity. Specimens of 14-gage Alclad 17S-T were exposed to the 20 per cent salt spray test for 8 years with no measurable decrease in strength. The use of Alclad 3S in the chemical industries is relatively new and is still considered experimental. However, numerous laboratory tests as well as limited use of the material in water lines, tea kettles, Mason jar caps, and special equipment for handling foods have shown that the Alclad material has much longer life than any of the other aluminum alloys under conditions which cause pitting. It now seems that the use of Alclad products will become extensive in chemical industry.

It is possible to obtain a protective aluminum coating without the use of Alclad materials. This is accomplished by spraying the surface of the finished apparatus with aluminum or suitable aluminum alloy after fabrication. Such coatings have the disadvantage of being porous and far less adherent than might be desired. They have the advantage that they can be applied to a wide variety of parts, including castings and welds. They may also be applied to other metals—for example, steel. Laboratory tests have shown that substantial protection can be obtained in this way. It has been reported that commercial applications have been successful.

Care of Aluminum Apparatus

After aluminum equipment has been properly designed and built of a suitable aluminum alloy, there still remains an important factor influencing the life of the apparatus—i. e., the care it receives in service.

In many applications periodic cleaning is necessary either for sanitary reasons or to remove some deposit. The use of uninhibited alkaline cleaners which will attack aluminum may greatly decrease the life of the apparatus. Numerous chemical cleaners are satisfactory for use with aluminum and are usually satisfactory as detergents. However, some heavy deposits such as beer scale and milk stone require special treatment. Beer scale is usually removed with nitric acid but may also be removed with inhibited hydrochloric acid or hydrofluoric acid in a suitable carrier. It is reported in the literature that hydrochloric acid can be inhibited with dibenzyl sulfate. Gum tragacanth held in solution with alcohol has been a satisfactory carrier for hydrofluoric acid. Milk stone may be removed with an aqueous solution of tartaric acid and sodium fluoride.

Whether or not there is any deposit or scale which must

TABLE I. TYPICAL MECHANICAL PROPERTIES OF ALUMINUM ALLOYS[a]

Alloy and Temper	Yield Strength[b] (Set = 0.2%)	Ultimate Strength	Elongation in 2 In.[c] 14-gage sheet specimen	Elongation in 2 In.[c] Round specimen	Brinell Hardness (500 kg., 10-mm. Ball)	Shearing Strength[d]	Endurance Limit[e]
	Pounds/square inch	Pounds/square inch	%	%		Pounds/square inch	Pounds/square inch
2S-O	4,000	13,000	35	45	23	9,500	5,000
2S-1/4H	13,000	15,000	12	25	28	10,000	6,000
2S-1/2H	14,000	17,000	9	20	32	11,000	7,000
2S-3/4H	17,000	20,000	6	17	38	12,000	8,000
2S-H	21,000	24,000	5	15	44	13,000	8,500
3S-O	5,000	16,000	30	40	28	11,000	7,000
3S-1/4H	15,000	18,000	10	20	35	12,000	8,000
3S-1/2H	18,000	21,000	8	16	40	14,000	9,000
3S-3/4H	21,000	25,000	5	14	47	15,000	9,500
3S-H	25,000	29,000	4	10	55	16,000	10,000
4S-O	10,000	26,000	20	25	45	16,000	14,000
4S-1/4H	22,000	30,000	10	17	52	16,000	14,500
4S-1/2H	27,000	33,000	9	12	63	18,000	15,000
4S-3/4H	31,000	37,000	5	9	70	20,000	15,500
4S-H	34,000	40,000	5	6	77	21,000	16,000
52S-O	14,000	29,000	25	30	45	18,000	17,000
52S-1/4H	26,000	34,000	12	18	62	20,000	18,000
52S-1/2H	29,000	37,000	10	14	67	21,000	19,000
52S-3/4H	34,000	39,000	8	10	74	23,000	20,000
52S-H	36,000	41,000	7	8	85	24,000	20,500
53S-O	7,000	16,000	25	35	26	11,000	7,500
53S-W	20,000	33,000	22	30	65	22,000	10,000
53S-T	32,000	38,000	14	20	80	26,000	11,000
43	9,000	19,000	..	4	40	15,000	6,500
214	12,000	25,000	..	9	50	19,000	5,500
216	16,000	27,000	..	6	60	23,500	....
220-T4	25,000	44,000	..	13	75	33,500	7,000
356-T4	16,000	28,000	..	6	55	22,000	....
356-T6	22,000	32,000	..	4	70	23,000	8,000
356-T51	20,000	25,000	..	2	55	18,000	6,000
13	....	33,000	..	1.3	..	....	....

