

ESTABLISHED 1902

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MATERIAL AND MATERIEL

BACK in the dismal days of the depression, we argued endlessly about whether our troubles were caused by over-production or under-consumption. Today when some essential war industries are being slowed down by inadequate supplies of raw materials, everyone is asking,—“Are these real shortages, or are we suffering temporarily from maldistribution and unbalanced inventories?” The answer, now just as it was ten years ago, is that it is academic to argue over nomenclature. We face, as we did then, a definite situation. We must make immediately the necessary corrections and adjustments so that we can get going again at the highest overall rate for the things we need most. That that means maximum production of war goods and absolute minimum of everything else, now goes without saying.

We know that we have not made the best use of our material resources in the past two years, but we have built a tremendous war industry in much shorter time than any other nation in the world. Time has been of the essence and we have had to fight for everything we needed to do the job assigned to us. The priority system itself encouraged competitive acquisitions. There have been too many top ratings for too little supply, particularly for steel and other critical construction materials. Is it any wonder that some inventories are badly unbalanced, that often substantial quantities of materials are tied up for want of one or two parts or products? We have heard reports of a million-dollar war project held up for want of \$20,000 worth of alloy steels. Meanwhile other plants to supply complementary materials must shut down or mark time to keep from piling up “too much and too soon.”

Donald Nelson, who has lately had to fight off his critics with his back almost to the wall, had the only common-sense answer. “The big job ahead of us right now,” he said on August 22nd, “is to bring our program into balance and to make sure we use our materials and our facilities as

wisely as possible.” Whether such good advice is going to be followed voluntarily by industry is an open question. A workable system of inventory control through complete allocation of production requirements might be the answer. But when it comes to requisitioning and redistributing goods already in private hands, something more than general directives from Washington will be needed. Definite policies must be established and enforced by the government. Here is a job that calls for stronger, more direct action than any we have yet had from this administration.

One blind spot in many of our calculations is the large percentages of the output of certain raw materials that have been and are still going out of the country. This is part of a grand strategy, which apparently has the approval of the military authorities. Yet in cases where critical war production in this country is held up for want of materials being exported under Lease-Lend, it is obvious that we are not following that “wisest” course in utilizing our own great resources.

In our concern with the immediate situation, which we hope is already in the process of being corrected, let us not lose sight of the fact that we are in a period of transition to a different and more abundant materials economy. We are operating many basic industries at higher levels than ever before in history. We are just beginning to realize some of the advantages as well as limitations of a greatly expanded volume of business. For the first time we are seeing what our science and technology can do when the production engineer is given the right of way with the throttle wide open!

So, as we push ahead to produce the tremendous supplies of materiel required for our war effort, we may take some byproduct credit for helping to build a better post-war economy. In that process of meeting today's problems and preparing for tomorrow's, we hope that this Tenth Materials of Construction issue of *Chem. & Met.* will serve as a

useful and practical source of reference—both for information and inspiration. It tells many stories of material and materiel of which the chemical engineering profession may well be proud.

LIFE BEGINS

FORTY years is not very long in the history of American industry. Yet since Vol. 1 No. 1 of this magazine appeared as *Electrochemical Industry* in September 1902, its field has undergone significant changes. First there was the budding industry that sprang up around Niagara Falls as cheaper hydro-electric power first became available. Electrometallurgy followed closely on the heels of electrochemistry and in 1905 the field of the magazine was extended in that direction.

"Engineering" first became a part of our name in January 1910 because, said the editor, "we wish to emphasize that this journal is not, on the one hand, a trade paper, nor on the other hand a periodical representative of pure science. Rather, we are concerned with . . . what is needful in the work of the engineer in the conduct and management of . . . chemical works."

It is interesting to note that the same editorial forecast the unit-operation concept of chemical engineering when it remarked that all those "engaged in engineering practice in industrial establishments are more or less interested in the same processes—in crushing and grinding, concentration and separation, drying and evaporation . . . etc."

Chemical engineering arose to meet the challenge of the first World War and that ascendancy was duly noted July 1, 1918, when, "*Met. & Chem.*" became "*Chem. & Met.*" That was almost a quarter of a century ago. Today all of us are again

faced with new problems and responsibilities. We on *Chem. & Met.* consider ourselves fortunate to be allied with a resourceful industry and profession that offers so many opportunities for serving our country in its present need. We are encouraged to believe with Professor Pitkin that "Life Begins at Forty."

GET IN THE SCRAP!

WALTER CARPENTER, able president of the du Pont company, is helping the American Industries Salvage Committee to carry its program into every company in the chemical industry. He has urged his fellow executives to get behind the work of the Industrial Salvage Section of W.P.B. "This is a situation," he said, "wherein by helping our Government, we are also helping ourselves; because industry cannot do a satisfactory job of production without more scrap materials than are normally available. . . . There is needed an extraordinary cleanup of our factories, involving recognition of the fact that if a machine or pipeline, a heating plant, a building . . . is not absolutely essential for production at this time, then consideration should be given to scrapping it. If we don't win this war, most of our factories will be scrapped anyway!"

In 1,200 different communities, W.P.B. has set up general salvage committees. In 400 industrial centers there are representatives of its Industrial Salvage Section ready to help in organizing effective salvage work in factories, offices and laboratories. This assistance is yours for the asking. Write or wire the Conservation Division, War Production Board, Railroad Retirement Building, in Washington.

Washington Highlights

PRIORITY policies now pinch severely on research and control laboratories which use as much as \$5,000 per quarter of scarce metals. This makes the laboratory director responsible for P.R.P. quarterly filings and the pursuance of the rest of the Preference Rating ritual. Obvious remedy is to adapt old facilities to new purposes in the lab as well as in the works, whenever this is possible, even with the sacrifice of a bit on efficiency.

CONCENTRATION of production in a few plants is to be extensively practiced in metal-working industries. There may be a few cases where this practice can be helpfully applied in the chemical industries. If a single producer has facilities to manufacture all the needed quantity of some chemical, there ought to be means by which anti-monopoly rules can be

suspended to permit that efficient plan of operation, if it is really of benefit in saving skilled manpower. But long transportation and confusion in supply for essential users must not creep in as a secondary effect or the benefits of concentration of production will be overshadowed and the war program hurt rather than helped. Probably only a few chemical cases will really qualify for this program.

GUARANTEES of both quality and price for domestic soap supplies is undertaken in recent actions of O.P.A. One wonders how the quality of certain detergents can be guaranteed when almost essential raw materials like coconut oil are obviously not available. Maybe O.P.A. will provide some new laboratory techniques to help the much buffeted soap experts. We wonder.

RECORD PRODUCTION of synthetic organic chemicals in 1941 is reported by the preliminary statistics of U. S. Tariff Commission, issued in mid-August. This division of the chemicals industry sold \$724,000,000 worth of goods last year. This was an increase of 50 percent over the previous year's sales which had been the highest on record. The rate of growth and the adequacy of synthetic chemicals supply probably surprises no one, except, we believe, our Axis contemporaries.

NEW COSMETICS are virtually prohibited by the regulations restricting containers and the use of container materials. Comparable policy is suggested by W.P.B. actions on more important industrial materials. But fortunately there is no tendency to discourage new chemicals which have a real war-time service value.

Materials for the Construction of Chemical Engineering Equipment

The war is having a tremendous effect on all materials, in particular aluminum, stainless steels, nickel, copper, rubber, and others which the chemical engineer has become accustomed to specify for construction of his equipment. The source of natural rubber is in the hands of the enemy, stainless steels are in demand for ships, guns, and tanks; copper for shells; aluminum for airplanes; rubber for jeep tires and a thousand other uses. The process industries must share the supplies of these strategic materials. It is essential that the limited amounts be conserved and made to stretch as far as possible, that life of present equipment be prolonged throughout the period of the emergency, and that substitutes be used whenever practical. For the success of the Victory Program depends in no small measure on their availability for the construction of equipment so badly needed to swell the supplies of synthetic rubber, 100-octane gasoline, and chemical warfare agents for the armed forces. Chem. & Met.'s Tenth Materials of Construction Issue should serve a timely and useful purpose. It presents the ways and means for conserving and protecting materials and equipment. Its data sheets bring up to date the basic information on manufacturers, composition, and corrosion, heat and abrasion resistance. In effect, it is a complete mobilization of available information.

Materials of Construction for Today and Tomorrow

SUMMARY AND CONCLUSIONS

Realizing the seriousness of the present situation in materials for corrosion, heat and abrasion resistance, the editors in this report have suggested means by which engineers can get most out of what they now have. For the benefit of those who can not obtain the materials they would normally specify, the availability of substitutes or alternates is discussed. The world upheaval is necessarily having a tremendous influence on the entire field of materials and has called for a look at the materials of tomorrow.

Properties of metals and alloys are presented for the first time on a series of fold-out inserts for

simplicity in handling. For each material are given the manufacturer's name and address, the composition, and resistance to abrasion, to heat, and to commonly encountered chemicals. The trend towards adoption of standard uniform nomenclature for all alloys has been given further impetus by development of a system of designations for heat and corrosion resisting castings by the Alloy Castings Institute. The influence of the war is reflected in the tabulations of information on non-metallic materials. A vast new synthetic rubber industry is in the making and new plastics are available to the engineer for the first time.

Conservation of Materials

“THE CIVILIAN ECONOMY is fast going on a minimum subsistence standard, vital materials no longer can be used except for war, and for the maintenance of those things necessary to carry on the war. The past months have been relatively easy, the military has taken from the civilian to meet its needs. This pool is nearly dry, from here on out it will be a continuous problem to meet the needs of our fighting forces. Industry must get ready to ‘Patch and Pray’ to keep existing equipment at work,” warns W. L. Batt, chairman of the Requirements Committee of WPB. Just as long as the emergency exists the metals and their alloys, with the exception of lead, which the chemical engineer has become accustomed to depend upon for the construction of his process equipment will be difficult to obtain unless he is fortunate enough to possess a high priority. This situation is not limited to the metallic materials, for rubber is in the same category. And while there are not the same restrictions on chemical stoneware, glass, wood, and the other non-metallic materials, nevertheless, the heavy demand makes delivery of new equipment slower than it is in normal times.

As Mr. Batt warned, the engineer must be resourceful in conserving the

supplies of strategic materials and in prolonging the life of present equipment. When new equipment is planned much can be done to stretch the supply of strategic metals. In some instances this may be accomplished by specifying linings over a base metal. Probably the greatest conservation can be obtained by more careful study of each item, and use of the lowest possible alloys which are now in commercial production, as V. W. Whitmer recently stated before the A.S.T.M. For example, there are undoubtedly many applications using chromium-nickel alloys where the straight chromium could be very easily substituted.

Favorable design should be considered which will provide against the presence of crevices, pockets, or other areas that might promote accumulation of deposits or stagnant liquors. In cases where excessive corrosion at one or more points in a vessel has been troublesome it is well to examine carefully for the presence of those areas which might be responsible for this susceptibility to corrosion.

Excessive wear in vessels, pumps and piping frequently is due to inadequacies of design. Reduction in rates of flow, or slight changes in direction of flow, might be sufficient to reduce

excessive wearing of piping and valves. Excessive wear of pump parts might be due to use of improper alloys for wearing members; as well as to improper or inadequate lubrication.

The design and location of vapor connections should be such as to provide against refluxed condensate running down the walls of the vessel instead of dropping freely into the liquid. Improvements frequently result through changing the location of critical parts to points outside the condensation zone, or by process changes which limit the region in which condensation is occurring, as for example by reduction in process temperature, jacketing the vessel, or similar operation readjustments.

Use of the same type of metals together where possible is recommended in order to avoid galvanic corrosion. In the cases where necessity demands that dissimilar metals and alloys be used together in corrosive environments there are certain definite rules to follow in order to assure success of the combination. When dissimilar materials are to be used together it is best to determine beforehand that both have adequate resistance to corrosion by the process liquors under normal conditions. Nickel, Monel and the other high-nickel alloys may normally be used together with safety, and with copper, bronze, brass and

other copper-base alloys. In combinations with plain and low-alloy steels and cast irons, and with aluminum, zinc, and other metals less noble than nickel opportunities for appreciable galvanic corrosion may exist, and the proposed metal combinations should be considered carefully before new installations or changes in existing equipment are made.

Combinations of the relatively noble nickel and high-nickel alloys with less noble materials, such as steel and cast iron, are usually satisfactory when the exposed area of more noble material is small in comparison with that of the less noble.

When it is impossible to avoid using galvanic couples suspected as being dangerous non-metallic insulation in the form of gaskets, sleeves, and washers are recommended. These insulating gaskets should be applied in a manner to provide complete electrical insulation between the materials forming the couple.

It is good practice whenever feasible to coat large surfaces of the more noble metal in a galvanic couple with an insulating paint so as to reduce the effective area of the cathode in the galvanic cell. The use of cathodic protection, either from applied current or by sacrificial corrosion of a less noble metal such as zinc, may serve to lessen galvanic corrosion which otherwise might occur. In some instances where galvanic corrosion is not a problem the application of a protective current may serve to prolong equipment life or reduce metallic contamination where such is an important factor.

"AN OUNCE OF PREVENTION"

Many means may be used for extending the life of equipment already in service. Periodic and careful cleaning of equipment is a most important factor in assuring greatest possible life. Be sure to use cleaning agent recommended for the surface material. In the case of wire mesh and other process equipment utilizing metal in small sections it is of the utmost importance that acid cleaning agents be thoroughly flushed and rinsed off after the desired cleaning has been accomplished. This is important because the presence of diluted acid in restricted areas, away from free flow of process liquors, might promote concentration cell corrosion. This same precaution is necessary in large vessels especially around seams and connections where the type of joint is likely to be such as to provide a crevice.

Other precautions that will

lengthen the life of equipment should be mentioned. Be sure that the metal is recommended for use in the production and handling of the particular chemical or combination of chemicals. Inhibitors are widely used to prevent attack by hydrochloric acid and other chemicals, but several authorities contend that even greater use could be made of these interesting agents.

STAINLESS STEELS

The service life of stainless steel equipment can be lengthened by following certain precautions. Remove materials and deposits that tend to adhere to the surface, especially in crevices and corners. Cleanliness can not be stressed too strongly. Work for uniformity in regard to solutions, temperatures, agitation, concentration and surface conditions. Avoid prolonged standing of chlorides, bromides, thiocyanates and iodides in stainless steel equipment, especially if acid condition exists. The pitting action of these compounds may be retarded or avoided by making solutions alkaline. If this is not possible, avoid long contact of compounds with the metal and clean frequently. Be sure to avoid corrosion fatigue. This is usually the result of a combination of cyclic stresses and weld corrodents. The remedy is to make the equipment sufficiently strong to withstand any stresses which may be encountered. If this is not possible, the equipment or unit should be so constructed as to permit freedom of movement of the entire unit.

NICKEL

In the case of nickel and the family of high-nickel alloys, cleaning may be done with any of the alkaline cleaners. Dilute acid cleaners, such as sulphuric and hydrochloric, are also used extensively, and when so employed in correct strengths and at warm temperatures are not detrimental to the life of the materials. With some exceptions, nickel, Monel, and other nickel alloys which do not contain substantial amounts of chromium should never be cleaned with nitric or other oxidizing acids since these are corrosive to nickel and the other alloys mentioned, and will cause loss of metal through corrosion.

Scouring of nickel and nickel alloys is best accomplished with abrasive cleaners, such as finely divided pumice, or with those preparations compounded for household use. Steel wool or steel wire brushes should never be used on nickel and nickel alloy equip-

ment since their use presupposes the likelihood that fine particles of steel will become embedded in the metallic surfaces with later development of rusting, and occasionally localized attack under the rust deposits. If brushes are to be used with the abrasive cleansers a stiff type of fiber brush is the best choice. Metallic wool scouring pads of nickel and Monel are commercially available and should be used where more severe scrubbing or scouring is indicated.

The use of organic inhibitors, of the types added to steel pickling acid solutions, with the cleaning acids employed on nickel alloy equipment is recommended.

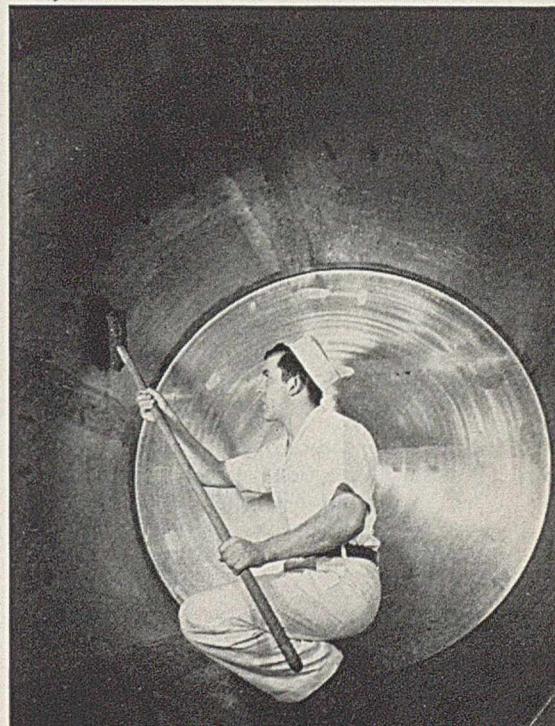
The use of improper welding or brazing rods in making repairs on nickel and nickel alloy equipment frequently leads to trouble since the weld metal being of different composition from that of the parent metal may if less noble suffer accelerated galvanic corrosion. Fabrication and repairs are of course best made with rods of composition identical with that of the material being joined.

LEAD

Lead's resistance to corrosion depends in part on the extent to which its protective surface layer can be kept continuous and unbroken. By designing equipment in such a way as to restrict unnecessary movements of the metal or by exercising reasonable care to prevent mechanical injury to the protective coating lead will often last for a long time.

Regarding installation, the important point to remember is that lead requires adequate support at all

Life of stainless steel may be lengthened by removal of adhering materials



points where stresses may occur. Proper support not only reduces the possibility of mechanical failure but also restricts movements of the metal which, as pointed out above, are a contributing factor in corrosion.

Lead pipes in the horizontal position are usually supported by placing them in steel or wooden troughs. Vertical pipe lines may be held in position with steel straps, spaced 18 in. or so apart and securely bolted to a rigid supporting structure. Another method of supporting lead pipe, either vertically or horizontally, is by inserting and expanding it in standard steel pipe. Users of this procedure report that it is not only more satisfactory but cheaper than angle iron or wooden supports.

As in the handling and installation of lead, so in the treatment of lead equipment in service avoidance of physical injury and a proper regard for the metal's mechanical limitations are the guiding principles.

For example, when depositing or removing objects from a tank, care should be taken to avoid unnecessary contacts with the lining which might nick the lead or abrade its protective coating. Again, chemical solutions often deposit crystals, scales, crusts and the like, the removal of which is a common source of injury to linings. Workmen entering the tank should wear rubbers or other shoe coverings. Shovels, hoes, rakes and similar tools should be used with an appreciation of the necessity for careful handling to avoid trouble.

Where heating coils are employed, turning on of the steam should be done gradually through the use of needle valves. A sudden surge of pressure may distort the coils, rupturing the protective coating as well as weakening the metal structurally. The installation of thermostatic or pressure controllers which guard against excessive pressures and temperatures frequently prevents damage to coils through carelessness. The use of hot water instead of steam as the heating medium is another method of prolonging coil life, particularly where moderate temperatures are employed with chemicals such as chromic acid. While the former takes longer to raise the solution to the desired temperature, corrosion of the coil itself is retarded.

ALUMINUM

For most applications there is little or no reaction between aluminum and the substances being processed. In other cases, some reaction may occur. In cases of this type, it is often pos-

sible to extend the life of equipment appreciably by suitable protective measures (H. J. Fahrney and R. B. Mears, *Chem. & Met.*, Vol. 49, pp. 86-89, July, 1942).

Several protective measures which have proved beneficial are available. These methods include: (1) cathodic protection, (2) coatings, (3) chemical inhibitors, and (4) periodic cleaning.

Each of these methods has special fields of usefulness. Cathodic protection is particularly suitable for preventing attack by unrecirculated waters and by nearly neutral or slightly acid salt solutions. The liquids must have a relatively high conductivity and only areas of the metal exposed in contact with the liquid can be cathodically protected. In cases where it is applicable, cathodic protection is usually the cheapest and most effective method of preventing attack.

Chemical inhibitors are particularly useful in recirculated waters or in cases where the same material is to be stored for relatively long periods of time in the equipment under consideration. As with cathodic protection, only the metal areas below the liquid level are normally protected by inhibitors.

Protection against more severe conditions, such as the stronger acids, can best be obtained by coatings. These can be applied most readily to new equipment or to units which can be easily handled.

Periodic cleaning has proved most useful in cases where solid products settle out on the metal surface and adhere tenaciously to it. It is generally of little use where the liquids being processed uniformly dissolve the metal surfaces which they contact.

RUBBER

How to conserve rubber equipment was discussed in a recent article (O. S. True, *Chem. & Met.*, Vol. 49, pp. 88-89, Mar., 1942). In the planning which precedes the actual installation of rubber-lined equipment, the engineer should be careful to give the rubber manufacturer full and accurate information concerning service conditions. Specifications differ appreciably and the life of any installation may depend greatly on the completeness of the original information.