[a] Young's modulus of elasticity is approximately 10,300,000 pounds per square inch.
[b] Stress which produces a permanent set of 0.2 per cent of the initial gage length (Am. Soc. for Testing Materials Specification for Methods of Tension Testing, E8-33).
[c] Elongation values vary with the form and size of the tension test specimen. Thin sheet has somewhat lower elongation than values for 1/16-inch sheet shown in the table. Thicker material, from which standard round tension test specimens (0.505-inch diameter) are tested, may have lower elongation because of the effect of commercial flattening operations on this property.
[d] Single-shear strength values obtained from double-shear tests.
[e] Based on withstanding 500,000,000 cycles of completely reversed stress, using the R. R. Moore type of machine and specimen.

TABLE II. FACTORS FOR DESIGN STRESSES AT ELEVATED TEMPERATURES

Alloy	100° F.	200° F.	300° F.	400° F.	500° F.	Type of Material
3S-O	1.0	0.85	0.70	0.60	0.40	Wrought
3S-1/2H	1.0	0.75	0.60	0.45	0.30	Wrought
3S-H	1.0	0.75	0.60	0.35	0.25	Wrought
4S-O	1.0	0.90	0.80	0.50	0.40	Wrought
4S-1/2H	1.0	0.90	0.65	0.30	0.25	Wrought
4S-H	1.0	0.80	0.55	0.25	0.20	Wrought
52S-O	1.0	0.95	0.90	0.70	0.55	Wrought
52S-3/4H	1.0	0.95	0.80	0.50	0.30	Wrought
53S-O	1.0	0.80	0.60	0.50	0.30	Wrought
53S-T	1.0	0.85	0.70	0.40	0.15	Wrought
43	1.0	0.80	0.70	0.55	0.40	Cast
214	1.0	0.95	0.90	0.75	0.50	Cast
220-T4	1.0	0.85	0.75	0.50	0.30	Cast
356-T4	1.0	0.95	0.85	0.50	0.30	Cast