In the case of rubber-lined equipment, if it is necessary to enter, workmen should wear rubber-soled shoes to avoid abrading and cutting the lining. Care should be taken against the possibility of welding sparks or tools

dropping into the tank from construction overhead. If there is a possibility of mechanical damage to the lining, it should be protected by wood bumper strips or brick linings set with acid-proof cement. Hard rubber-lined equipment should be protected against external shock—particularly in cold weather.

In the case of solid hard rubber material, operators should be instructed that the material is brittle and that normal methods of pipe handling should not be used. Pipe lengths should be fully supported, strap wrenches should be used for drawing threaded ends together, and temperatures and pressures should be within a range suggested by the manufacturer. Such pipe should be kept away from points where there is an excess of traffic and especially away from hand trucks, etc.

CARBON AND GRAPHITE

Carbon and graphite piping must be handled with a minimum use of high-pressure tools. It is recommended that pipe be handled and tightened by hand or with assistance of a rope wrench.

It is a good idea to carry in stock repair couplings and slab material. If a break does occur the broken pieces can be collected, fitted into original position and cemented together using carbonaceous cements recommended for the particular purpose by the carbon manufacturers. Should the broken pieces be too small to justify this type of repair it can be made by using the slab stock in store. Carbon slabs can easily be shaped to proper dimensions and cemented over the opening in the vessel.

GLASS LININGS

Glass-lined equipment that receives reasonable care is long-lived. There are many installations in good working order that have had continued use for over 20 years. The manufacturers report that if the following instructions are followed the life of linings can be lengthened materially:

1. When ready to clean, cool the equipment by flooding the jacket with cold water, then rinse the inside with cold water to remove deposits from the surface.

2. Scrub the glass lined surface with detergent solution. Use a commercial detergent which contains only a fine abrasive and soap. Take one part detergent and two or three parts water, mix and boil. (When boiling with direct steam in solution, use only two parts water.) Permit solution to cool, stirring occasionally to keep abrasive powder in suspension. Solution will form jellylike mass with abrasive evenly suspended.

3. Dip wet brush into detergent solution and scrub equipment. Do not put detergent solution in the vat.

4. After equipment has been scrubbed thoroughly, rinse with cold water.

5. Then rinse with hot water.

6. Sterilize according to normal procedure, either by heating through the jacket or directly with a steam hose. In case of the latter procedure, keep the end of the hose at least 12 in. from the glass-lined surface. Do not use hose with metal nozzle or metal weight on end of hose.

FUSED SILICA AND STONEWARE

Vitreous silica industrial equipment gives little trouble, but there are a few precautions that if followed will add length to its life. Avoid use of rigid joints between fused silica and other materials, all of which have higher thermal expansion, if the joint is to be subjected to high temperatures. It is advisable to avoid the use of hard setting cement on fused silica equipment at high temperatures for the same reason.

This equipment is suitable for operating temperatures up to 1,000-1,100 deg. C. in the absence of certain mineral salts or reducing gases which may accelerate breakdown due to denitrification. Temperatures as high as 1,350 deg. C. are possible if critical temperature zones between 1,250 deg. C. and 1,300 deg. C. and below 300 deg. C. are avoided.

Failure of chemical stoneware equipment may usually be traced to the use of the wrong body or to faulty installation. Stoneware bodies differ in their physical properties as widely as do different grades of steel and must be selected with equal care with particular reference to the service expected of them. The equipment should be installed so as to allow for expansion and contraction, to minimize vibration and tensile stress, and to take full advantage of the extremely high compressive strength that is characteristic of the ware.

SYNTHETIC RESIN

Tanks or other pieces of phenolic resin equipment, damaged in transit or by accidents in operation in such a manner as to produce holes or breaks may be refilled with some of the same type of resin and made as good as new without excessive cost. Minor repairs can be made on the premises by the user's own men and the equipment can be placed in service again after only a few hours. Surface damage need cause no concern as the material possesses uniform chemical resistance throughout.

The foregoing attempts to suggest a few of the ways by which the extremely limited stocks of strategic metals and alloys may be made to go farther and means for protecting what equipment we already have in an effort to make it last through the emergency. Every success that is thus achieved helps in winning the final Victory.

Alternate Materials

MOST CONSTRUCTION materials problems, met in the design of equipment and buildings for chemical process industries are capable of a number of different solutions, and in normal times the engineer's task is to discover those materials which come closest to the ideal. These, however, are not normal times. Metals in particular, as well as rubber and plastics, are becoming increasingly difficult to secure, partly on account of actual shortages, and partly because of excessive inventory stocking on the part of some manufacturers. Certain of the scarcest materials are already subject to complete allocation, and others are sure to be added to the list. At present allocated materials can be had only for the most essential purposes and when nothing else, in the opinion of the authorities, can be substituted. But if current War Production Board moves are carried through, it is probable that such materials will not be available at all for production equipment, but only for the manufacture of offensive weapons.

To an ever larger extent, therefore, chemical engineers are finding it necessary to use materials which are inherently more plentiful, or in less demand, than the ones they may have been accustomed to use. Sometimes new materials can be found which will perform as satisfactorily as the old materials, or even better. In other cases, new uses are possible for old

materials, or new ways of using them can be discovered. In general, however, the question of alternates comes down very largely to the application of well-known materials, which for reasons of personal preference, higher costs, or certain not-so-satisfactory properties, were ruled out before the preferred materials became unavailable. It is in the last group of possibilities that the great preponderance of solutions will be found.

Unfortunately, many of the construction materials that are being advanced as alternates are themselves hard to get today, owing to difficulties in transportation, or lack of sufficient production capacity to meet the present inflated demand. With many, the demand is now so large that reasonably rapid delivery can be made only to holders of relatively high priority ratings. Still, this statement is true only in a number of cases, and does not apply to all materials, nor to all equipment manufacturers. Each case must be checked individually. Furthermore, the supply situation is in a constant state of flux, and generalizations which are correct at one time may be untrue a week or a month later. An example is the case of lead, which a few months ago was one of the scarcest metals. At present, lead is listed in the War Production Board's Materials Group III, which includes materials available for substitution.

Capacity to produce, rather than the availability of raw materials, is the limiting factor with most alternate materials. As a general rule, the best prospects for adequate supply are found with those materials which require the least manufacture, and make use of the least metal. Wood, cement and clay products are in this category, although even these may be scarce in some localities, while certain types such as structural lumber and refractory brick may be difficult to obtain anywhere.

Conversely, manufacturing bottlenecks in the case of other materials which ordinarily are easy to obtain have become fairly pronounced at present, and may become even more severe. Chemical stoneware, especially the more highly fabricated forms, requires materially increased delivery time. The same is true of structural carbon and of industrial glassware. Several of the plastics which would ordinarily be considered as available for alternate use are even harder to get than metals, including phenol-formaldehyde, acrylic and methacrylate, and vinyl chloride plastics, as well as synthetic rubbers and rubber reaction products. With the exception of natural rubber, all of these materials are of domestic origin, but competition with other war products for necessary raw materials and intermediates, and competition for the finished plastics, has made them unavailable for all but exceptional uses.

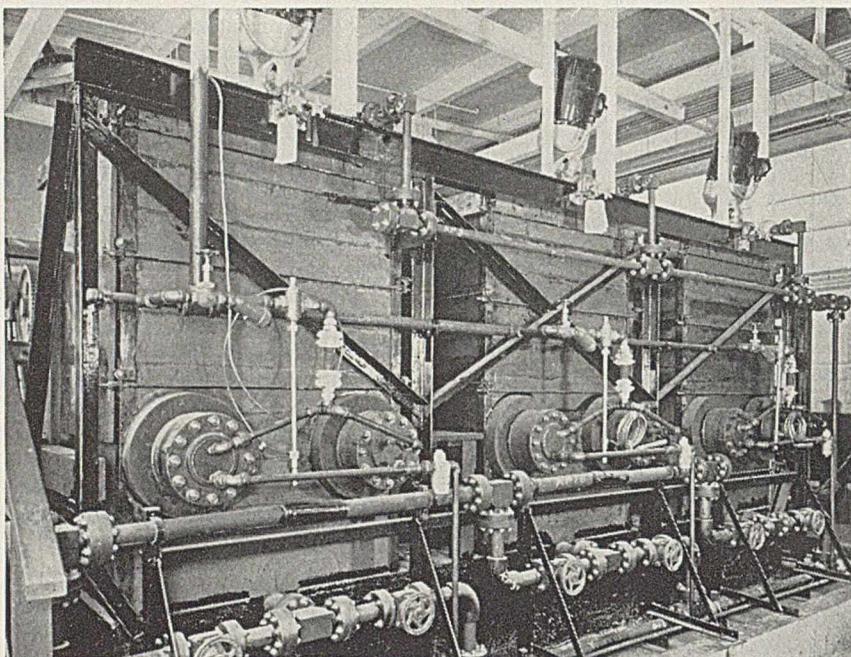
The higher alloy steels together with copper, nickel, aluminum, magnesium and their alloys can, of course, be obtained only on allocations. To save alloying elements in those steels which emphasize mechanical and physical properties, rather than temperature or corrosion resistance, several new series of lean alloy steels, known as the NE (National Emergency) steels have been developed by the steel industry and accepted by the War Production Board, and such steels must now be specified by metal fabricators for all uses where the need for higher alloys cannot be definitely established. Even these steels, however, can be obtained only with WPB permission, for the supply must be conserved for essential uses.

In the process industries, obviously, many construction materials are selected for their corrosion or heat resistance, rather than for mechanical properties, and so with alloys it is generally impossible to achieve the necessary resistance and still scale down the alloy content to any considerable extent. This situation is in part recognized in WPB Order M-21-g, which sets the maximum alloy content for a variety of heat-resisting applications.

The situation regarding cast iron seems to vary considerably. Some foundries appear to have plenty of material and are able to give rapid service, whereas others are demanding and getting high priorities for the work they perform. In any event, together with other metal fabricators, the foundries which consume more than \$5,000 worth of metal per quarter must now submit their detailed quarterly requirements for government approval under the Production Requirements Plan. Presumably, as this plan becomes more effective through application of the experience now being gained with it, cast iron may become somewhat less freely obtainable.

METALS FOR METALS

Although most metals used for corrosion resistance, for alloying and for plating are on the critical list, there are several metals which can still be secured for use as substitutes. Also, of course, there is always the possibility of conserving the scarcer metals by using them as 10 or 20 percent plymetals. One interesting substitution that has recently been proposed to replace tantalum is to use platinum plated on copper or brass tubes for applications in contact with hydrochloric acid where good heat transfer must be secured. Gold is available for



These three boiling tanks are built of Karbate structural carbon which is used for wall slabs, heater tubes and heads and the pipes, valves and fittings

such applications and may be employed either as a plated coating or in the form of a plymetal. Silver, originally believed to be adequate in quantity for substitution, is now almost entirely under allocation.

As has already been noted, lead is now quite plentiful, which applies also to certain of its alloys used for equipment construction purposes, such as tellurium and antimonial lead. Another available material is a new high strength lead alloy, designed particularly for water-service piping.

NON-METALLIC ALTERNATES

Carbon—Applications of structural carbon have developed rapidly in recent years. Ample raw material is available despite the enormous demand for carbon electrodes. The present chief deterrent to more widespread use of structural products lies in facilities for producing finished materials. Carbon can be obtained in both ordinary and impervious forms, as well as in a porous variety for filtration and bubble-producing applications. It is being fabricated in a wide variety of standard brick and block shapes, the latter so large as materially to reduce construction time of large equipment. Carbon tubes are being used extensively for their high heat transfer ability in the assembly of heat exchangers. All-carbon centrifugal pumps are being made, together with small vessels, cylindrical tower sections, valve bodies, fittings and pipes and a variety of other fabricated forms.

Concrete—Many ways have been developed for the use of concrete in tanks and vessels for liquids. Many proprietary compounds have been introduced for waterproofing concrete and for making it proof against other substances. Although some of these were based on rubber, many now obtainable with greater or lesser difficulty are plastic-base materials. For example, a new coating for concrete, wood or metal is made from a furfural type plastic said to be obtainable in quantities limited only by present production equipment. Films of this coating, built up by a number of brush applications, are thick enough for use in contact with all solvents, mineral and oxidizing acids in moderate concentration, vegetable and mineral oils and high octane fuels, according to the manufacturer. This coating, known as Tygon F, is intended for use up to 350 deg. F.

For other applications of concrete tanks, linings of chemical stoneware and porcelainware, or of structural carbon, may be used where the service is too severe for coatings. Most of the cements required for laying up these linings can be secured without difficulty, as well as the bituminous-base types of sheet lining material which are sometimes employed as a cushion and liquid proofing between the tile and the concrete wall.

Owing to metal shortages, cement-asbestos pipe has come into great demand, particularly for the handling of water and mildly corrosive solutions, as well as for fume ducts and

stacks. For more severe duty, cement-asbestos pipe is now being produced with resin-base coatings designed for a variety of degrees of service severity. Several manufacturers supply cement-asbestos pipe, together with a variety of fittings and couplings for working pressures up to 150 lb. per sq.in. or even higher.

Chemical Stoneware—Chemical stoneware, one of the old standbys of the chemical industry, and its newer cousin, chemical porcelainware, are produced in all of the forms in which structural carbon is available, as well as some additional forms which are possible because of the better working properties of clays as compared with carbon during the forming stage. For example, large single-piece storage vessels are built in sizes to several hundred gallons. Chemical stoneware is resistant to all corrosive agents with the exception of hydrofluoric acid, and in some modifications has good resistance to heat-shock. Recently developed types are much superior to the earlier grades in heat transfer and, with proper installation and use, modern materials of these types are not unduly fragile.

Enamel—Enamels, particularly the highly acid-resisting glass enamels which are proof against all acids except hydrofluoric (and sometimes phosphoric), are time-tried materials for producing an acid resisting coating on the more readily available base metals, including cast iron and low-carbon steel. A wide variety of processing equipment can be produced in glass-enameled metal, including kettles in all sizes up to 2,000 gal., or even larger; valves, pipes and fittings; storage tanks; stills and columns; pans and evaporators; and heat exchangers. Vessels are regularly built for internal pressures as high as 300 lb. per sq. in., while experimental autoclaves have proved successful under internal pressures as high as 1,000 lb., with temperatures to 600 deg. F.

Glass—Glass is an excellent example of an old material for which new forms and many new uses have recently been found through aggressive research on the part of several leading manufacturers. An example is the 96 percent silica glass which comes close to fused quartz in its resistance to thermal shock.

Industrial glass pipe has now become widespread, such pipe being made at present in diameters up to 4 in. An electric welding process for field erection of pipe, now in process of development, will doubtless extend

this application much farther. The same type of chemically resistant, low-expansion glass has been employed in the manufacture of a standard design of all-glass centrifugal pump, in the fabrication of distilling column sections in diameters up to 23 in., in valves, in precision-bore tubing for flowmeters, in cooling coils and heat exchangers, and in other forms.

Glass blocks, in recent years, have become important adjuncts to building construction, owing to the fact that they are capable of transmitting light while at the same time they give considerable heat insulation and are capable of carrying a moderate load. An important advantage at present is that windows constructed from such units require metal only if movable sashes are to be installed.

FIBROUS GLASS

Fibrous glass is another important way in which this versatile material is making a conspicuous contribution to the war effort. Fibrous glass can be woven into acid- and high-temperature-resistant filter cloths for liquid and gas filtration. It is being used to a large extent in the manufacture of electrical tapes and wire insulations. It is available for heat insulation in loose, pelleted, blanket, batt, and also in rigid forms. The last, one of the new products intended particularly for cold insulation, is impregnated for moisture proofness.

Perhaps the newest form of glass is the cellular product recently introduced for insulation, particularly in the low-temperature field, and for corrosion resisting floats of various kinds. This product is a foamy form of glass, the bubbles of which are non-communicating, yielding a material which is totally impervious to moisture absorption. Weighing about 10-11 lb. per cu.ft., the new glass has a heat transmission coefficient of 0.45 B.t.u. per sq.ft., deg. F., hour and inch of thickness and has sufficient strength to impart considerable structural rigidity and load-carrying capacity.

One novel use for glass has recently been suggested and appears to have possibilities as a war-time substitute for large metal pipe intended for operation at high pressures. The scheme is to blow or otherwise form pipe of suitable diameter and incase it in concrete to give adequate strength for such applications as over-land pipelines. Another suggestion for the same use is to substitute terra cotta pipe for glass, likewise incasing the terra cotta in concrete for strength.

Paints and Coatings—Chlorinated rubber is under allocation and hence is not regularly available for chemically resistant finishes. Resin coatings, such as the phenolics, are also scarce but are obtainable on priority ratings and can frequently be used in place of galvanizing or for the imparting of corrosion resistance to equipment constructed of the more plentiful materials. Some drying oils, resins and pigments are critical but adequate substitutes are available for use by the paint industry in the manufacture of most ordinary protection materials.

Plastics—The range of plastics now produced is extremely broad, but it is significant that several of these are required directly by the war program. For example, acrylic and methacrylate resins, recently used to a considerable extent in pump ends and stop valves for proportioning pumps and in a variety of small equipment where visibility of the contents was necessary, are now going largely into airplane cockpit covers and bomber windows. Listed by the WPB in Group I (the scarcest materials) are the phenol-formaldehyde, polystyrene and polyvinyl chloride plastics, and in Group II (the somewhat less scarce materials), the urea-formaldehyde, vinyl, and vinylidene chloride plastics. Nevertheless, when they can be secured on sufficiently high priority, some of the polyvinyl, vinyl and vinylidene derivatives are being offered in interesting forms for substitution for metal pipes. Three such types include Saran, a vinylidene chloride derivative, Tygon, a vinyl chloride product, and Resistoflex, a polyvinyl alcohol derivative.

Saran is now being made in pipe sizes to 2 in. The material can be cut and threaded, coupled with compression-type couplings, or welded by heating the adjacent ends to the fusing temperature and then pressing them together. Saran is now being mentioned prominently as a possible substitute for brass and copper pipe in general piping applications. The material is suitable for temperatures up to about 175 deg. F. and is said to be satisfactory for contact with brines, hydrocarbons, solvents, organic compounds, acids and alcohols, except cyclic oxygen compounds and concentrated alkalis. Tygon is said to be more resistant to oxygen-containing compounds and strong alkalis, but is unsatisfactory with solvents such as benzol and chlorinated hydrocarbons. This material also is applicable at temperatures up to about 175 deg. F. Resistoflex, which is suitable

for temperatures to 285 deg. F., resists oils and solvents, but is not recommended for weak brines, acids and alkalis.

Silica—Fused silica, another of the old standbys of the chemical industry for use where great resistance to thermal shock and to all acids except hydrofluoric is required, is still available in adequate quantities, in spite of the fact that much of it is imported from England. The material is also fabricated in the United States.

Sulphur—Sulphur can be produced to meet any likely demand. In recent years various combinations of sulphur with inert materials and with a variety of hydrocarbons have been offered for use as acid-resisting cements for the setting of chemical stoneware units. Such materials continue to be available. Furthermore, some of these sulphur compositions are now under investigation for a variety of metal-replacing uses as yet unannounced.

Synthetic Rubbers—With the extreme shortage of natural rubber, a variety of applications for which no material but another rubber-like substance can substitute will necessarily fall in the province of the several synthetic rubbers. These at present can be obtained only in small quantities, but later will be produced on a large tonnage basis. The principal types to be manufactured will include the older synthetic rubbers, neoprene and Thiokol, together with Buna S, Buna N, and Butyl rubber. In general, these materials are characterized by a higher degree of resistance to solvents and other hydrocarbons than natural rubber. Generally, their tem-

perature and aging resistance are better, their abrasion resistance relatively poor. However, the art of compounding synthetic rubbers for purposes similar to the principal uses of natural rubber is now developing rapidly in the United States, and present limitations on their applications will doubtless be overcome. Such necessary products as essential synthetic rubber linings, hose, tubing and gaskets will continue to be available. For example, neoprene coatings and linings, suitable for temperatures up to 220 deg. F., can be applied to metal equipment for resistance to strong oxidizing agents, aromatic and chlorinated hydrocarbons, and many other organics including certain ketones, esters, and phenols. Since such coatings can now be applied by brushing on a neoprene solution, they can effect an important saving of material amounting to two-thirds or three-quarters as compared with sheet linings.

Other plastics and synthetic rubber-like materials are also made for similar purposes. For example, Tygon, a name covering several different classes of coating and lining materials, is produced in one form for the sheet lining of various types of equipment, and in another form for brushing on. Tygon gaskets are being manufactured, as are gaskets made of Resistoflex.

Wood—Although in recent months construction sizes of lumber have been difficult to secure in many localities, the situation has varied so much from place to place that no general statement about availability can be made. Adequate material for wood

tanks seems to be in the hands of most tank manufacturers and builders of cooling towers. When construction lumber is not to be had in one type or size, other types can often be adapted through changes in design or through the use of modern lumber connectors, which permit the fabrication of many forms of built-up trusses and beams.

Wood is also being employed in a variety of fabricated forms. For example, one oil company has announced the development of a plywood drum for the marketing of greases which will save some 2,000 tons of steel per year. The inner surface is chemically treated to prevent grease from penetrating the pores of the wood. Sheet plywood can be employed for many constructional purposes, but is hard to get in many localities, especially those waterproof types having a restricted binder. A high strength, super-compressed plywood for special strength-requiring applications is understood to be in process of development.

Wood, one of the oldest of all construction materials, has many desirable properties from an engineering standpoint. With the exercise of ingenuity, it can be adapted to many chemical industry uses as a substitute for metals. Wood tanks, without linings, are resistant to relatively severe attack from many chemicals. Linings of lead, sheet plastics, brushed-on plastics and ceramic materials can easily be applied. Even such applications as the construction of distilling columns (*Chem. & Met.*, May, 1942, p. 129) are possible with this versatile material.

Materials of Tomorrow

BACK IN THE FOOLISH DAYS OF 1929 a group of research metallurgists met in a smoke-filled room at the Boök-Cadillac in Detroit to solve the future problems of one of our great industries. Before their surreptitious supply of synthetic stimulants had been exhausted, they had evolved complete specifications for a new alloy they christened "*automobilium*." We have since forgotten most of its properties, but still recall that it was to be as light as aluminum, as malleable as lead, as hard as a diamond, more machinable than butter, and as cheap as dirt—or thereabouts. Needless to say, this alloy, to solve all alloy problems of the automobile industry, somehow got lost in the depression.

But the story now has a modern and more successful sequel. On a hot Wednesday afternoon last July, a WPB executive telephoned the office of the American Iron & Steel Institute in New York. "We're holding a meeting here in Washington a week from Saturday to establish new steel specifications for . . ." and here the WPB man named certain important war products. "We'd like to have your alloy steel committee get busy and present at that meeting a series of new alloy steels which (1) can be made entirely from scrap with almost no addition of virgin alloying elements, and (2) can be used in place of the steels now doing the job without any change in design of the parts.

Can it be done?"

The answer is that the seemingly impossible was accomplished. Working their laboratory staffs night and day for ten days, the top-flight metallurgists of five prominent alloy steel producing companies licked the problem and presented their report on schedule in Washington. Today the new steels, officially approved for war use, are in commercial production. They are expected to do their job fully as well as the steels they replaced, and in some respects even better.

Steel men may be justifiably proud of records such as these. Since 1939 they have practically trebled alloy steel production—from three to over eight million tons last year. And the curve is still going up!

All this resourcefulness on the part

of the metallurgical producers has its significance to chemical engineers who are looking ahead to the post-war period. Already we can visualize many new and superior steels tailored to fit the severest requirements of chemical processes. This war will leave us with a vast fund of metallurgical knowledge and experience on which we can build the chemical industries of the future.

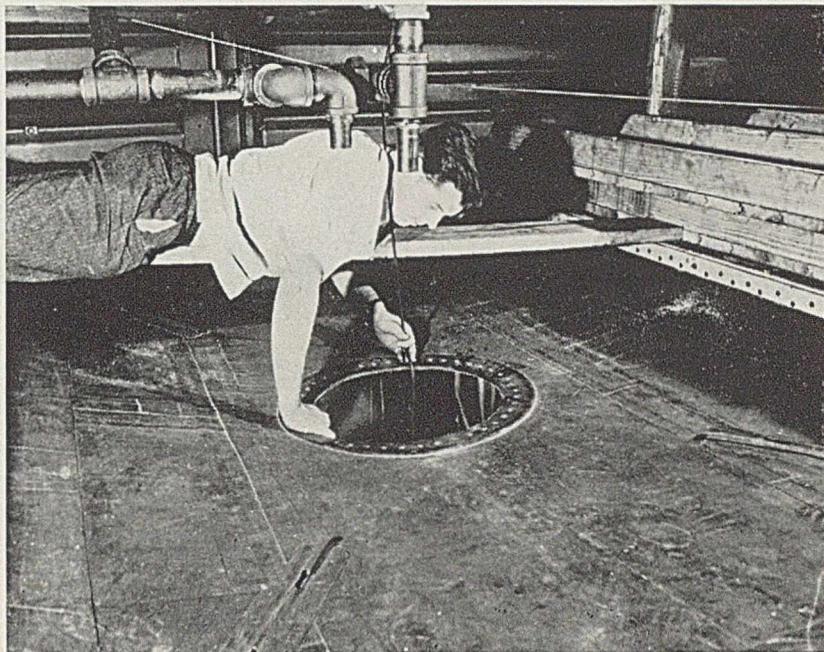
MAGAL AGE APPROACHES

Steel's dominant position as a material of construction is not likely to be challenged immediately, but a new competition with other metals and alloys, plastics and glass, is certainly in the offing. Dr. William J. Hale, who became famous when he coined that useful word "chemurgy," predicted back in 1933 that we would shortly pass from the "Iron Age" to the "Magal Age"—when magnesium and aluminum and their alloys would best characterize our industrial progress.

Something more than the bare outlines of this Magal Age are already visible. By the end of 1943 we will have produced over 2 billion pounds of aluminum—6.5 times the production in 1939. Our magnesium output is variously estimated at 50 to 100 times the pre-war peak. In other words, on a purely weight basis we will have more tons of magnesium than we formerly had of aluminum, and more tons of both metals than we had of copper and zinc together in 1940. When we consider the different specific gravities of these metals and their relative effectiveness ton for ton in meeting various uses, it becomes obvious that the light alloys will offer increasingly severe competition to their older rivals on a volume, rather than weight, basis.

Now that the war has brought the price of aluminum down from 20 to 15c. per lb., and magnesium from 37.5 to 22.5c., there is an entirely different cost basis on which these metals will compete, once they are released from war uses. Calculated on the basis of equalized volume, with steel at 2c. per lb., the relative price for the same unit of volume for magnesium is 5.1c., for aluminum 5.45c., for zinc, 7.3c., and for copper 13.1c. And we must remember that the long-time trend of Magal prices is in one direction only—downward.

What can these lighter metals do for the chemical process industries? We can only project into the post-war future some of the trends and developments of the immediate past. Here are some present accomplishments that point toward the future:



Synthetic rubber bag converts box car into tank car

These cells represent the rubber industry's latest effort to solve the fuel transportation problem. Here you see a worker inspecting a cell following installation in the first experimental box car

1. An important manufacturer of vacuum pumps makes certain eccentric cams from magnesium alloys. They weigh but 2 lb. 10 oz. as against 9 lb. 12 oz. if they were made of cast iron. These lighter cams greatly reduce vibration, give better performance and longer equipment life.

2. A high speed laboratory centrifuge formerly had heads made of bronze that weighed 51 lb. The same design made of Magal weighed only 21 lb., greatly reduced starting inertia and wear on thrust bearings. The new equipment was easier to handle and actually cost less to manufacture.

3. Railway Express Agency wanted portable conveyors of the gravity type that could be used to unload their trucks and express cars. They had to be of light-weight construction yet able to stand up under constant and hard usage. Again, one of the new light alloys solved the problem. The new conveyor in sections 10 ft. long and 18 in. wide with 30 ball bearing rollers weighs only 68 lb. One man can carry it under his arm.

Aluminum stream-lined trains give us something else to think about. We have barely begun to use the light alloys on the scale their properties warrant. A freight car weighs 45,000 lb. and carries a load of 30,000 lb. One of the same capacity can be built to weigh only 15,000 lb. and should some day reduce transportation costs considerably.

PLASTICS TO THE FORE

In defining the limits of the Magal Age, Dr. Hale reminds us that the same conditions, which are now ushering light alloys into wider industrial use, will eventually demand even

greater strength with still further decrease in weight. It so happens there is no metal lighter than magnesium which is stable under atmospheric conditions. Hence the next step, in his opinion, must be outside of the domain of metals and into the organic chemical field. In fact, he predicts that by 1950 someone will have succeeded in incorporating partially oxidized silicon into the molecular structure of a new plastic that will thus combine the advantages of organic and inorganic compounds. Such "materials of tomorrow" he believes will exhibit tremendous strength, rigidity and resistance to weathering and oxidation. Most important, they should be cheaper and lighter in weight than any plastics now used as engineering materials.

In a metal-hungry economy such as ours today, plastics are finding many novel and valuable applications. A pump impeller made with a combination of a special phenolic plastic and an acid-resisting alloy has increased the efficiency of the pump in handling corrosive acids, at the same time reducing the weight of the impeller by 75 percent. This is typical of what is happening as designing engineers appreciate the fact that plastics are man-made materials and have greater versatility than most other structural materials. They can be literally "tailored" to fit almost any pattern of needs.

One of the most striking of such

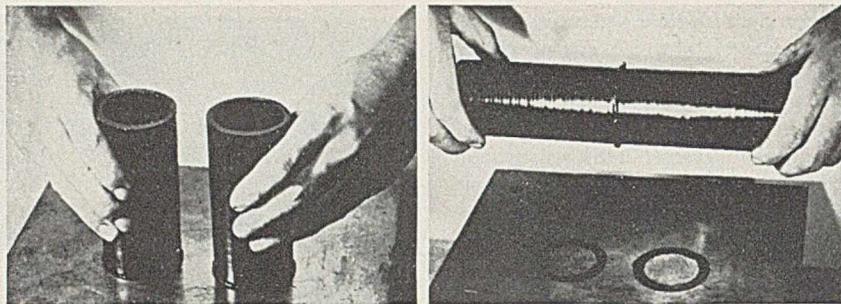
applications is seen in the current announcement of a new plastic pipe. Made of Dow's vinylidene chloride plastic, it is highly resistant to moisture and most chemicals and solvents. Because it is thermoplastic, it can readily be heated and bent, and, of perhaps the most interest to plant engineers, it can be readily welded. For those who want to stick to the more orthodox procedures of the pipe fitter, the new plastic pipe can be threaded with ordinary iron pipe dies. Fittings, except for standard flanges, are not yet available, but threaded ells, tees and couplings are coming along soon. Thus vital metals and rubber are released for more urgent war needs and the chemical engineer has another new raw material with which to build his industries of the future.

TONS OF SYNTHETIC RUBBER

Back in 1939 we celebrated the one hundredth anniversary of the vulcanization of rubber. Since then we have been made to realize all too poignantly that most of our little world rolls on this remarkable material. Now we are busy in a prodigious effort to make in the next two or three years almost twice as much rubber as we ever imported in a single year. Most of it we hope will be better—at least for certain purposes—than is the natural product.

Whether or not we shall ever return to the latter will depend on how good a job we do in our synthetic rubber plants, how greatly we can reduce the cost and improve the product. Assuming we are as successful as

Glass pipe can now be jointed on the job by electric welding using pin-point oxy-hydrogen flames to carry the high-frequency current



New plastic pipe welded in less than a minute

Pipe ends are first placed on a hot plate at 375 deg. F until melting begins, then firmly pressed together and allowed to cool for ten seconds. Resultant weld has greater joint strength than pipe itself

we hope we may be, our post-war economy is going to have another great new material resource.

"THROUGH THE GLASS—DARKLY"

One of the lasting benefits likely to come out of our "ersatz" program in the United States is greater knowledge and valuable experience in using that most versatile of materials—glass. Fortunately, we did not have to start from scratch. In the past 15 or 20 years chemical engineers have installed literally miles of glass piping and have been building larger and more intricate equipment of this useful material. Centrifugal pumps that will deliver 100 g.p.m. of corrosive acid against a 65-ft. head are already here and pumps for higher pressures are coming. Tubular heat exchangers have been constructed with hundreds of 20 ft. lengths of thin-walled piping and fittings. Simple leak-proof methods of jointing are used on glass pipes up to 4 in. i.d. handling pressures up to 100 p.s.i. The next jump is going to be 6-in. pipes for use at slightly lower pressures.

Now comes the promise in the not very distant future of electric welding on the job as the equipment is being erected. Engineers with Corning Glass Works have been experimenting with portable equipment using oxy-hydrogen flames to act as conductors for a high-frequency current which will weld pipe ends together quickly and efficiently, thus eliminating all of the plant operator's headache associated with gasket troubles, leakage, corrosion and production contamination. Once this equipment is available and its operation is made fool-proof, nearly every plant will want to train its own "glass plumbers." Pipefitting may yet become a lost art!

Quartz is in many ways the ideal of the glassman who wants to serve industry. He worships it for its amazing strength and resistance to thermal

shock, even though he knows how difficult it is to melt and shape to useful purpose. Recently, however, he has learned to put to industrial use the new 96 percent silica glass that comes awfully close to his prayer for quartz-like glass or glass-like quartz. Furthermore, the material is readily shaped and can easily be produced in intricate forms. With it he has been able to make things that could never before be accomplished—for example, thermocouple protector tubes that will stand up to 1,000 deg. C. in highly corrosive atmospheres, centrifugal pump seals that will run "dry" in almost red heat, and then withstand the thermal shock when cold liquid is again drawn into the pump.

Looking farther into the future the chemical engineer visualizes a greater place for glass as a material for the construction of reaction vessels, kettles and autoclaves. Trouble can not hide very long in transparent equipment, and there are obvious advantages in the visual control of many chemical reactions—particularly in the fine chemical and pharmaceutical fields. To prevent corrosion and resultant contamination of materials is the motive that will lead to ever-greater use of all-glass and glass-lined steel equipment.

* * * * *

So, "through the glass darkly" we look ahead to the post-war period confident that there will be an ever increasing and more ingenious use of all the newer materials of construction. In a world gone mad with destruction there is consolation and encouragement to be gained from the fact that the war has brought us constructive achievements. They stand out as a challenge to the chemical engineer who is looking for new "materials of reconstruction" with which to build better and more efficiently in the future.

NON-METALLIC MATERIALS

CHEMICAL, STONEWARE, PORCELAIN, CEMENTS

Physical Properties of Chemical Stoneware and Porcelainware

The accompanying table, which has been prepared for us by the General Ceramics Co., gives the physical properties of an average grade of chemical stoneware. It should be emphasized here that "chemical stoneware" is not the name of a definite material, such as an alloy, but a generic term applied to a wide variety of ceramic compositions, and hence that in any particular composition designed to give optimum properties in one respect, it will ordinarily be impossible to secure optimum properties in all other respects.

Chemical Stoneware	
Specific gravity.....	2.2
Hardness, scleroscope.....	100
Ultimate tensile strength, lb. per sq. in.....	2,000-3,000
Ultimate compressive strength, lb. per sq. in.....	80,000
Modulus of rupture, lb. per sq. in.....	5,000-13,000
Modulus of elasticity, lb. per sq. in.....	8,000,000
Specific heat.....	0.2
Thermal cond., B.t.u. per hr., sq. ft., °F., in.....	10-35
Linear thermal expansion, per °F.....	0.0000020
Water absorption, per cent.....	0-2

Chemical Porcelainware	
Data supplied by Lapp Insulator Co.	
Specific gravity.....	2.41
Ultimate tensile strength, lb. per sq. in.....	5-8,000
Ultimate compressive strength, lb. per sq. in.....	100,000
Modulus of rupture, lb. per sq. in.....	12-15,000
Modulus of elasticity, lb. per sq. in.....	10,400,000
Specific heat.....	0.2
Thermal cond., B.t.u. per hr., sq. ft., °F., in.....	8.4
Linear thermal expansion, per °F.....	0.000023
Water absorption, per cent.....	0

Makers of Chemical Stoneware, Porcelain, Acidproof Brick and Stone

MANUFACTURER (Name and Address)	Materials	MANUFACTURER (Name and Address)	Materials
Chemical Stoneware			
General Ceramics Co., New York, N. Y.....	Complete line, see note below	Harbison-Walker Refractories Co., Pittsburgh, Pa.....	Acidproof brick
Maurice A. Knight, Akron, Ohio.....	Complete line, see note below	B. Mifflin Hood Co., Daisy, Tenn.....	Acidproof brick tower packings, flooring tiles
United States Stoneware Co., Akron, Ohio.....	Complete line, see note below	Ironton Fire Brick Co., Ironton, Ohio.....	Acidproof brick
Chemical Porcelain		Keagler Brick Co., Steubenville, Ohio.....	Acidproof brick
Coors Porcelain Co., Golden, Colo.....	Porcelain laboratory ware	Kewaunee Mfg. Co., Kewaunee, Wis.....	Karcite acidproof ceramic ware, and Kem-rock chemical resistant stone
Illinois Electric Porcelain Co., Macomb, Ill.....	Chemical porcelain ware of all types	Laclede-Christy Clay Prod. Co., St. Louis, Mo.....	Acidproof brick
Lapp Insulator Co., LeRoy, N. Y.....	Chemical porcelain ware of all types	McLain Fire Brick Co., Pittsburgh, Pa.....	Acidproof brick
Acidproof Brick and Other		McLeod & Henry Co., Troy, N. Y.....	Acidproof brick
Acme Brick Co., FortWorth, Tex.....	Acidproof brick	Metropolitan Paving Brick Co., Canton, Ohio.....	Acidproof brick
Alabama Clay Products Co., Birmingham, Ala.....	Acidproof brick	National Carbon Co., Inc., Cleveland, Ohio.....	Carbon brick
Alberene Stone Corp. of Va., New York, N. Y.....	Acidproof stone	Nukem Products Corp., Buffalo, N. Y.....	Acid and alkali proof construction
Atlas Mineral Products Co., Mertztown, Pa.....	Acidproof brick construction	Parker-Russell Mining & Mfg. Co., St. Louis, Mo.....	Acidproof brick
Belden Brick Co., Canton, Ohio.....	Acidproof brick	Patterson Foundry & Machine Co., East Liverpool, Ohio.....	Acidproof lining blocks and grinding balls
Charlotte Chemical Labs., Charlotte, N. C.....	Acidproof brick, rings	Quigley Co., New York, N. Y.....	Acidproof brick
Claycraft Co., Columbus, Ohio.....	Acidproof brick	Robinson Clay Product Co. of N. Y., New York, N. Y.....	Acidproof and vitrified sewer tile
Custodis Construction Co., New York, N. Y.....	Acidproof brick construction, towers, tanks	Southern Clay Mfg. Co., Chattanooga, Tenn.....	Acidproof brick
Electro-Chemical Supply & Engineering Co., Paoli, Pa.....	Acidproof brick and masonry materials	Thornton Fire Brick Co., Clarksburg, W. Va.....	Acidproof brick
Filtros, Inc., East Rochester, N. Y.....	Acidproof mineral as plates, cylinders, etc.	Uhl Pottery Co., Huntingburg, Ind.....	Acidproof ceramics
General Refractories Co., Philadelphia, Pa.....	Acidproof tower packing, brick		

Note: Makers of complete lines of chemical stoneware supply such equipment as acid plants; ball mills; brick and tile; blowers and exhausters; coils; filters; acid-proof laboratory sinks, drain and vent lines; jars; jugs; kettles; pipe, fittings and valves; stills; tourills; towers, tower linings and tower packings; tanks and pumps; and many types of special equipment.

Makers of Cements and Putties for Acidproof Brick and Stoneware

MANUFACTURER (Name and Address)	Trade Names	Compositions, Applications, Types
Anti-Hydro Waterproofing Co., Newark, N. J.....	Anti-Hydro.....	Water-, acid-, alkali-, oil-resisting concrete mix
Atlas Lumnite Cement Co., New York, N. Y.....	Lumnite cement.....	Cement for corrosion and temp.-resistant concrete
Atlas Mineral Products Co., Mertztown, Pa.....	Tegul-Vitrobond, Mineralead, Tileset, Korez, G. K., others.....	Thiokol-sulphur-base, chemical-setting silicate and resin-base and other cements for acid and alkali proof construction
Charlotte Chemical Labs., Charlotte, N. C.....	Carolina Acid-Proof Cement. Acid-proof putty.....	Acid-proof cements and putty
Chemical Construction Corp., New York, N. Y.....	Acipruf.....	Acidproof cement
Custodis Construction Co., Inc., New York, N. Y.....	Custodis resin cement, Penclor, Asplit.....	Synthetic resin, sodium silicate & phenolic base cements, resp.
Electro-Chemical Supply & Engineering Co., Paoli, Pa.....	Duro Standard, Triple X, Syntho, Brimsto, Kemitite, Alk-Li-Pruf.....	Cements for all acid and alkali conditions; also water and steam
Filtros, Inc., East Rochester, N. Y.....	Filtros.....	Acidproof cement
General Ceramics Co., New York, N. Y.....	Acidproof Nos. 1, 6, 7, 8.....	Silicate cements and linseed oil- and asphalt-base putties
B. F. Goodrich Rubber Co., Akron, Ohio.....	Plastikon.....	Rubber-base putty
The Haveg Corp., Newark, Del.....	Havegit 41, 43, 50.....	Self-hardening phenolic resin cements for acids and alkali
M. W. Kellogg Co., New York, N. Y.....	Knight.....	Acidproof cement
Maurice A. Knight, Akron, Ohio.....		Silicate cements for strong acids

(Continued next page)

Makers of Cements and Putties (Continued)

MANUFACTURER (Name and Address)	Trade Names	Compositions, Applications, Types
Nukem Products Co., Buffalo, N. Y.	Basolit, Plasul, Basolit, Hydro-Plasul, Nukem Resinous Cements, Nu-Mastic, Nukem Primer, Nukem Enamel	Rubberized Sulphur Cements, acid and alkali resin base cements and others for complete acid-proof construction and protection
Paraffine Cos., San Francisco, Calif.		Acidproof cement
Patterson Foundry & Machine Co., East Liverpool, Ohio	Porox Cement	Silicate cement for strong acids
Pecora Paint Co., Philadelphia, Pa.	Acitite, Acichlor, Cushion Putty	Slow- and quick-drying cements and elastic putties for acids
Pennsylvania Salt Mfg. Co., Philadelphia, Pa.	Penchlor acid-proof cement, Asplit, Causplit	Chemical-setting silicate cement for acids; self-hardening resin cements for acids and alkalis
Philadelphia Quartz Co., Philadelphia, Pa.	"S" Brand and N38 Special Sodium Silicates	Sodium silicates for regular and quick-setting acidproof cements
Quigley Co., New York, N. Y.	Acid-proof, black, gray, quick setting	Silicate cements for acid gases and mineral acids
Reardon Cement Co., Cincinnati, Ohio	Bedford	Acid and alkali resisting cements and plastics
The Sullivan Co., Memphis, Tenn.	Acidol, Sulsilo	Pouring cements and pre-mixed silicate cements for strong acids
Sauereisen Cements Co., Sharpsburg, Pa.	Insa-Lute Nos. 31, 48, 46, 44	Quick-setting, air-drying, sulphur and bitumastic cements
United States Stoneware Co., Akron, Ohio	Portite, Pre-Mixt, Calkite and others	Silicate cements of all types, resin cements, putties, etc.
Union Bay State Co., Cambridge, Mass.	N Series (neoprene base) cements, and special base cements	Neoprene and special base cements. For painting metals, rubber, wood, or concrete. Coating cloth. As adhesive

STRUCTURAL CARBON AND GRAPHITE

Representative Physical Properties of Porous Carbon and Porous Graphite

Grade Porous Carbon ("Carbocell") and Porous Graphite ("Graphiceil")	Porosity Percent	Average Pore Diameter		Filter Action Min. Diameter Particle Retained Inches	Av. Water * Permeability at 5 Lb./sq.in. Pressure Gal./sq.ft./min.	Av. Air ** Permeability at 2 inches H ₂ O Pressure Cu.ft./sq.ft./min.
		Inches	Microns			
Grade C	36	0.0002	5	—	0.30	....
Grade 60	48	0.0013	33	0.00047	14.0	....
Grade 50	48	0.0019	48	0.00079	30.0	....
Grade 40	48	0.0027	69	0.00098	45.0	4.0
Grade 30	48	0.0039	99	0.00173	80.0	8.5
Grade 20	48	0.0055	140	0.00300	120.0	17.0
Grade 10	48	0.0075	190	0.00590	175.0	33.0

NOTE: "Carbocell" products can be treated so as to be wettable for use in caustic filtration. Both "Carbocell" and "Graphiceil" products are resistant to most acids and alkalis.
 * Water at 70 deg. F, 1 inch thick plate. ** Air at 70 deg. F and 760 mm. Hg pressure, 15 per cent relative humidity, 1 inch thick plate.