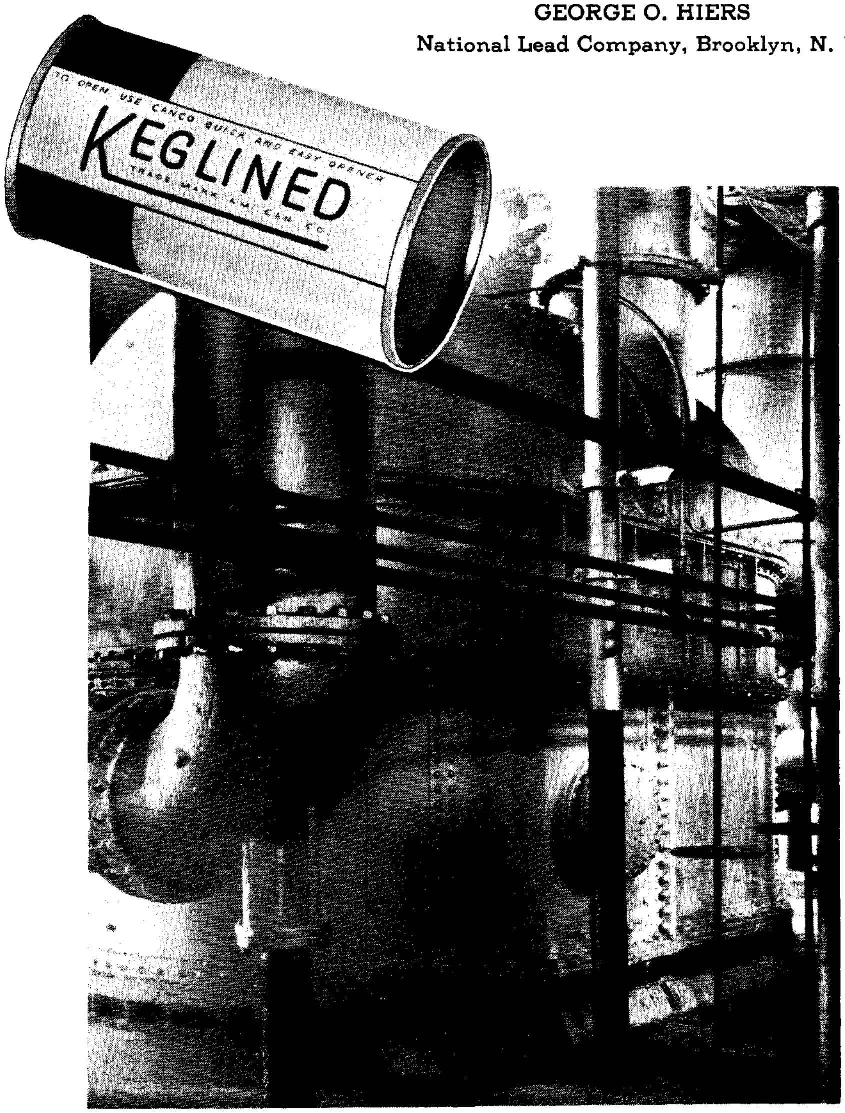
be removed, thorough periodic cleaning may greatly increase the length of service. This is particularly true when solutions of heavy metal salts are in contact with the aluminum. Each cleaning removes the precipitated metal and thus arrests the growth of the small pits which have been induced by electrolytic attack since the last cleaning. In this way the depth of pitting is greatly reduced. On the other hand, cleaning should be avoided when the layer of corrosion product is required to protect the underlying material, as with ammonia and formaldehyde.

Aluminum used in contact with foods must be regularly sterilized. Wherever possible this should be done with steam. If a chemical sterilizer containing chlorine has to be used, it should be suitably inhibited. Sodium silicate is frequently a satisfactory inhibitor for such solutions.

RECEIVED September 12, 1936.

NEW METALS AND ALLOYS FROM LEAD, TIN, ZINC, AND ANTIMONY

GEORGE O. HIERS
National Lead Company, Brooklyn, N. Y.



COKE PLANT SATURATOR OF STEEL LINED WITH SHEET LEAD 1.25 INCH THICK
(*Inset*) BEER CAN OF TIN

THE research worker in the base metals—lead, tin, zinc, and antimony—is developing new uses for old metals, new alloys for old jobs, new combinations of metals to perform newly created tasks. This paper discusses the alloys based on these metals.

Lead

Although new uses have been found for this historic and modern metal, the most important recent developments are in lead alloys. In 1919 it was demonstrated that the addition of a small amount of copper to lead improved lead's resistance to corrosion by sulfuric acid at elevated temperatures because it tended to offset the deleterious actions of bismuth and antimony. Then tellurium was also shown to improve the behavior of lead under certain laboratory test conditions, but it was not until comparatively recently that the tellurium alloys in use today were developed and commercialized.

One of the large lead producers recently introduced to the American market a new type of chemical lead containing not only 0.04 to 0.08 per cent copper but also approximately 0.02 per cent bismuth. It is claimed that this alloy or new variety of lead can be used for many purposes as satisfactorily as the A. S. T. M. standard chemical lead; in addition, it is said to possess some advantages in mechanical properties.

One of the most spectacular recent developments is tellurium lead, which is ordinary lead containing about 0.05 per cent tellurium. It was developed in England and is now extensively used on