Representative Physical Characteristics of Carbon and Graphite Products

	Density		Strength, Lb. per Sq. In.			Elastic Modulus Lb./sq.in. Multiply by 10 ⁵	Specific Resistance Ohms./in. ³	α (Thermal Expansion, See Note)	Thermal Conductivity B.t.u./hr./ sq.ft./°F per ft.
	G./c.c.	Lb./cu.ft.	Tensile	Compressive	Transverse				
Carbon Cylinders									
8 inch dia.	1.54	96.1	660	2,920	1,320	5.5	0.0013	13	6.0
10-14 inch dia. inc.	1.525	95.2	470	2,120	950	5.4	0.0013	12	6.0
17-24 inch dia. inc.	1.54	96.1	400	2,200	790	5.4	0.0014	13	6.0
30-40 inch dia. inc.	1.54	96.1	400	1,910	810	4.3	0.0026	12	6.0
Carbon Beams and Blocks									
4x4 inch to 6x6 inch inc.	1.57	98.0	840	4,100	1,670	9.4	0.0018	14	4.0
6x6 inch to 20x20 inch inc.	1.55	96.7	500	2,140	990	7.1	0.0016	15	4.0
15x30, 24x30 & 24 inch sq.	1.54	96.1	400	1,910	810	4.3	0.0026	12	4.0
Carbon Pipe and Tubes									
½-4 inch I. D. inc.	1.51	94.2	885	10,200	2,700	21.0	0.0014	15	3.0
5-10 inch I. D. inc.	1.49	93.0	980	8,140	2,550	17.0	0.0016	21	3.0
Carbon Brick									
Standard sizes	1.55	96.7	1,530	8,320	3,070	10.3	0.0016	13	3.0
Graphite Cylinders									
To 5-½ inch dia. inc.	1.56	97.3	760	3,050	1,750	8.8	0.00036	5-12	84.0
6-12 inch dia. inc.	1.55	96.7	610	3,420	1,810	8.0	0.00037	6-12	79.0
14 inch dia.	1.53	95.5	580	3,180	1,490	6.7	0.00039	8-12	70.0
16 & 18 inch dia.	1.53	95.5	500	3,180	1,490	6.7	0.00040	8-12	70.0
20 inch dia.	1.53	95.5	440	3,180	1,490	6.7	0.00040	8-12	70.0
Graphite Beams and Blocks									
To 5 inch thick inc.	1.56	97.3	700	3,050	1,750	8.8	0.00036	5-12	94.0
6 inch thick to 144 sq. in.	1.55	96.7	700	3,420	1,810	8.0	0.00037	6-12	84.0
Over 144 sq. in. section	1.53	95.5	570	3,180	1,490	6.7	0.00039	8-12	79.0
Graphite Pipe and Tubes									
½-4 inch I. D. inc.	1.68	104.8	780	4,550	2,820	14.0	0.0003	12	94.0
5-10 inch I. D. inc.	1.67	104.2	870	5,100	2,980	13.0	0.0003	12	84.0

Structural Carbon and Graphite (Continued)

	Density		Strength, Lb. per Sq. In.			Elastic Modulus Lb./sq.in. Multiply by 10 ⁵	Specific Resistance Ohms./In. ⁵	α (Thermal Expansion, See Note)	Thermal Conductivity B.t.u./hr./ sq.ft./°F per ft.
	G./c.c.	Lb./cu.ft.	Tensile	Compressive	Transverse				
Graphite Brick									
Standard sizes.....	1.56	97.3	700	3,050	1,750	8.8	0.00036	5-12	84.0
"Karbate" Pipes and Tubes, 10 Series*									
½-2 inch I. D. inc.....	1.77	110.0	1,700	10,500	4,170	29.0	0.00164	27	3.0
Over 2 inch I. D.....	1.76	110.0	2,000	10,500	4,640	26.0	0.0016	33	2.8
"Karbate" Pipe and Tubes, 20 Series*									
½-2 inch I. D. inc.....	1.86	116.0	2,600	8,900	4,650	23.0	0.00034	23	85.0
Over 2 inch I. D.....	1.91	119.0	2,350	10,500	4,980	21.0	0.00033	24	75.0
"Carbocell" (Porous Carbon)†									
Grade C (Finest).....	1.34	83.6	500	2,700	1,530	>1.2	0.0020	6	3.0
Grade 60.....	1.05	65.5	190	850	600	>1.2	0.0070	27	1.5
Grade 50.....	1.05	65.5	180	830	500	>1.2	0.0070	27	1.4
Grade 40.....	1.04	64.9	120	900	320	>1.2	0.0057	27	1.0
Grade 30.....	1.04	64.9	100	770	250	>1.2	0.0070	27	1.0
Grade 20.....	1.03	64.3	90	700	240	>1.2	0.0070	27	1.0
Grade 10.....	1.03	64.3	80	300	160	>1.2	0.0080	27	1.0
"Graphicell" (Porous Graphite)†									
Grade C (Finest).....	1.35	84.3	600	1,680	1,080	....	0.00045	6	60.0
Grade 60.....	1.05	65.5	110	500	250	....	0.0012	21	50.0
Grade 50.....	1.05	65.5	110	500	250	....	0.0012	21	45.0
Grade 40.....	1.04	64.9	100	500	190	....	0.0013	21	45.0
Grade 30.....	1.04	64.9	80	520	200	....	0.0017	21	40.0
Grade 20.....	1.03	64.3	60	310	140	....	0.0020	21	30.0
Grade 10.....	1.03	64.3	50	270	140	....	0.0020	22	20.0

Carbon and graphite products are resistant to most acids and alkalis. * For chemical resistance see table in Chem. & Met. Sept. 1940, p. 607. † See preceding table for additional data.
NOTE: Coefficient of Thermal Expansion per Degree: To Temperature °F = [α+0.0039t (°F)] 10⁻⁷; to Temperature t°C = [1.8 α+0.007t (°C)] 10⁻⁷.

Makers of Structural Carbon and Graphite Products

MANUFACTURER (Name and Address)	Products	MANUFACTURER (Name and Address)	Products
Acheson Graphite Corp., New York, N. Y.	Graphite electrodes and various shapes	Speer Carbon Co., St. Mary's, Pa.	Carbon and graphite brick, plates, blocks, tubes, cylinders, bushings, shapes
International Graphite & Electrode Corp., St. Mary's, Pa.	Graphite electrodes and various shapes	Stackpole Carbon Co., St. Mary's, Pa.	Various carbon and graphite products
National Carbon Co., Inc., Cleveland, Ohio.	Carbon and graphite brick, tile, tower packing, tubes, pipe, special shapes, electrodes		

Note: Manufacturers of graphite crucibles are listed under "Refractories"

SYNTHETIC RUBBER

Chemical Properties of Synthetic Rubber

EDITOR'S NOTE: The following paragraphs describing the chemical properties of some of the synthetics have been supplied to us by the manufacturers. They are intended to give an indication of the possibilities and the limitations of these materials. However, for a particular application it is generally advisable to contact the manufacturer and have specific tests made.

BUTYL RUBBER

Butyl rubber is a hydrocarbon polymer obtained by the copolymerization of an olefin and a diolefin. The chemical unsaturation is much less than that present in natural rubber and is usually between 1 and 5 percent of natural rubber. Butyl rubber undergoes thermal curing in the presence of sulphur and aided by many of the common rubber accelerators as well as by zinc oxide and fatty acids its tensile strength is greatly increased, its cold or hot flow properties suppressed, and its elongation reduced. After thermal curing butyl rubber compounds resemble natural rubber compounds in many of their mechanical properties. In the uncured state or "as received" butyl rubber is of a consistency equivalent to moderately well broken down natural rubber. It can be processed and generally han-

dled much the same as natural rubber using the same type of equipment.

The general physical properties of vulcanized butyl rubber compounds can be compared with natural rubber as follows:

Elasticity and extensibility in the range of natural rubber—resilience lower than natural rubber at room temperatures but increases remarkably with increasing temperatures.

Abrasion resistance—equal to natural rubber for some services and slightly inferior for other services.

Compression set—somewhat higher than natural rubber.

Tear resistance—equal to natural rubber.

Flexibility at low temperatures—equal to natural rubber.

Butyl rubber is far superior to natural rubber for:

1. Resistance to water absorption.
2. Aging in storage and sunlight.
3. Resistance to the action of air and ozone.
4. Resistance to deterioration by heat.
5. Resistance to the action of nitrogen-containing solvents such as nitrobenzene and aniline.
6. Resistance to oxygenated solvents such as ethers, alcohols, and esters.
7. Resistance to swelling in vegetable and animal oils.

8. Resistance to many corrosive chemicals.
9. Extremely low gas permeability.

Exposure 2 Weeks At Room Temperature

		Effect
Hydrochloric acid.....	37%	Slight
Sulphuric acid.....	95.5%	None
Nitric acid.....	71.5%	Not serious
Phosphoric acid.....	85%	Slight
Ammonium hydroxide.....	25%	Slight
Sodium hydroxide.....	30%	None
Lactic acid.....	85%	None

Swelling in Vegetable and Animal Oils

3 mo. exposure in	Natural Rubber		
	Rubber	Perbutan	Butyl
Linseed oil.....	124	17.2	10
Rapeseed oil.....	106	0.4	6
Soya bean oil.....	199	0.0	4
Lard oil.....	111	0.7	10
Olive oil.....	121	2.9	12
Oleic acid.....	196	35.0	108
Cotton seed oil.....	84	—	9

HYCAR

Hycar is available in two types, oil resistant (OR) and oil soluble (OS).

Rubber and Like Products (Continued)

Either type can be compounded to give a wide range of physical properties, depending on the qualities desired. Hycar OR is extremely resistant to all petroleum products, vegetable oils, fats, paint and ink driers. It is quite resistant to benzol and carbon tetrachloride, but is badly swollen by acetone. It has a high resistance to water as compared to natural rubber and may be used where resistance to dilute acids and alkalis is important. Ordinary compounds of Hycar OR have excellent heat resistance and special compounds designed specifically for heat resistance are outstanding. It can be used at temperatures of 300 deg. F. and in a few limited applications can be considered for use up to 400 deg. F. Stiffening occurs at temperatures of -50 deg. F., but pliability is recovered immediately when temperature rises. Abrasion and age resistance are much superior to natural rubber. Ability to absorb energy is much better than natural rubber and flex life is comparable, making it excellent for vibration dampening service.

Hycar OS is equal to OR in resistance to heat, cold, sun, abrasion, aging, but gives somewhat lower tensiles. While not especially resistant to petroleum products, it is less affected by aliphatic hydrocarbons than natural rubber. It is superior to Hycar OR in elasticity and rebound and in general more nearly resembles natural rubber than other synthetics. Hycar OR and OS can be blended together to form many desirable compounds. Likewise they are compatible with poly vinyl chloride and many similar materials and usually in the blend the better properties of both are found.

NEOPRENE

Neoprene is a basic thermosetting raw material which is mixed with compounding ingredients and processed into finished products by rubber manufacturers. There are several different basic types of neoprene which have widely varying properties. Neoprene is available in black, white and colors, odorless when specified.

Animal, vegetable and petroleum-base products cause slight swelling but have little effect on the physical properties. Neoprene does not dissolve, become gummy or slough off.

In general, neoprene may be used in contact with inorganic chemicals. Salts have little effect. Even strong alkalis may be successfully handled. Mineral acids cause deterioration when used in concentrations above 50 per cent. Strong oxidizing acids, such as sulphuric, nitric and chromic, should be avoided. Halogens cause embrittlement in liquid form; however, dilute gas and aqueous solutions may be handled satisfactorily.

Neoprene resists the attack of most organic compounds, the more highly saturated compounds having less effect than the less saturated. Neoprene is not recommended for use with the chlorinated hydrocarbons or with creosote. Certain aromatic solvents such as benzol also cause rapid swelling.

The Union Bay State Co. has compounded and the Gates Engineering Co. has developed a technique for applying Gaco-Neoprene linings to tanks by simply brushing it on in the form of solutions of highly concentrated surfacing compound over suitable primers. The primer will not soften below 260 deg. F. which prevents blistering and falling when the temperature accidentally rises a little too high. By this means tanks may be corrosion proofed on the job at relatively low cost. The neoprene lining thus applied may be allowed to vulcanize itself at room temperature or cured immediately by means of steam or hot water. The process only requires about 1/4 to 1/2 as much neoprene as is required by the sheet method of lining tanks. The linings are very satisfactory for resisting the following chemicals:

Chemical	Conc.	Probable Safe Max. Temp.
Chlorine water	Up to 3%	82F
Hydrochloric acid	Up to 20%	212
Hydrochloric acid	Over 20%	82
Phosphoric acid	Up to 85%	220
Sulphuric acid	Up to 50%	220
Aluminum chloride	Up to 25%	160
Ammonium nitrate	Up to 50%	220

Calcium chloride	Up to sat.	220
Ferric chloride	Up to 25%	200
Silver plating sol.	Standard	220
Sea water		220
Sodium chloride	Up to sat.	220
Sodium hydroxide	Up to 70%	220
Sodium sulphide	Any	200
Acetone		Boiling Pt.
Formaldehyde	Up to 40% aqueous sol.	82

PERBUNAN

Perbunan is a synthetic rubber-like material which can be processed and vulcanized with sulphur in much the same way as natural rubber. Like the latter, it can be compounded to give varying physical properties depending on the particular application in mind. With active carbon black it can be reinforced to give compounds of high tensile strength and superior abrasion resistance. In addition, it has high elasticity and resilient energy (low hysteresis loss), and has good resistance to prolonged stress (slight creep under prolonged loading). The heat conductivity is about 20 per cent higher than that of natural rubber.

Perbunan has excellent aging properties and possesses good heat and fatigue resistance. With proper compounding it can be used at temperatures up to 300 deg. F. and will remain flexible at temperatures as low as -45 deg. F. Perbunan compounds of the ebonite or hard rubber type can be used for much more severe temperature conditions than natural rubber ebonite compounds.

Perbunan is unaffected by water dilute acids or alkalis, or salt solutions of any concentration. It swells very slightly in aliphatic hydrocarbons, vegetable and animal oils and fats. The reduction in physical properties as a result of swelling is small, making Perbunan especially suitable for gasoline and oil-resistant applications. Crude Perbunan or uncured Perbunan compounds are soluble in aromatic hydrocarbons. However, cured compounds swell to a much lesser extent than cured natural rubber compounds. It is superior to natural rubber for mixtures

Physical Properties of Synthetic and Natural Rubber

Material	Specific Gravity	Tensile Strength, lb./sq. in.	Hardness, Shore Durometer	Max. Temp. for Use, °F.	Dielectric Strength, v./mm.	Effect of Heat	Abrasion Resistance	Effect of Sunlight	Effect of Aging	Machining Qualities
Buna S	0.94	3,800	15-90	300	.....	Stiffens	Equal to rubber	Slight	Equal to rubber	Can be ground
Butyl Rubber	0.91	500-3,000	15-90	250-300	25,000	Softens slightly	Good	None	Better than rubber	Can be ground
Chemigum, Oil Resistant	1.0-1.5	800-4,000	30-90	300	.....	Stiffens	Excellent	Equal to rubber	Stiffens	Can be ground
Chemigum, Tire	1.0-1.15	1,000-4,000	50-65	450	.....	Stiffens	Excellent	Deteriorates	None	.....
Hycar, OR or OS, hard	1.1-1.3	4,000-11,000	.....	300	.....	Softens at 300 F.	Good	Very slight	None	Excellent
Hycar, OR, soft	0.99-1.6	1,000-4,500	15-95	300	.....	Stiffens slightly	Excellent	Slight	Highly resistant	Can be ground
Hycar, OS, soft	0.96-1.20	1,000-4,000	20-95	280	....	Stiffens slightly	Excellent	Slight	Highly resistant	Can be ground
Koroseal, hard	1.3-1.4	2,000-9,000	80-100	212	30,000-50,000	Softens	Good	None	None	Good
Koroseal, soft	1.2-1.3	500-2,500	30-80	190	15,000-30,000	Softens	Good	None	None	Can be ground
Neoprene	1.25-1.30	1,000-4,500	10-95	300	.....	Stiffens slightly	Excellent	None	Highly resistant	Can be ground
Perbunan	0.96	500-5,000	30-90	300	.....	Stiffens	Excellent	Slight	Highly resistant	Can be ground
Pliolite, No. 40	1.06	4,000-5,000	.....	160-248	.....	Softens	.....	None	None	.....
Resistoflex	1.26	2,000-5,000	.....	250	6,000-10,000	Softens	Good	None	None	.....
Thiokol FA	1.34	1,400	25-90	200	.....	Hardens slightly	Fairly good	None	None	Excellent
Tygon T	1.33-1.36	9,000	.....	175	35,000-50,000	Softens	Good	None	.....	Excellent
Vistanex, Medium	0.9	200	.....	.....	.....	.....	.....	None	Better than rubber	Cannot be mach.
Vistanex, High	0.9	550	.....	.....	.....	.....	.....	None	Better than rubber	Cannot be mach.
Natural Rubber, hard	1.17-1.18	4,000-11,000	70-100	220	.....	Softens	Good	Discolors	None	Excellent
Natural Rubber, soft	0.93-1.17	1,000-6,000	30-80	150-180	.....	Softens and det.	Excellent	Deteriorates	Highly resistant	Can be ground

Rubber and Like Products (Continued)

of gasoline with aromatic hydrocarbons. Chlorinated hydrocarbons and organic bases have a strong swelling action on Perbunan. Ketones, organic acids, alcohols and esters have a greater swelling effect than on natural rubber.

VISTANEX

Vistanex is the name of a series of polymers formed by the low-temperature polymerization of isobutylene. The chemical unsaturation of Vistanex is substantially nil, and consequently it is unattacked by the strongest chemicals, such as sulphuric acid, nitric acid and caustic soda. Hot concentrated nitric acid, however, after prolonged treatment, yields a yellow, sticky, oxidized product. Vistanex is also inert to ozone and is therefore useful in improving the ozone resistance of rubber compounds. Lacking in unsaturation, it therefore cannot be vulcanized and must be used in the raw gum state or with compounding agents to impart structural strength. It is soluble in all hydrocarbon solvents and oils and it may be precipitated from these solutions by the addition of low molecular weight alcohols, ethers or ketones.

Rubber compounds containing 50 per cent of Vistanex show no cracking with ozone within 10 to 20 min. while natural rubber shows considerable. A similar relation is observed in the action of sulphuric acid on rubber-Vistanex compounds. Vistanex is superior to natural

rubber for resistance to water absorption, aging in storage, sunlight and all atmospheric conditions, resistance to ozone, resistance to strong chemicals, alkalies, salts and the usual oxidizing agents.

THIOKOL

The manufacturers of Thiokol synthetic rubbers state that a number of different organic polysulphide polymers that vary in characteristics from soft to hard rubber are made under this name. However, unlike natural rubber, the products are practically unaffected by petroleum hydrocarbons and most commercial solvents. They are resistant to alcohol, esters and ketones. The swell of these products in aromatic hydrocarbons varies from practically no swell to around 100 percent increase in volume, depending on the type. Even when Thiokol swells in aromatic solvents, it still retains good physical characteristics. It is not materially affected by carbon tetrachloride but is attacked by ethylene dichloride in varying degrees. Thiokol is not affected by sunlight, air, azone or ultra-violet.

It can be compounded to give various hardnesses and characteristics suitable for each particular application. While not possessing original tensile strength as great as natural rubber, it is stated for to exceed natural rubber in both strength and abrasion resistance when in contact with gasoline and oils.

TYGONS

The Tygons are synthetic materials, resembling rubber in many physical characteristics, yet entirely different in chemical structure. They consist of a series of modified halid polymers and diene derivatives compounded to various formulas to produce materials with a wide range of properties. Tygon may be compounded to be resistant to all inorganic acids (except fuming nitric), all inorganic salts, all organic acids (except glacial acetic), alkali solutions, and most of the hydrocarbons and solvents. It is unaffected by mineral oils, gasolines, fresh or salt waters.

Surface Affect of Immersion in Solutions for 7 Days at 25 Deg. C. for Tygon T.

30% Sulphuric acid.....	None
3% Sulphuric acid.....	"
10% Nitric acid.....	"
10% Hydrochloric acid.....	"
5% Acetic acid.....	"
10% Sodium hydroxide.....	"
10% Ammon. hydroxide.....	"
10% Sodium chloride.....	"
Distilled water.....	"
50% Ethyl alcohol.....	"
Acetone.....	Dissolved
Ethylene dichloride.....	"
Toluene.....	Soft, rubbery
Gasoline.....	None

Representative Makers of Industrial Rubber Products and Rubber-Like Materials

MANUFACTURER (Name and Address)	Products	MANUFACTURER (Name and Address)	Products
American Hard Rubber Co., New York, N. Y.	Hard and soft rubber, neoprene and Thiokol linings, pipe, fittings, shapes, pails, pumps, rubber paint, anode process, etc.	Linear Packing & Rubber Co., Philadelphia, Pa.	Rubber and synthetic rubber packings
Atlas Mineral Products Co. of Pa., Mertztown, Pa.	Rewbon seamless rubber linings, Neobon and Zerok synthetic resin linings	Luzerne Rubber Co., Trenton, N. J.	Hard rubber pipe, fittings, valves, shapes tanks, rayon apparatus and other equipment
Boston Woven Hose & Rubber Co., Boston, Mass.	Conveyor and transmission belts, hose, mechanical rubber goods	Manhattan Rubber Mfg. Div., Passaic, N. J.	Transmission and conveyor belting, blocks, hose, piping, rolls, brake lining, bearings
Crane Packing Co., Chicago, Ill.	Rubber and synthetic rubber packings and seals	Miller Rubber Industrial Prod. Div., B. F. Goodrich Co., Akron, Ohio	Rubber and synthetic rubber hydraulic oil packings and seals
Custodis Construction Co., New York, N. Y.	Custoplast soft rubber and neoprene tank linings	Paramount Rubber Co., Detroit, Mich.	Seamless rubber, neoprene and Paramount plastic linings, rubber paint, molds, coatings and insulations
Dayton Rubber Mfg. Co., Dayton, Ohio	Oilproof rubber belts, transmission belting, synthetic rubber products	Resistoflex Corp., Belleville, N. J.	Rubber-like oil-resisting resin — tubing, hose, sheets, molded shapes, gloves, aprons, solutions
E. I. du Pont de Nemours & Co., Neoprene Div., Wilmington, Del.	Neoprene polymerized chloroprene rubber	Self-Vulcanizing Rubber Co., Chicago, Ill.	Liquid and plastic rubber self-vulcanizing coatings and lining materials
Firestone Tire & Rubber Co., Akron, Ohio	Perbunan synthetic rubber	Standard Oil Development Co., Elizabeth, N.J.	Perbunan synthetic rubber
Garlock Packing Co., Palmyra, N. Y.	Rubber packings, transmission belting, molded goods	Jos. Stokes Rubber Co., Trenton, N. J.	Hard rubber and synthetic molded and extruded products
Gates Rubber Co., Denver, Colo.	V-belts, molded rubber goods, hose	Thermoid Rubber Div., Thermoid Co., Trenton, N. J.	Transmission belting, multiple V-belts and drives, conveyor and elevator belting wrapped and molded hose, packings, industrial brake linings and friction products rubber covered rolls, pulley lagging
L. H. Gilmer Co., Tacony, Philadelphia, Pa.	Transmission belting and special molded parts	Thiokol Corp., Trenton, N. J.	Thiokol olefine polysulphide synthetic rubber — crude sheet, molding powder and liquid dispersions
B. F. Goodrich Co., Akron, Ohio	Acid- and abrasion-resistant linings, hose, conveyor and transmission belting, packings, hard-rubber pipe and molded goods, corrosion resisting paints, Koroseal, Anode process, Ameripol tires and mechanical goods	U. S. Rubber Co., New York, N. Y.	Hose; conveyor, elevator and power transmission belting; packings; molded and extruded rubber; rubber bonded to metal; rubber linings (hard, semi-hard, soft for tanks, pipe, fittings, chutes and valves)
Goodyear Tire & Rubber Co., Akron, Ohio	Hose, conveyor and transmission belting, packings, linings, Ploweld rubber lined tanks, pipe, etc., mechanical rubber goods, molded goods, Pliolite modified rubber plastic, Chemigum	U. S. Stoneware Co., Akron, Ohio	Tygon synthetic resin products: tank linings, gaskets, tubing, acid-proof paints, cements, molded or extruded goods. Molded or extruded mechanical rubber goods, rubber linings
Hewitt Rubber Corp., Buffalo, N. Y.	Hose, transmission and conveyor belting, packings	Union Bay State Co., Cambridge, Mass.	Gacco (neoprene base) compounds for tank surfacing and similar corrosion proofing purposes
Hycar Chemical Co., Akron, Ohio	Synthetic rubbers (Hycar)	Vulcanized Rubber Co., New York, N. Y.	Hard and semi-hard rubber molded products
Jenkins Bros. Rubber Div., Bridgeport, Conn.	Mechanical rubber goods, rubber and synthetic rubber packings, valve discs, molded and extruded products, friction and insulated tape and tire valves		
The Osborn Mfg. Co., Johns Conveyor Div., Cleveland, Ohio	Johns rubber and synthetic rubber "moving pipe-line" conveyors		
Maurice A. Knight, Akron, Ohio	All-rubber acid shipping drums. Pyroflex resin-base tank linings		

PLASTICS AS ENGINEERING MATERIALS

Physical Properties of Principal Plastics Used as Engineering Materials

(From forthcoming book, "Plastics for Industrial Use", by John Sasso, McGraw-Hill Book Co., 1942)

Materials	Tensile Strength, (Lb. per sq. in.)	Compressive Strength, (Lb. per sq. in.)	Flexural Strength, (Lb. per sq. in.)	Impact Strength, Izod (Ft.-lb. per in. of notch, $\frac{1}{2} \times \frac{1}{2}$ in. bar)	Thermal Conductivity, 10^{-4} cal./sec./sq. cm./ (deg. C./cm.)	Distortion Point, deg. F.	Thermal Expansion, (In. per in. per deg. C.) ($\times 10^{-4}$)	Dielectric Strength, (Short time, volts per mil, $\frac{1}{8}$ in. Thickness, 1,000,000 cycles)	Water Absorption (Percent in 24 hours)
Phenolic:									
Wood-flour filled.....	4,000-11,000	16,000-36,000	8,000-15,000	0.15-0.25	4-12	240	5.5	300-500	0.2-0.6
Mineral-filled.....	4,000-10,000	18,000-35,000	8,000-20,000	0.13-0.72	8-20	290	3.2	250-400	0.01-0.3
Fabric-filled.....	5,000-8,000	20,000-32,000	8,000-13,000	0.8-4.8	.....	.....	4	150-450	0.5-2.5
Cast phenolic.....	5,000-12,000	10,000-30,000	9,000-14,000	0.3-0.4	3-5	.....	.....	300-450	0.01-0.5
Laminated Phenolic:									
Paper base.....	7,000-15,000	20,000-40,000	13,000-20,000	0.6-7.6	5-8	.....	.....	400-1,000	0.3-9.0
Cotton base.....	8,000-12,000	30,000-44,000	13,000-30,000	1.4-15	5-8	.....	.....	150-600	.....
Asbestos base.....	7,000-12,000	18,000-45,000	10,000-35,000	1.8-11	7-9	.....	.....	100-150	.....
Phenol-furfural:									
Wood-flour filled.....	6,000-11,000	28,000-36,000	8,000-15,000	0.30-0.56	3-5	.....	3	400-600	.....
Mineral-filled.....	5,000-10,000	24,000-36,000	26,000-30,000	0.32-0.74	10-20	.....	2	200-500	.....
Fabric-filled.....	6,000-8,000	26,000-30,000	10,000-13,000	1.20-4.60	5-8	.....	5	200-500	.....
Urea-formaldehyde.....	5,000-13,000	24,000-35,000	10,000-15,000	0.28-0.32	7	260	3	650-720	1-3
Vinyl chloride.....	8,000-10,000	10,000-12,000	12,000-14,000	0.6-1.2	4	140	7	.....	.....
Vinylidene chloride.....	5,000-7,000	7,500-8,500	15,000-17,000	2.0-8.0	2.2	240	16	500	0.0
Me. methacrylate.....	4,000-7,000	10,000-15,000	10,000-15,000	0.2-0.4	4-8	160	8	500	0.4-0.5
Polystyrene.....	5,000-9,000	11,500-13,500	14,000-19,000	0.35-0.50	3-5	170	7	500-525	0.0
Ethyl cellulose.....	6,000-9,000	10,000-12,000	4,000-12,000	0.6-6.5	5-6	140	12	.....	0.5-1.5
Cel. acet. butyrate.....	2,500-7,500	7,500-22,000	2,800-13,000	0.8-5.5	5-8	150	13	.....	.....
Cellulose acetate.....	3,000-10,000	7,000-27,000	3,700-10,000	0.7-4.2	5-8	150	12	350-900	1.3-6.9

Types, Trade Names and Manufacturers of Principal Plastics*

Types	Trade Names	Manufacturers	Types	Trade Names	Manufacturers		
Phenolic materials....	Bakelite	Bakelite Corp., N. Y.	Vinylidene Chloride....	Saran	Dow Chemical Co., Midland, Mich.		
	Cardolite	Irvington Varnish & Ins. Co., Irvington, N. J.		Polystyrene.....	Bakelite	Bakelite Corp., N. Y.	
	Celaron	Continental Diamond Fibre Co., Newark, Del.			Loalin	Catalin Corp., N. Y.	
	Coltrock	Colt's Patent Fire Arms Mfg. Co., Hartford, Conn.			Lustron	Monsanto Chemical Co., E. Springfield, Mass.	
	Durez	Durez Plastics & Chemicals, Inc., N. Tonawanda, N. Y.			Styron	Dow Chemical Co., Midland, Mich.	
	Durite	Durite Plastics, Philadelphia, Pa.			Cellulose Acetate.....	Bakelite	Bakelite Corp., N. Y.
	Haveg	Haveg Corp., E. Newark, Del.				Cellulite	National Plastics Co., Detroit, Mich.
	Heresite	Heresite & Chemical Co., Manitowoc, Wis.				Fibestos	Monsanto Chemical Co., E. Springfield, Mass.
	Indur	Reilly Tar & Chemical Corp., Indianapolis, Ind.				Gemloid	Gemloid Corp., N. Y.
	Insurok	Richardson Co., Melrose Park, Ill.				Lumarith	Celanese Celluloid Corp., N. Y.
	Makalot	Makalot Corp., Boston, Mass.				Macite	Manufacturers Chemical Corp., Jersey City, N. J.
	Resinox	Monsanto Chemical Co., E. Springfield, Mass.				Nixonite	Nixon Nitration Works, Nixon, N. J.
Templux	Bryant Electric Co., Bridgeport, Conn.	Plastacele	E. I. duPont de Nemours & Co., Arlington, N. J.				
Textolite	General Electric Co., Pittsfield, Mass.	Tenite I	Tennessee Eastman Corp., Kingsport, Tenn.				
Phenolic, cast.....	Bakelite	Bakelite Corp., N. Y.	Cellulose Acetate Butyrate.....	Tenite II.....		Tennessee Eastman Corp., Kingsport, Tenn.	
	Catalin	Catalin Corp., N. Y.		Ethyl Cellulose.....		Ethocel	Dow Chemical Co., Midland, Mich.
	Gemstone	A. Knuedler Co., Lancaster, Pa.				Hercules	Hercules Powder Co., Wilmington, Del.
	Mariolette	Marbette's Corp., L. I. City, N. Y.			Laminated Materials..	Aqualite	National Vulcanized Fibre Co., Wilmington, Del.
	Opalon	Monsanto Chemical Co., E. Springfield, Mass.				Celanite	Continental Diamond Fibre Co., Newark, Del.
Prystal	Catalin Corp., N. Y.	Celaron	Continental Diamond Fibre Co., Newark, Del.				
Urea.....	Bakelite	Bakelite Corp., N. Y.	Coffite	Formica Insulation Co., Cincinnati, Ohio			
	Beetle	American Cyanamid Co., N. Y.	Corresite	S. Bleckman, Inc., Weehawken, N. J.			
	Cibanoid	Ciba Corp., N. Y.	Dilecto	Continental Diamond Fibre Co., Newark, Del.			
	Plaskon	Plaskon Co., Toledo, Ohio	Dilectene	Continental Diamond Fibre Co., Newark, Del.			
	Uformite	Resinous Products & Chemicals Co., Phila., Pa.	Duraloy	Detroit Paper Products Co., Detroit, Mich.			
	Melamines.....	Melamac	American Cyanamid Co., N. Y.	Formica	Formica Insulation Co., Cincinnati, Ohio		
		Malamine	Plaskon Co., Toledo, Ohio	Insurok	Richardson Co., Melrose Park, Ill.		
	Acrylics.....	Crystalite	Rohm & Haas, Phila., Pa.	Lamicoid	Mica Insulation Co., N. Y.		
		Lucite	E. I. duPont de Nemours Co., Arlington, N. J.	Lamitex	Franklin Fibre-Lamitex Corp., Wilmington, Del.		
	Vinyls.....	Plexiglas	Rohm & Haas, Phila., Pa.	Micarta	Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.		
Alvar		Shawinigan Prod. Corp., N. Y.	Panelyte	Panelyte Corp., N. Y.			
Butacite		E. I. duPont de Nemours Co., Wilmington, Del.	Ohmoid	Wilmington Fibre Specialty Co., Wilmington, Del.			
Butvar		Shawinigan Prod. Corp., N. Y.	Phenolite	National Vulcanized Fibre Co., Wilmington, Del.			
Formvar		Shawinigan Prod. Corp., N. Y.	Spauldite	Spaulding Fibre Co., Tonawanda, N. Y.			
Gelva		Shawinigan Prod. Corp., N. Y.	Synthane	Synthane Corp., Oaks, Pa.			
Koroseal		B. F. Goodrich Co., Akron, Ohio	Taylor	Taylor Fibre Co., Norristown, Pa.			
Resistoflex		Resistoflex Corp., Belleville, N. J.	Textolite	General Electric Co., Pittsfield, Mass.			
Tygon		U. S. Stoneware Co., Akron, Ohio	Ucinite	Ucinite Co., Newtonville, Mass.			
Vinylite		Carbide & Carbon Chemicals Corp., N. Y.	Vulcoid	Continental Diamond Fibre Co., Newark, Del.			

* In this table only the more usual engineering plastics materials are listed by trade name and manufacturers. No attempt has been made to include all types of plastics materials, as that is beyond the scope of this issue of *Chem. & Met.*, which is concerned primarily with materials of

construction for chemical engineering equipment. The engineer may find listings of molders and extruders as well as other valuable data in the forthcoming book by John Sasso, "Plastics for Industrial Use," McGraw-Hill Co., (1942), from which this list was largely compiled.

Plastics (Continued)

Determining the Most Suitable Plastics for use as Engineering Materials

The "Plastics Comparator" has been prepared by the Bakelite Corporation to serve as a guide in selecting the plastic or plastics to consider for industrial use. It rates the materials numerically without any attempt to indicate relative differences. Thus, the number (1) indicates the most suitable, and the larger numbers the order of suitability. The difference between (1) and (2) may in some instances be negligible and in others appreciable. The ratings are made taking into

consideration the most commonly used materials of each type. Special formulas under any one type might change the order of suitability. Thus, exact technical interpretation of it should be avoided. After using it as a guide, "stop, look and listen" by examining closely the detailed technical data published elsewhere on each specific group of materials before proceeding. Remember that progress is being made constantly in improving the properties of practically all plastics.

The ratings given in the Comparator may not in all instances confirm published data, including that appearing in this issue of *Chem. & Met.* The materials are rated here according to usage experience, as well as to test data. For example, urea on the basis of A.S.T.M. water absorption tests would warrant a better rating. However, on continuous exposure to high humidity or water, the rating shown in the Comparator is 8.

PLASTIC MATERIAL	PLASTICS COMPARATOR																		
	Toughness (Impact Strength)	Flexural Strength	Tensile Strength	Color Stability	Cold Flow	Water Resistance	Acid Resistance	Caustic Resistance	Solvent Resistance	Dimensional Change on Aging	Heat Resistance (Continuous Heat)	Flammability	Heat Insulation	Specific Gravity	Hardness	Loss Factor	Resistivity	Dielectric Strength	Moldability Around Inserts
Phenolic: General Purpose	10	3	3	7	1	5	3	4	1	4	2	3	2	8	5	10	7	4	2
Phenolic: Low-Loss	11	3	7	7	1	2	4	4	1	2	3	1	7	12	3	4	3	3	2
Phenolic: Heat-Resistant	9	4	8	7	1	2	4	4	1	1	1	1	7	13	2	8	8	2	
Phenolic: Acid and Alkali-Resistant	10	6	8	7	1	3	2	3	1	5	3	2	2	5	4	7	3	3	
Phenolic: Shock-Resistant	2	1	5	7	1	6	4	5	1	6	3	4	3	10	5	9	8	1	
Phenolic: Transparent	7	1	3	7	1	3	3	3	1	5	3	2	2	6	4	7	5	6	3
Urea	8	1	1	1	2	8	4	4	1	7	7	5	5	11	1	9	4	2	4
Polystyrene	7	2	7	4	4	1	1	1	3	3	6	6	1	1	6	1	1	1	6
Cellulose-Acerate	4	6	9	3	8	10	4	6	3	9	5	6	4	7	9	8	6	5	5
Aceto-Butyrate	1	5	10	3	6	7	4	4	3	8	4	6	6	4	8	3	5	5	
Ethyl-Cellulose	3	2	6	6	7	9	4	2	3	8	5	6	4	2	8	2	2	1	5
Methyl-Methacrylate	6	1	4	2	5	4	2	2	3	8	9	6	2	3	7	5	2	6	
Vinyl (No Filler)	5	1	2	5	3	1	1	1	2	3	8	5	2	9	7	6	2	1	5

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Effect on Plastics of Immersion for 7 Days in Chemical Reagents at 25 Deg. C.

	Phenol-Formaldehyde Molded	Phenol-Formaldehyde Cast	Phenol-Formaldehyde Laminated	Urea-Formaldehyde Molded	Urea-Formaldehyde Laminated	Vinyl Chloride-Acetate Resin	Vinyl Butyral Resin	Methyl Methacrylate Resin	Styrene Resin Molded	Cellulose Nitrate	Cellulose Acetate	Ethyl-Cellulose No. 1	Cold-Molded Phenolic	Casein Plastic
30% Sulphuric acid	Surface roughened	None	Edges swollen	Surface roughened	Surface attacked	None	None	None	None	None	Crazed; softened	None	None	Rubbery
3% Sulphuric acid	Surface roughened	None	Edges swollen	Surface roughened	Surface attacked	None	Cloudy	None	None	None	Swollen	None	None	Swollen; rubbery
10% Nitric acid	Surface roughened	None	Edges swollen	Surface roughened	Delaminated	None	Cloudy	None	None	None	Decomposed	None	None	Swollen; cracked
10% Hydrochloric acid	Surface roughened	None	Edges swollen	Surface roughened	Delaminated	None	Cloudy	None	None	None	Decomposed	None	Cracked on drying	Swollen; cracked
5% Acetic acid	None	None	Edges swollen	None	None	None	Cloudy	None	None	None	Swollen	None	None	Rubbery; split
Oleic acid	None	None	None	None	None	None	Tacky	None	None	None	None	Decomposed	None	None
10% Sodium hydroxide	Decomposed	Decomposed	Delaminated	None	Surface attacked	None	None	None	None	Crazed	Decomposed	None	Decomposed	Decomposed
1% Sodium hydroxide	Surface roughened	Decomposed	Edges swollen	None	None	None	Slightly cloudy	None	None	Crazed	Surface attacked	None	Decomposed	Broken up

(Continued on next page)

Effect on Plastics of Immersion for 7 Days in Chemical Reagents at 25 Deg. C. (Cont'd.)

	Phenol-Formaldehyde Molded	Phenol-Formaldehyde Coat	Phenol-Formaldehyde Laminated	Urea-Formaldehyde Molded	Urea-Formaldehyde Laminated	Vinyl Chloride-Acetate Resin	Vinyl Butyral Resin	Methyl Methacrylate Resin	Styrene Resin Molded	Cellulose Nitrate	Cellulose Acetate	Ethyl-Cellulose No. 1	Cold-Molded Phenolic	Casein Plastic
10% Ammonium hydroxide	Surface dulled	Dis-colored	Dis-colored; edges swollen	None	None	None	Opaque	None	Dis-colored	Crazed; dis-colored	Opaque; soft	None	None	Swollen; split
2% Sodium carbonate	None	Dis-colored	Dis-colored	None	None	None	Slightly cloudy	None	None	None	Swollen	None	None	Swollen; rubbery
10% Sodium chloride	None	None	Edges swollen	None	None	None	None	None	None	None	None	None	None	None
3% Hydrogen peroxide	None	Dis-colored	None	Surface dulled	Delaminated	None	Cloudy	None	None	None	None	None	None	Swollen; rubbery
Distilled water	None	None	None	None	None	None	Cloudy	None	None	None	None	None	None	Swollen; rubbery
50% Ethyl alcohol	None	None	None	None	None	None	Swollen; rubbery	Slightly swollen	None	None	Partly dissolved	Swollen; cracked	None	Swollen; rubbery
95% Ethyl alcohol	None	None	None	None	None	None	Dissolved	Surface attacked	None	Dissolved	Partly dissolved	Dissolved	None	None
Acetone	None	Softened	Blistered	None	None	Dissolved	Swollen; opaque	Dissolved	Dissolved	Dissolved	Dissolved	Dissolved	None	None
Ethyl acetate	None	None	None	None	None	Decomposed	Decomposed	Dissolved	Dissolved	Dissolved	Dissolved	Dissolved	None	None
Ethylene chloride	None	None	None	None	None	Dissolved	Decomposed	Dissolved	Dissolved	Partly dissolved	Soft; swollen	Dissolved	None	None
Carbon tetrachloride	None	None	None	None	None	None	Swollen; rubbery	Surface attacked	Dissolved	None	None	Dissolved	None	None
Toluene	None	None	None	None	None	Soft; rubbery	Swollen; rubbery	Dissolved	Dissolved	Partly dissolved	None	Dissolved	None	None
Gasoline	None	None	None	None	None	None	None	None	Partly dissolved	None	None	Swollen; cracked	None	None

From a paper, Resistance of Plastics to Chemical Reagents, by G. M. Kline, R. C. Rinker and H. F. Meindl presented before Chicago meeting of A.S.T.M. June 24, 1941.

Properties of Phenol-Formaldehyde-Asbestos Plastics

Properties	Haveg 41	Haveg 43	Haveg 50	Corrosive Materials	Recommended Grade	Also Satisfactory	Not Satisfactory
Specific gravity.....	1.6	1.6	1.6	Ferric salts.....	41	43-50	...
Tensile strength, psi.....	2,500	2,500	1,800	Ferrous salts.....	41	43-50	...
Compressive strength, psi..	10,500	8,000	6,000	Fluosilicic acid.....	43	...	41-50
Flexural strength, psi.....	5,600	4,500	3,500	Formic acid.....	41	43	...
Shearing strength, psi.....	3,500	3,000	2,500	Gasoline (sour).....	41	43	50
Modulus of elasticity.....	1,000,000	850,000	...	Hydrobromic acid.....	41	43-50	...
Thermal conductivity				Hydrochloric acid.....	41	43-50	...
BTU/sq.ft./°F./hr./ft..	0.203	0.607	0.203	Hydrofluoric acid.....	43	...	41-50
Coefficient of expansion				Hydrofluosilicic acid.....	43	...	41-50
Inches per inch of length or	per deg. F. 0.000018 (18x10 ⁻⁶)			Hydrogen sulphide.....	41	43-50	...
Feet per foot of length	per deg. C. 0.000033 (33x10 ⁻⁶)			Lactic acid.....	41	43	...
				Lead acetate.....	41	43-50	...
				Muriatic acid.....	41	43-50	...
				Oxalic acid.....	41	43-50	...
				Phosphoric acid.....	41	43-50	...
				Potassium bisulphate.....	41	43-50	...
				Potassium chloride.....	41	43-50	...
				Potassium hydroxide.....	50	...	41-43
				Potassium sulphate.....	41	43-50	...
				Salt brine.....	41	43-50	...
				Sodium acid sulphate.....	41	43-50	...
				Sodium bicarbonate.....	41	43-50	...
				Sodium bisulphate.....	41	43-50	...
				Sodium carbonate.....	41	43-50	...
				Sodium hydroxide.....	50	...	41-43
				Sodium sulphate.....	41	43-50	...
				Sodium sulphite.....	41	43-50	...
				Sodium thiosulphate.....	41	43-50	...
				Sulphur dioxide.....	41	43-50	...
				Sulphuric acid (up to 50%).....	41	43-50	...
				Sulphurous acid.....	41	43-50	...
				Tannic acid.....	41	43-50	...
				Tartaric acid.....	41	43	...
				Tin chloride.....	41	43-50	...
				Trisodium phosphate.....	41	43-50	...
				Vinegar.....	41	43-50	...
				Zinc chloride.....	41	43-50	...
				Zinc sulphate.....	41	43-50	...

Chemical Resistance of Phenol-Formaldehyde-Asbestos Plastics (Haveg types)

Corrosive Materials	Recommended Grade	Also Satisfactory	Not Satisfactory
Acetic acid.....	41	43	50
Alcohol.....	41	43	50
Aluminum chloride.....	41	43-50	...
Aluminum sulphate.....	41	43-50	...
Ammonium chloride.....	41	43-50	...
Ammonium hydroxide.....	41	43-50	...
Ammonium sulphate.....	41	43-50	...
Aniline hydrochloride.....	41	43	...
Benzol.....	41	43	50
Boric acid.....	41	43-50	...
Calcium chloride.....	41	43-50	...
Carbon tetrachloride.....	41	43	...
Chlorine gas.....	41	43	...
Chlorine water.....	41	43	...
Citric acid.....	41	43	...
Coppers.....	41	43-50	...
Copper sulphate.....	41	43-50	...
Cupric chloride.....	41	43-50	...

Chemical Resistance of Phenol-Formaldehyde-Fiber Glass Plastics

Chemical resistance: Chlorine and its compounds, hydrochloric acid, dilute sulphuric acid, phosphoric acid, organic acids, solvents, trichlorethylene, carbon tetrachloride ethylene, chlorhydrin, hydrocarbons, metal salt solutions etc.

Physical properties: Specific gravity 1.35. Tensile strength 36,000 lb. per sq. in. Impact strength 16 ft. lb. per inch of notch. The material may be used for working temperatures up to 275 deg. F.

Available Forms: Pipes and fittings, rectangular and cylindrical tanks, and other large-size chemical plant equipment.

Data supplied for Corresite by S. Blickman, Inc., Weehawken, N. J.

Chemical Properties of Acrylic Plastics¹

Immersion Solution ²	Percent Weight Gain ³
30% Sulphuric acid.....	0.6
3% Sulphuric acid.....	1.0
10% Hydrochloric acid.....	0.7
10% Sodium hydroxide.....	0.8
1% Sodium hydroxide.....	1.0
10% Nitric acid.....	0.9
5% Acetic acid.....	1.0
2% Sodium carbonate.....	1.0
10% Sodium chloride.....	0.9
10% Ammonium hydroxide.....	0.9
3% Hydrogen peroxide.....	1.0
100% Distilled water.....	0.9

¹ Approved tests of the Committee on Plastics of the American Society for Testing Materials using pieces of material 1 in. x 3 in. x 0.125 in. totally immersed in the various chemical solutions for 192 hr. at 25° C. Data supplied for Plexiglas by Rohm & Haas Co., Philadelphia, Pa.

² All concentrations given in percent by weight in distilled water.

³ A gain in weight of one percent or less is considered negligible except in unusual applications. None of the above solutions appreciably affects the appearance or strength characteristics.

Plastics (Continued)

Chemical Resistance of Cellulose Acetate Molding Materials*

	Class I Percent	Class II Percent
Average Water Absorption — (Injection molded bar 5 in. x 1/2 in. x 1/8 in.)		
24 hours	2.00	1.50
48 hours	2.75	2.00
96 hours	3.75	2.70
Acids and Alkalies — Dilute	Slight effect	Slight effect
Concentrated	Decomposes	Decomposes
Effect of: Time	Slight on aging	Slight on aging
Sunlight	Slight	Slight
Heat	Slow burning rate	Slow burning rate
Solvents — Both Class I and Class II are soluble in ketones and esters, i.e., acetone, methyl acetate, the "Cellosolve" solvents affected slightly by alcohol. Insoluble in hydrocarbons, i.e., benzene, toluene, styrene, carbon tetrachloride and oils. Elevated temperatures influence the action of both solvents and non-solvents inducing swelling.		

Chemical Resistance of Polystyrene Molding Materials*

Resistance to Non-Oxidizing Acids — Excellent	Resistance to Alkalies — Excellent				
Resistance to Oxidizing Acids — Discolors Slightly	Resistance to Hydrochloric Acid — Good				
Dissolved or Attacked by:					
Styrene	Toluene	Ethyl Acetate	Ethyl Benzene	"Cellosolve" Acetate	Gasoline
Benzene	Dioxane	Turpentine	Ethylene Chloride	Carbon Tetrachloride	"Cellosolve" Solvent
Unaffected by:					
Acetic Acid	Sodium Hydroxide (30%)	Salt Water			
Formic Acid	Potassium Hydroxide (30%)	Bleaching Solutions			
Butanol	Ethylene Diamine	Photographic Chemicals			
Octyl Alcohol	Writing Inks	Most fats, animal and vegetable oils			

Chemical Resistance of Vinyl Copolymer Injection Molding Compounds

Reagent	Reaction	Reagent	Reaction
Weak acids	Excellent	Esters	Poor — dissolves
Strong acids	Excellent	Aromatic hydrocarbons	Poor — swells
Weak alkalis	Excellent	Aliphatic hydrocarbons	Excellent
Strong alkalis	Excellent	Mineral oils	Excellent
Alcohols	Excellent	Animal oils	Excellent
Ketones	Poor — dissolves	Vegetable oils	Excellent

*Data supplied by Bakelite Corporation, New York.

Chemical Resistance of Saran Pipe at Room Temperature After Three Months.

Reagent	Stability Rating
98% (Conc.) H ₂ SO ₄	Good
60% H ₂ SO ₄	Excellent
30% H ₂ SO ₄	Excellent
10% H ₂ SO ₄	Excellent
35% (Conc.) HCl	Excellent
10% HCl	Excellent
65% (Conc.) HNO ₃	Excellent
10% HNO ₃	Excellent
Glacial acetic	Excellent
10% Acetic	Excellent
5% H ₂ SO ₃	Excellent
50% NaOH	Fair
10% NaOH	Good
28% NH ₃	Unsuitable
10% NH ₃	Poor
Ethyl alcohol	Excellent
Ethyl acetate	Fair
Acetone	Fair
Methyl iso-butyl ketone	Fair
Carbon tetrachloride	Good
Ethylene dichloride	Poor
Di-ethyl ether	Poor
Dioxane	Unsuitable
Benzene	Fair
O-dichlor benzene	Poor
Triethanolamine	Excellent
Bromine water	Unsuitable
Chlorine water	Unsuitable
Bleaching solution	Excellent
10% Zinc hydrosulphite	Excellent
15% CaCl ₂	Excellent
15% FeSO ₄	Good
Water	Excellent
Air	Excellent

GLASS, GLASS-LINED AND FUSED SILICA

Physical Properties of Low-Expansion Glasses, Fused Quartz and Fused Silica

MATERIAL	Specific Gravity	Specific Volume, Cu. in. per lb.	Tensile Strength, Lb. per sq. in.	Modulus of Elasticity, Lb. per sq. in. (Multiply by 10 ⁹)	Hardness*	Thermal Expansion Per °C. (Multiply by 10 ⁻⁴)	Thermal Cond., Cal. per sec. cm. ² , °C., cm. (Multiply by 10 ⁹)	Specific Heat, Cal. per °C., gm.	Softening Point, °F.	Breakdown Voltage, 60 cycles, v. per mil	Dielectric Constant, 60 cycles	Refractive Index, n _D 20	Transparency†	Forms Available**
Borosilicate glass	2.23	12.4	10,000	98	....	0.32	24.5	0.20	1,505	3,200 (0.1 in.)	4.6	1.47	T, TL	S, R, T, other
96% silica glass	2.18	12.7	.....	.....	.....	0.080	.....	.....	2,750±90	3,000	4.0	1.458	T	R, T, other
Fused quartz	2.20	12.6	4,000	105-126	4.9	0.054	3.5	0.25	2,600	500 (1/4 in.)	3.8	1.459	T	S, R, T, other
Fused silica	2.07	13.4	400-800	94-114	....	0.054	25	.....	2,600	250 (1/4 in.)	3.7	....	TL, O	S, R, T, other

* Hardness: 2.5 mm. ball, 25 kg. load, depth in 1/200 mm. † T = transparent; TL = translucent; O = opaque. ** S = sheets; R = rods; T = tubes.

Makers of Glass, Glass-Lined and Fused Silica Equipment

MANUFACTURER (Name and Address)	Composition, Forms Available	MANUFACTURER (Name and Address)	Composition, Forms Available
Alsop Engineering Co., Milldale, Conn.	Glass-lined steel tanks and mixers	Hanovia Chemical & Mfg. Co., Newark, N. J.	Transparent fused quartz in all shapes
Amersil Corp., Hillside, N. J.	Fused silica ware such as pans, pipes, gas coolers, absorbers	Metal-Glass Products Co., Belding, Mich.	Glass-enameled steel equipment
Corning Glass Works, Corning, N. Y.	Special heat- and corrosion-resisting borosilicate glass supplied in various forms: pipe, columns, etc. Also 96 per cent high silica glassware now available for laboratory use	Owens-Corning Fiberglas Corp., Toledo, Ohio	Fibrous glass filter cloths and dust filters
Ertel Engineering Co., New York, N. Y.	Glass-enameled tanks	The Pfaunder Co., Rochester, N.Y.	Wide variety of standard and special glass-enameled steel equipment — various formulas
General Electric Co., Schenectady, N. Y.	Transparent fused quartz in various small sized articles	A. O. Smith Corp., Milwaukee, Wis.	Glass-enameled steel equipment
Glasco Products, Inc., Euclid, Ohio	Glass-enameled steel equipment	The Thermal Syndicate, Brooklyn, N. Y.	Fused silica (non-transparent) supplied in various large forms; fused quartz (transparent) in smaller sizes
		Vitreous Enameling & Stamping Co., New York, N. Y.	Enameled specialties, tanks
		Vitreous Steel Products Co., Cleveland, Ohio	Enameled trays and specialties

WOOD FOR CHEMICAL EQUIPMENT

Physical Properties of Woods Commonly Used for Equipment and Plant Structures

	Cypress	Douglas Fir (Coast)	L. L. Y. Pine	Redwood	Sugar Maple	White Oak
Lb. per cu. ft. (12% moisture).....	32	34	41	28	44	47
Tensile str., * lb. per sq. in. (12% moisture)....	7,200	8,100	9,300	6,900	9,500	7,900
Compressive str., * lb. per sq. in. (12% moisture)	4,740	6,450	6,150	4,560	5,390	4,350
Thermal cond., B.t.u. per sq. ft., hr., ° F., in....	0.83	0.77	0.96	0.76	1.16	1.22
Hardness.....	Med.	Med.	Hard	Mod. hard	Med.	Hard

*At proportional limit, in static bending, and compression parallel to grain, respectively.

Condition of Woods After 31 Days' Immersion in Cold Solutions*

(Examined after 7 days drying)

	Fir	Oak	Oregon Pine	Yellow Pine	Spruce	Redwood	Maple	Cypress
Hydrochloric Acid, 5%.....	NAC	NAC	NAC	SS	SS	SS	NAC	NAC
Hydrochloric Acid, 10%.....	NAC	NAC	NAC	SS	SS	SS	NAC	NAC
Hydrochloric Acid, 50%.....	SS,SB,SWF	SS,WF	S,WF	S,WF	S,WF	S,WF	S,WF	S,WF
Sulphuric Acid, 1%.....	NAC	NAC	NAC	SS	SS	NAC	NAC	SS,SB
Sulphuric Acid, 5%.....	SS	SS	SS	SS	SS,SB	SS,SB	NAC	SS,SB
Sulphuric Acid, 10%.....	S,FSD	S,FSD	S,FSD	S,FSD	S,FSD	S,FSD	S,FSD	S,FSD
Sulphuric Acid, 25%.....	SSp,FSD	SSp,FSD	SSp,FSD	SSp,FSD	SSp,FSD	SSp,FSD	SSp,FSD	SSp,FSD
Caustic Soda, 5%.....	S,NAC	MSh,SWp	SS	SS,FSD	SSp,FSD	SSp,FSD	MSh	SSp,FSD
Caustic Soda, 10%.....	S,FSD	MSh,WF,Horny	SS	SS,SB,FSD	SS,SB,FSD	SS,SB,FSD	MSh	S,SB,FSD
Alum, 13%.....	NAC	NAC	NAC	NAC	NAC	NAC	NAC	NAC
Sodium Carbonate, 10%.....	SB,GC	NAC	GC	SB,GC	SB,GC	SB,GC	GC	SB,GC
Calcium Chloride, 25%.....	NAC	NAC	NAC	NAC	NAC	NAC	NAC	NAC
Common Salt, 25%.....	NAC	NAC	NAC	SS,GC	SS,GC	SB,GC	NAC	NAC
Water.....	NAC	NAC	NAC	NAC	NAC	NAC	NAC	NAC
Sodium Sulphide.....	SS,SB	MSh,WF	SB	SB	SB	SB	MSh,FSD	FSD

Condition of Woods After 8 Hours Boiling in Solutions*

(Examined after 7 days drying)

	Fir	Oak	Oregon Pine	Yellow Pine	Spruce	Redwood	Maple	Cypress
Hydrochloric Acid, 10%.....	SB,S	FSD	FSD	FSD	FSD	FSD	FSD	FSD
Hydrochloric Acid, 50%.....	FD,Ch,B,S,NG	FD,Ch,B,S,NG	FD,Ch,B,S,NG	FD,Ch,B,S,NG	FD,Ch,B,S,NG	FD,Ch,B,S,NG	FD,Ch,B,S,NG	FD,Ch,B,S,NG
Sulphuric Acid, 4%.....	SB,GC	SB,GC	SB,GC	SB,GC	SB,GC	SB,GC	SB,GC	SB,GC
Sulphuric Acid, 5%.....	SS,GC	SB,GC	SB,GC	SB,GC	SB,FSD	SB,GC	SB,GC	SB,FSD
Sulphuric Acid, 10%.....	SS,GC	BFD,Wpd,NG	Sp,FD,NG	B,Sp,FD,NG	B,Sp,FD,NG	SB,FSD	SB,FSD	B,FD
Caustic Soda, 5%.....	SS	MSh	S	GC	S,GC	S,GC	Sh	SSp
Alum, 13%.....	SB,GC	NAC	NAC	SB,GC	SB,GC	SB,GC	NAC	SB,GC
Sodium Carbonate, 10%.....	SB,GC	GC	GC	GC	GC	GC	GC	SB,GC
Calcium Chloride, 25%.....	SB,GC	SB,SS,GC	NAC	SB,GC	SB,GC	NAC	NAC	SB,GC
Common Salt, 25%.....	NAC	NAC	NAC	SB,GC	NAC	SB,GC	NAC	NAC
Water.....	NAC	NAC	NAC	SB,GC	NAC	NAC	NAC	NAC

* The two tables describing the condition of eight varieties of woods used for tanks and other chemical-resistant uses are based on a report of James K. Stewart, consulting chemist, to the Mountain Copper Co., Martinez, Calif. Tests were conducted on samples 1 x 4 x 1/4 in. in size, seasoned and chosen so as to be as nearly as possible in the same physical condition as the woods would be when used for equipment construction. Results of the tests are described by terms explained in the following key:

Abbreviation Key	FSD — Fiber Slightly Disintegrated	S — Softer	SSp — Slightly Spongy
	GC — Good Condition	SB — Slightly Brittle	SWF — Slightly Weakened Fiber
B — Brittle	MSh — Much Shrunken	Sh — Shrunken	SWp — Slightly Warped
Ch — Charred	NAC — No Apparent Change	Sp — Spongy	WF — Weakened Fiber
FD — Fiber Disintegrated	NG — No Good	SS — Slightly Softer	Wpd — Warped

Representative Makers of Wood Tanks and Pipe for Chemical Applications

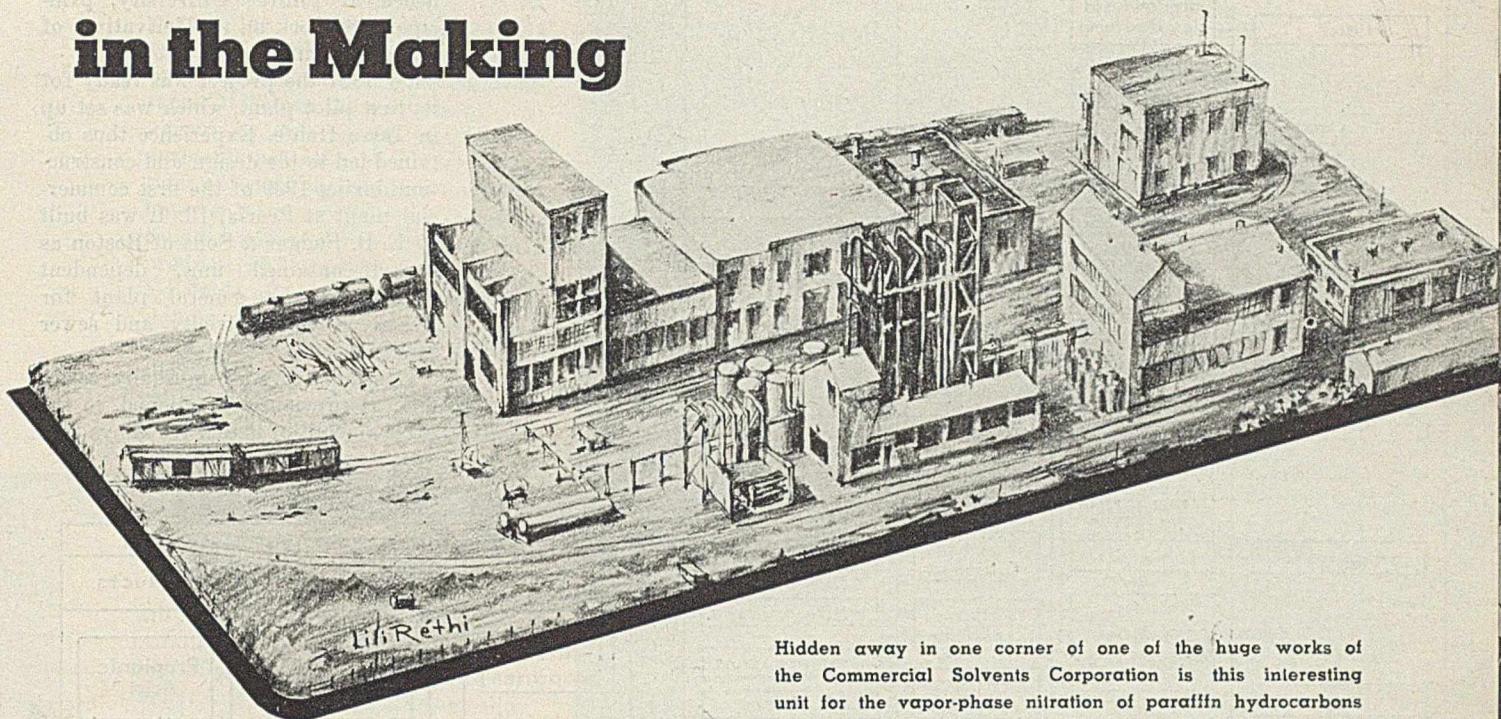
Acme Tank Co., New York, N. Y.	Dempster Mill Mfg. Co., Beatrice Neb.	Hauser-Stander Tank Co., Cincinnati, Ohio	National Tank & Pipe Co., Portland, Oregon	Wm. B. Scaife & Sons Co., Pittsburgh Dist., Oakland, Pa.
Alert Pipe & Supply Co., Bay City, Mich.	Drane Tank Co., Fort Worth, Texas	Hammond & Little River Redwood Co., Samoa, Calif.	New England Tank & Tower Co., Everett, Mass.	Schubert-Christy Corp., St. Louis
Atlantic Tank Corp., North Bergen, N. J.	Drummond Mfg. Co., Louisville, Ky.	Henderson Bros. Co., Waterbury Conn.	Pacific Cooperage Co., Portland, Oregon	A. T. Stearns Lumber Co., Boston
Axtell Co., Fort Worth, Texas	Dunk Tank Works, Inc., Milwaukee, Wis.	R. R. Howell & Co., Minneapolis	Pacific Wood Tank Corp., San Francisco, Calif.	Treadwell Construction Co., Station A., Midland, Pa.
Baltimore Cooperage Tank & Tower Co., Baltimore, Md.	G. Elias & Bro., Buffalo, N. Y.	James Hunter Machine Co., North Adams, Mass.	Pacific Tank & Pipe Co., Oakland Calif.	Union Lumber Co., Crocker Bldg. San Francisco, Calif.
Black, Sivalls & Bryson, Inc., Oklahoma City, Okla.	Engle Tank Co., Chicago, Ill.	Johnson & Carlson, Chicago, Ill.	Parkersburg Rig & Reel Co., Parkersburg, West Va.	U. S. Wind Engine & Pump Co., Batavia, Ill.
C. F. Braun & Co., Alhambra, Calif.	Fibre Conduit Co., Orangeburg, N. Y.	Kalamazoo Tank & Silo Co., Kalamazoo, Mich.	Fred C. Pfeil, Inc., Buffalo, N. Y.	Wendnagel Co., Chicago, Ill.
W. E. Caldwell Co., Louisville, Ky.	Fleming Tank Co., Pittsburgh, Pa.	Lincoln Tank Co., Shreveport, La.	J. F. Pritchard & Co., Kansas City, Mo.	C. H. Wheeler Mfg. Co., North Phila., Pa.
Challenge Co., Batavia, Ill.	Fluor Corp., Ltd., Los Angeles	Lille-Hoffman Cooling Towers, Inc., St. Louis, Mo.	Redwood Mfrs. Co., San Francisco, Calif.	G. Woolford Wood Tank Co., Darby, Pa.
Caspar Lumber Co., Hobart Bldg., San Francisco, Calif.	Foster Wheeler Corp., New York	Marley Co., Kansas City, Kan.	A. Wyckoff & Son Co., Elmira, N. Y.	
A. J. Corcoran, Inc., Jersey City, N. J.	Amos H. Hall & Sons, Philadelphia	Michigan Pipe Co., Bay City, Mich.		
Cypress Tank Co., Shreveport, La.	Harry Cooling & Equipment Co., Doylestown, Pa.	National Tank Co., Tulsa, Okla.		

Metals and Alloys for Construction of Chemical Engineering Equipment

Continued

No.	Material	Manufacturers	Essential Nominal Chemical Composition, Percent	Machining Qualities ¹	Methods of Fabrication	Forms Available	Sulphuric Acid							Hydrochloric Acid					Nitric Acid					Acetic Acid					Phosphoric Acid			Sodium Hydroxide				Sodium Hypochlorite		Resistance		No.		
							Temp.	0.5%	2.5%	10%	25%	60%	95%	Temp.	0.25%	1%	5%	20%	Conc.	Temp.	0.5%	5%	20%	65%	Temp.	0.5%	10%	80%	100%	Temp.	10%	50%	85%	Temp.	0.5%	50%	70%	Temp.	5% free Cl		20% free Cl	Heat
43	CE-30 Stainless Steel, cast	Note: These are the standard designations of cast compositions for nickel-chromium alloys published by the Alloy Casting Institute. The recommended uses have been assembled from published data of individual producers. These compositions are available from one or more of the following foundries: Allegheny Ludlum Steel Corp., Pittsburgh, Pa. American Manganese Steel Div. of the American Brake Shoe & Fdry. Co., Chicago Heights, Ill. American Steel Castings Co., Newark, N. J. Atlas Foundry Co., Irvington, N. J. Babcock & Wilcox Co., Barberton, Ohio Chicago Steel Foundry, Chicago, Ill. Cooper Alloy Foundry Co., Elizabeth, N. J. Crane Co., Chicago, Ill. Driver Harris Co., Harrison, N. J. Duraloy Co., Scottdale, Pa. Duriron Co., Inc., Dayton, Ohio Electric Steel Foundry Co., Portland, Ore. Electro-Alloys Co., Elyria, Ohio Empire Steel Castings, Inc., Reading, Pa. General Alloys Co., Boston, Mass. Hokins Mfg. Co., Detroit, Mich. Lebanon Steel Foundry, Lebanon, Pa. Michiana Products Corp., Michigan City, Ind. Michigan Steel Casting Co., Detroit, Mich. Midvale Co., Philadelphia, Pa. National Alloy Div. of the Blaw-Knox Co., Blawnox, Pa. Ohio Steel Foundry Co., Lima and Springfield, Ohio Otis Elevator Co., Buffalo, N. Y. Sivyer Steel Casting Co., Milwaukee, Wis. Standard Alloy Co., Cleveland, Ohio Symington-Gould Corp., Rochester, N. Y. Taylor Wharton Iron & Steel Co., High Bridge, N. J. Warman Steel Casting Co., Huntington Park, Calif. Utility Electric Steel Foundry, Los Angeles, Calif.	Fe; Cr, 27-30; Ni, 8-11; C, 0.30 max.	Fair		Castings	Room	R	R.004	.03					Room		.08								Room	R	R	R	R	R	Room	R	R	R	R	Room	R		Good	Fair	43	
44	CF-7 Stainless Steel, cast		Fe; Cr, 18-20; Ni, 8-10; C, 0.07 max.	Fair		Castings	Room	R	R 0.2	0.7					Room	R										Room	R	R	R	R	R	Room	R	R	R	R	Room	R		Fair	Poor	44
45	CF-10 Stainless Steel, cast		Fe; Cr, 18-20; Ni, 8-10; C, 0.10 max.	Fair		Castings	Room	R ²	R ²	R ²					Room	R	R									Room	R ²	R ²	R ²	R ²	R ²	Room	R	R	R	R	Room	R		Fair	Fair	45
46	CF-16 Stainless Steel, cast		Fe; Cr, 18-20; Ni, 8-10; C, 0.16 max.	Good	B, F, R, W	Castings	Room	R	R	R					Room	R	R									Room	R	R	R	R	R	Room	R	R	R	R	Room	R		Fair	Fair	46
47	CF-20 Stainless Steel, cast		Fe; Cr, 18-20; Ni, 8-10; C, 0.20 max.	Fair		Castings									Room	R	R	R	R	R						Room	R	R	R	R	R	Room	R	R	R	R	Room	R		Fair	Poor	47
48	CF-7Se Stainless Steel, cast		Fe; Cr, 18-20; Ni, 8-10; C, 0.07 max.; Se, 0.20-0.35			Castings																																			48	
49	CF-7C Stainless Steel, cast		Fe; Cr, 18-20; Ni, 8-10; C, 0.07 max.; Cb, 10XC		R, W	Castings	Room	R	R						Room	R	R	R	R	R						Room	R	R	R	R	R	Room	R	R	R	R	Room	R		Fair	Fair	49
50	CF-7M Stainless Steel, cast		Fe; Cr, 18-20; Ni, 8-10; C, 0.07 max.; Mo, 2.5-3.5	Fair		Castings	Room	R	R .002	R .003		R			Room	R	R .0007									Room	R	R	R	R	R	Room	R	R	R	R	Room	R		Fair	Poor	50
51	CF-10M Stainless Steel, cast		Fe; Cr, 18-20; Ni, 8-10; C, 0.10 max.; Mo, 2.5-3.5	Poor	B, W	Castings																																		51		
52	CF-16M Stainless Steel, cast		Fe; Cr, 18-20; Ni, 8-10; C, 0.16 max.; Mo, 2.5-3.5			Castings	Room	R	R		R	R	R		Room	R	R	R	R	R						Room	R	R	R	R	R	Room	R	R	R	R	Room	R		Good	Good	52
53	CF-7MC Stainless Steel, cast		Fe; Cr, 18-20; Ni, 8-10; C, 0.07 max.; Mo, 2.5-3.5; Cb, 10XC			Castings																																		53		
54	CG-7 Stainless Steel, cast		Fe; Cr, 20-22; Ni, 10-12; C, 0.07 max.	Poor	F, R, W	Castings	Room	R	R						Room	R	R	R	R	R						Room	R	R	R	R	R	Room	R	R	R	R	Room	R				54
55	CG-10 Stainless Steel, cast		Fe; Cr, 20-22; Ni, 10-12; C, 0.10 max.	Good	B, F, R, W	Castings	Room	R	R						Room	R	R	R	R	R						Room	R	R	R	R	R	Room	R	R	R	R	Room	R		Fair	Fair	55
56	CG-16 Stainless Steel, cast		Fe; Cr, 20-22; Ni, 10-12; C, 0.16 max.			Castings																																		56		
57	CG-16Se Stainless Steel, cast		Fe; Cr, 20-22; Ni, 10-12; C, 0.16 max.; Se, 0.20-0.35			Castings																																			57	
58	CG-7C Stainless Steel, cast		Fe; Cr, 20-22; Ni, 10-12; C, 0.07 max.; Cb, 10XC	Good	F, R, W	Castings	Room	R	R						Room	R	R	R	R	R						Room	R	R	R	R	R	Room	R	R	R	R	Room	R		Fair	Fair	58
59	CG-7M Stainless Steel, cast		Fe; Cr, 20-22; Ni, 10-12; C, 0.07 max.; Mo, 2.5-3.5			Castings																																		59		
60	CG-10M Stainless Steel, cast		Fe; Cr, 20-22; Ni, 10-12; C, 0.10 max.; Mo, 2.5-3.5	Good	B, F, R, W	Castings	Room	R	R	R	R	R	R		Room	R	R	R	R	R						Room	R	R	R	R	R	Room	R	R	R	R	Room	R		Fair	Fair	60
61	CG-16M Stainless Steel, cast		Fe; Cr, 20-22; Ni, 10-12; C, 0.16 max.; Mo, 2.5-3.5		R, W	Castings	Room	R	R		R	R	R		Room	R	R	R	R	R						Room	R	R	R	R	R	Room	R	R	R	R	Room	R		Fair	Fair	61
62	CG-7MC Stainless Steel, cast		Fe; Cr, 20-22; Ni, 10-12; C, 0.07 max.; Mo, 2.5-3.5; Cb, 10XC			Castings																																		62		
63	CH-10 Stainless Steel, cast		Fe; Cr, 23-26; Ni, 10-12; C, 0.10 max.		R, W	Castings	Room	R	R						Room	R	R	R	R	R						Room	R	R	R	R	R	Room	R	R	R	R	Room	R				63
64	CH-20 Stainless Steel, cast		Fe; Cr, 23-26; Ni, 10-12; C, 0.20 max.	Fair		B, C	Room	R	R .0025	R .005					Room	R	.06									Room	R	R	R	R	R	Room	R	R	R	R	Room	R		Good	Fair	64
65	CH-10C Stainless Steel, cast		Fe; Cr, 23-26; Ni, 10-12; C, 0.10 max.; Cb, 10XC			Castings																																		65		
66	CH-10M Stainless Steel, cast		Fe; Cr, 23-26; Ni, 10-12; C, 0.10 max.; Mo, 2.5-3.5	Fair	W	Castings	Room	R	R <.004	R <.004	R <.004	R <.004	R <.004	R <.004	Room	R	R	R	R	R						Room	R	R	R	R	R	Room	R	R	R	R	Room	R		Fair	Good	66
67	CH-20M Stainless Steel, cast		Fe; Cr, 23-26; Ni, 10-12; C, 0.20 max.; Mo, 2.5-3.5	Fair		B, C	Room	R	R .0001	R .001	R .001	R			Room	R	R .0001	R	R	R						Room	R	R	R	R	R	Room	R	R	R	R	Room	R		Good	Fair	67
68	CH-10MC Stainless Steel, cast		Fe; Cr, 23-26; Ni, 10-12; C, 0.10 max.; Mo, 2.5-3.5; Cb, 10XC			Castings																																		68		
69	CK-25 Stainless Steel, cast		Fe; Cr, 23-26; Ni, 19-21; C, 0.25 max.		R, W	Castings	Room	R	R						Room	R	R	R	R	R						Room	R	R	R	R	R	Room	R	R	R	R	Room	R		Fair	Fair	69
70	CM-25 Stainless Steel, cast		Fe; Cr, 8-11; Ni, 19-21; C, 0.25 max.			Castings																																		70		
71	HB Stainless Steel, cast		Fe; Cr, 18-22; Ni, 2 max.			Castings																																		71		
72	HC Stainless Steel, cast		Fe; Cr, 27-30; Ni, 3 max.	Fair		Castings									Room	R	R	R	R	R						Room	R													Good	Good	72
73	HD Stainless Steel, cast		Fe; Cr, 27-30; Ni, 3-6			Castings									Room	R	R	R	R	R						Room	R	R	R	R	R	Room	R	R	R	R	Room	R				73
74	HE Stainless Steel, cast		Fe; Cr, 27-30; Ni, 8-11			Castings																																		74		
75	HH Stainless Steel, cast		Fe; Cr, 27-27; Ni, 10-13	Fair		Castings									Room	R	R	R	R	R						Room	R	R	R	R	R	Room	R	R	R	R	Room	R		Good	Fair	75
76	HK Stainless Steel, cast	Fe; Cr, 23-26; Ni, 19-21	Good	W	Castings																																		Good	Poor	76	
77	HL Stainless Steel, cast	Fe; Cr, 28-32; Ni, 19-21			Castings																																		77			
78	HP Stainless Steel, cast	Fe; Cr, 28-32; Ni, 29-31			Castings																																		78			
79	HS Stainless Steel, cast	Fe; Cr, 8-12; Ni, 29-32			Castings																																		79			
80	HT Stainless Steel, cast	Fe; Cr, 13-17; Ni, 34-37	Good		Castings																																		Good	Fair	80	
81	HU Stainless Steel, cast	Fe; Cr, 17-21; Ni, 37-40	Good	W	Castings																																			Good	Good	81
82	HW Stainless Steel, cast	Fe; Cr, 10-14; Ni, 59-62	Good		Castings	Room	R	R	R	R	R	R		Room	R	R	R	R	R						Room</																	

Post-War Industry in the Making



Hidden away in one corner of one of the huge works of the Commercial Solvents Corporation is this interesting unit for the vapor-phase nitration of paraffin hydrocarbons

SIDNEY D. KIRKPATRICK *Editor, Chemical & Metallurgical Engineering*

Chem. & Met. INTERPRETATION

Corrosion-resistant metals and alloys have made possible the successful commercial development of the vapor-phase process for the nitration of petroleum hydrocarbons, thereby producing basic raw materials for future chemical industries. The nitroparaffins and their derivatives are already demonstrating their usefulness in a wide range of chemical and process applications. This article is the first to describe their production in the new model plant at Peoria, Ill., and to show by typical flowsheets how chemical engineers are using these versatile materials to produce many valuable derivatives. Other equally important applications await exploration.—*Editors.*

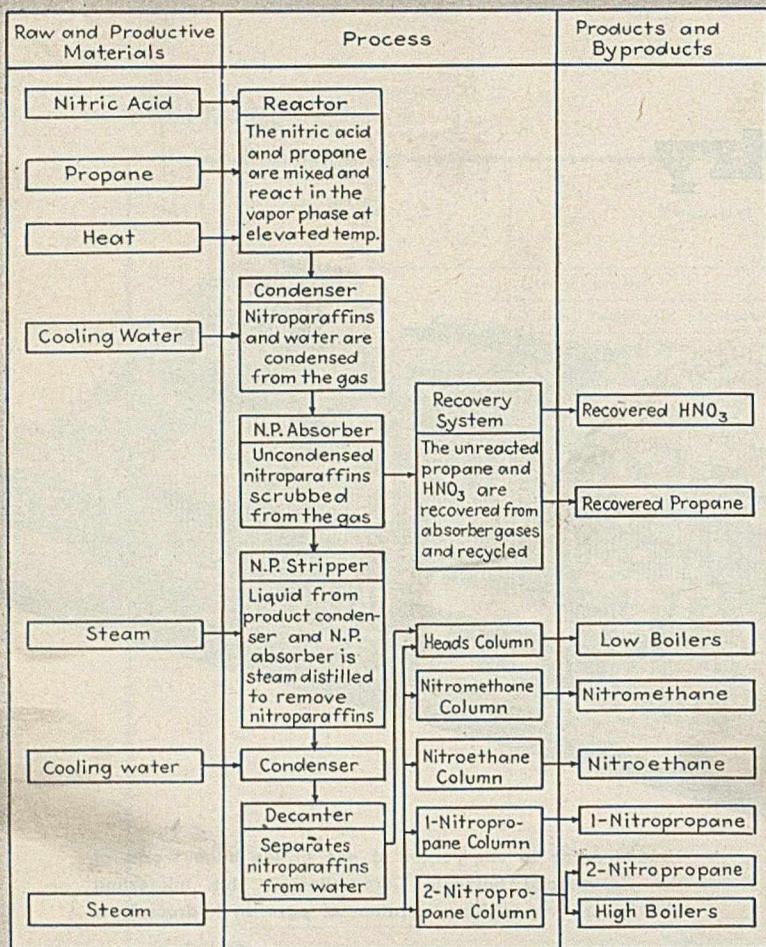
A NEW FAMILY of organic chemicals is making its bid for industrial recognition. A few years ago they were regarded as laboratory curiosities—new playthings for the research chemists and molecule jugglers. Today the nitroparaffins are being shipped in tank cars to serve as the basic raw materials for new industries. Exploratory research is continuing to develop hundreds of new derivatives and many of these are finding jobs as building stones in present and post-war projects. Thus the whole development is following

the familiar pattern of industrial growth as an entirely new field of organic chemistry widens its circles of usefulness and influence.

How many of us realize, however, that the nitroparaffin industry itself would scarcely have been possible had it not been for the modern corrosion- and heat-resistant materials available for plant and equipment construction? A new process of vapor-phase nitration required the handling of nitric acid at temperatures far above its boiling point—a field in which there was practically

no experience on which to draw. The problem was further complicated by the reaction products that behaved badly at high temperatures. Fortunately in the period directly after the first World War we had learned a lot in this country about the use of high chromium iron and the chromium-nickel steels. It was this knowledge, increased by costly research and experimentation, that made possible the construction of the first commercial plant in the world to produce the nitroparaffins by vapor phase nitration. It has been in commercial operation since April, 1940. At present it produces the four best known of the NP's—nitromethane, nitroethane, 1-nitropropane and 2-nitropropane—as well as approximately 20 of their important derivatives.

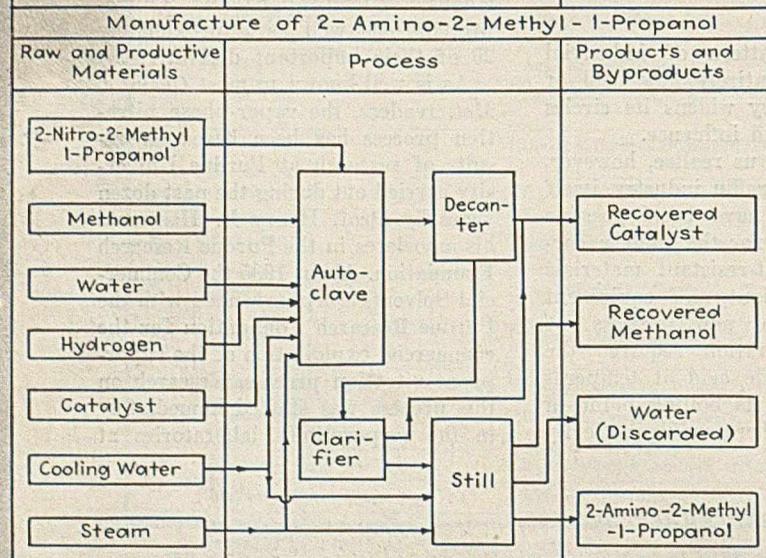
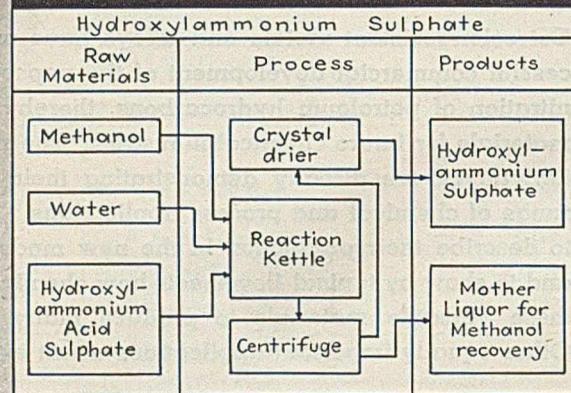
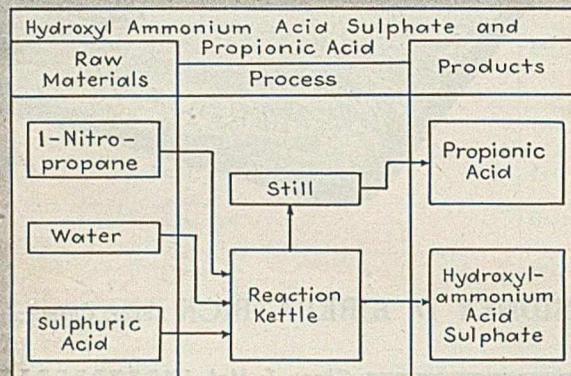
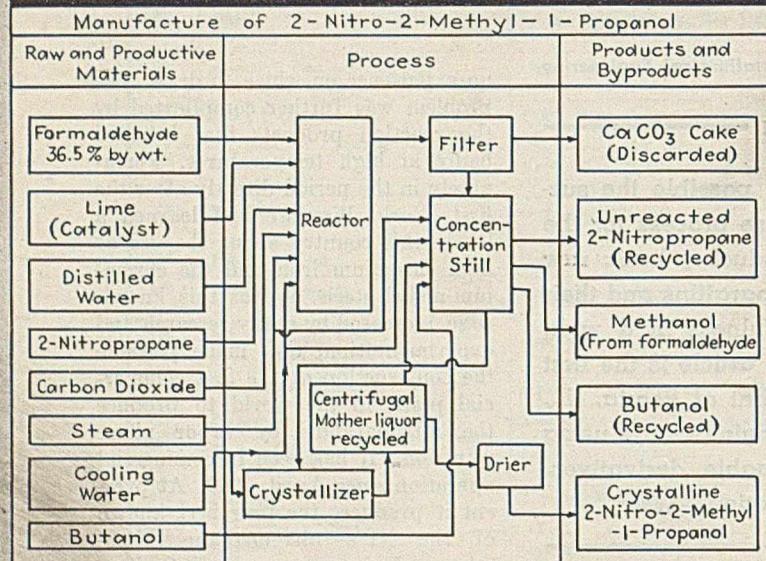
As is well known to most *Chem. & Met.* readers, the vapor-phase nitration process has been based on results of research at Purdue University carried out during the past dozen years by Prof. Henry B. Hass and his associates in the Purdue Research Foundation. About 1935 the Commercial Solvents Corp. arranged with the Purdue Research Foundation for the commercial exploitation of the vapor-phase nitration process. Research on this process was started immediately in the corporation's laboratories at



Terre Haute, Ind., and at the same time various fellowships were established at Purdue University, principally to work on the derivatives of the nitroparaffins.

By 1937 the project was ready for its first pilot plant, which was set up in Terre Haute. Experience thus obtained led to the design and construction during 1939 of the first commercial plant at Peoria, Ill. It was built by E. B. Badger & Sons of Boston as a self-contained unit, dependent only upon the general plant for steam, water, electricity and sewer facilities.¹

Construction was unusually costly due, as previously mentioned, to the large amount of expensive alloys that



were required to resist the severely corrosive conditions. As is so often the case, laboratory corrosion tests were not generally applicable to plant conditions. Hence it was necessary to carry on considerable experimentation in the construction of the pilot plant. To get the benefit of as much experience as possible from the metal suppliers, the stainless steels and other alloys were purchased from a

¹A much larger plant is on the drafting boards for post-war construction. S.D.K.

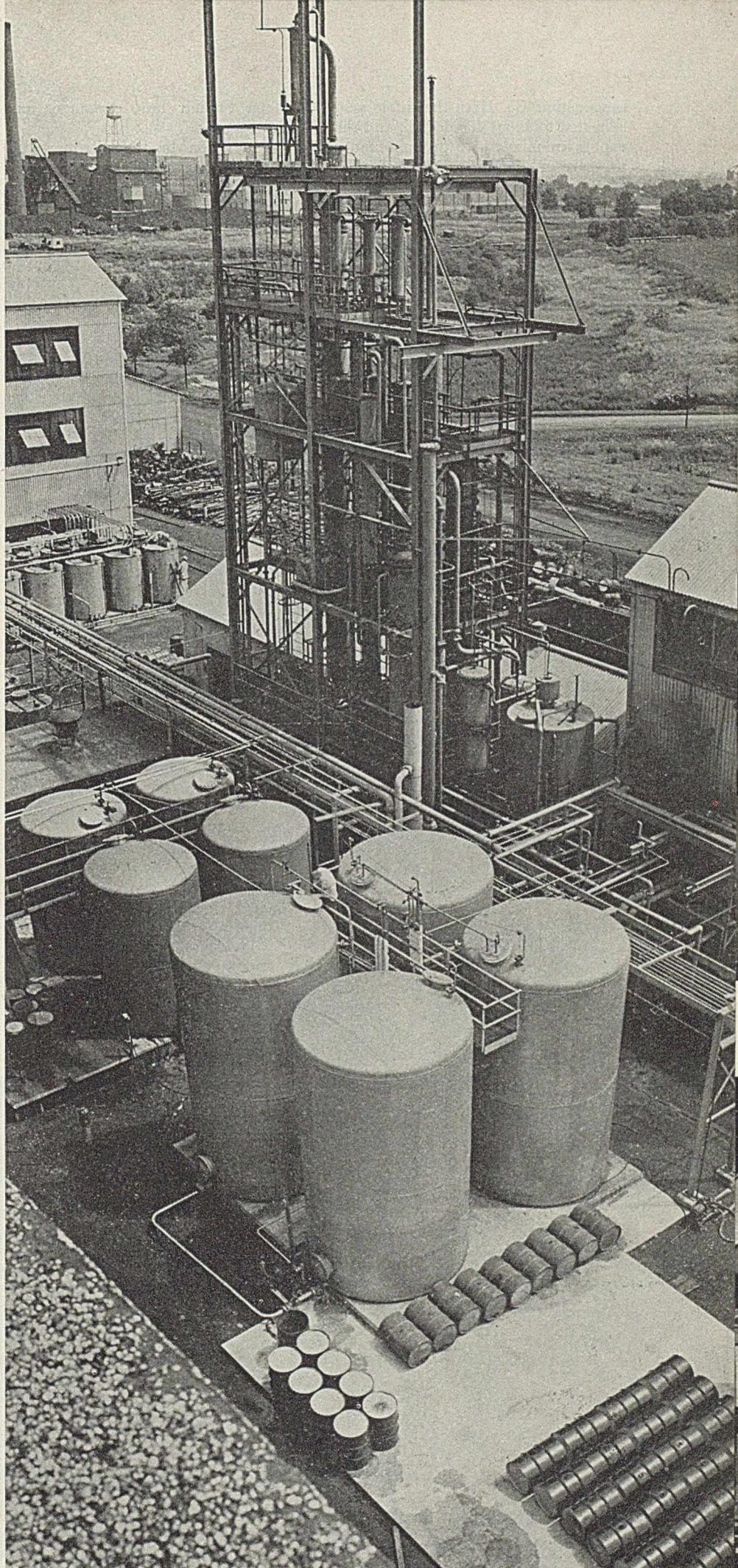
number of different manufacturers. All were given an opportunity to test out their products and to bid for part of the business. This process of splitting up the contract proved to have both advantages and disadvantages. It helped the corporation's engineers as well as the suppliers to evaluate the materials under conditions of actual service. In a few cases, however, inexperienced concerns found it necessary to replace their products and costly delays resulted. No single alloy was found to be outstanding for all applications. Some large pieces of equipment made of alloys that satisfactorily handled hot vapors were seriously damaged by superheated nitric acid in liquid phase. In other instances the reverse happened. Gradually, however, the corrosion problems that appeared to present almost insurmountable difficulties have been overcome.

Long-range corrosion studies are still being conducted in the Peoria installation. It is not uncommon to find different sections of various columns composed of different alloy steels. Likewise, performance studies are being made in nearly every place where spare pieces of equipment have been installed or where duplicate units can be used for the same purpose. Thus the equipment as well as the materials of different manufacturers are being studied.

The process used at Peoria for the commercial production of the nitro-paraffins consists of three steps or stages: (1) The high-temperature nitration of propane in vapor phase; (2) separation of reaction products and recovery of unreacted materials for recycling and (3) fractional distillation and purification of the nitro-paraffins. Thus it will be seen that the two principal raw materials are propane and nitric acid. Both are received at the plant in tank cars, the former coming from a mid-continent petroleum refiner and the acid from a nearby chemical manufacturer. Chrome-iron tanks are used for the storage of the nitric acid, which is pumped to process in Labour centrifugal pumps, also of chrome iron.

The nitration unit itself, or reactor, as it is called, is housed between reinforced masonry walls and consists of a gas-fired, refractory-lined furnace built by the Surface

Aluminum storage tanks, stainless steel fractionating towers and piping, asbestos-cement buildings—help the chemical engineer to solve corrosion problems involved in nitroparaffin manufacture



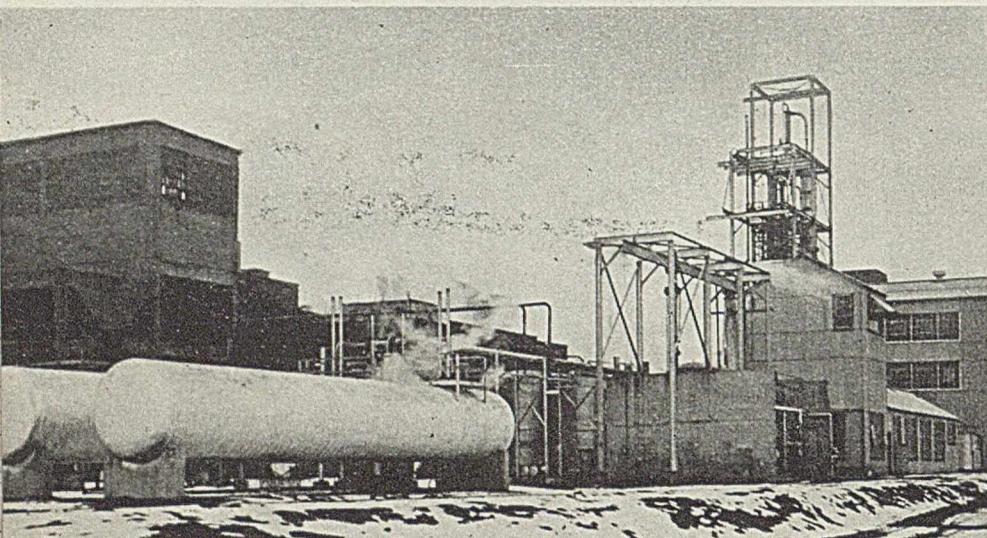
Combustion Co. Here the nitric acid is heated to about 400 deg. C. and the vapors are mixed with propane under pressure of about 150 psi. The highly exothermic reaction takes place instantly and unless the products of the reaction are rapidly cooled, there is a progressive oxidation of the hydrocarbons to CO and CO₂. This cooling is accomplished with water in

a long tubular heat exchanger and condenser.

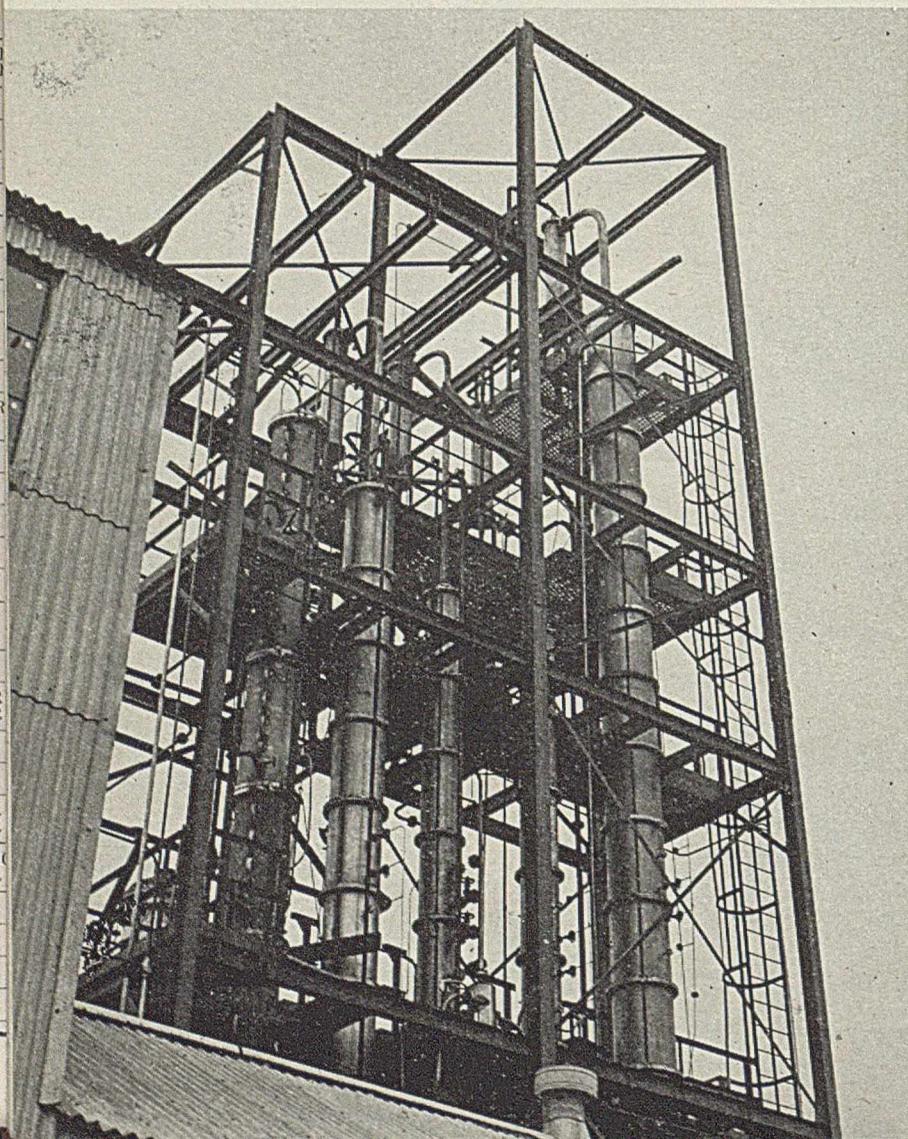
In addition to the nitroparaffins the condensate contains water introduced with the nitric acid and that formed by the reaction. Nitroparaffins still remaining in the gas are removed by counter-current scrubbing operations, after which the crude NP's are recovered from the

scrub liquor and condensate by steam distillation. The crude nitroparaffins are decanted from the condensed steam and separated into the individual components by continuous vacuum distillation and fractionation. As will be noted from the accompanying flow diagram (Fig. 1), there are six fractions—the four commercial NP's—nitromethane, nitroethane, 1-nitropropane and 2-nitropropane—and the low and high boiling fractions. Nitration gases from the condenser and nitroparaffin absorber contain unreacted propane and oxides of nitrogen which are recovered and recycled.

Successful operation of a continuous vapor-phase nitration plant requires the maintenance of uniform temperatures, pressures and flows throughout the system. The nitration process, the product condensation and recovery, the distillation of the crude paraffins and the recovery and



Chrome-steel tanks for nitric-acid storage in foreground. Notice also concrete barriers shielding the gas-fired furnace in which the nitration is effected



Open-type construction made possible by use of corrosion-resistant materials

recycling of the unconsumed reactants must all operate steadily and in constant balance with one another. This can only be accomplished by complete instrumentation and maximum use of automatic control. Some idea of the magnitude of the control problem and the number and variety of the instruments needed can be gathered from the fact that the control panel for the Peoria plant is nearly 50 ft. long and contains 30 recording and controlling instruments and over 50 indicating devices, in addition to the numerous automatic controls that make it possible for two men per shift to operate the entire plant.

Before describing the adjoining plant for the production of derivatives, it may be of interest to list some of the many rapidly increasing uses for the nitroparaffins themselves. We naturally think of them first as solvents for they have much in their favor in this field. They are medium-boiling, mildly odored and have strong dissolving power for many difficultly soluble materials. For example, the nitropropanes will dissolve hundred of waxes, natural resins and gums, tars and pitches, coating materials, oils, fats, dyes and

organic chemicals. Sometimes the solubility is increased ("activated") by the presence of alcohol. As solvents for cellulose acetate, they have certain advantages over low-boiling materials that cause poor flow or "blushing" of lacquers and over the high-boiling, slowly-evaporating solvents that delay the final hardening of the film. The nitroparaffins are among the most powerful solvents known for vinyl acetate-vinyl chloride polymers and can be advantageously used with the higher ketones in most vinyl resin-solutions.

Immediately adjoining the NP plant is the large three-story building in which many of the more important chemical derivatives are now being manufactured. As will be noted from the accompanying illustrations, the equipment in this plant is that of a thoroughly modern factory for the production of fine chemicals. At present approximately 20 derivatives are being made at Peoria but the plant has been equipped to provide extreme flexibility in all of its operations.

Typical of the amino-hydroxy derivatives, of which five are now produced, is the manufacture of 2-nitro-2-methyl-1-propanol shown in the accompanying flow diagram (2).

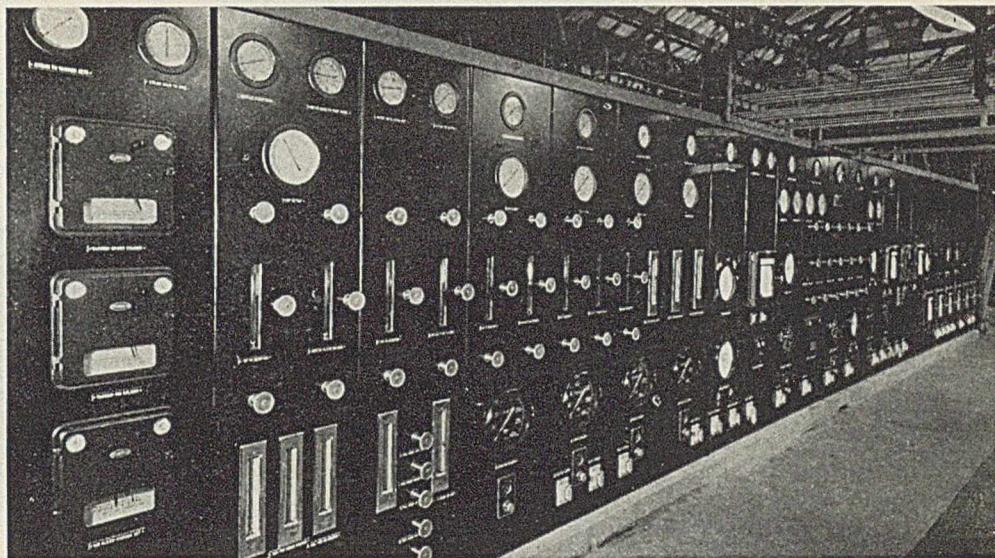
Typical of the amino-hydroxy derivatives, of which five are now produced at Peoria, is the manufacture of 2-amino-2-methyl-1-propanol shown in Fig. 3. This is one of the most versatile of the emulsifying agents available today for the preparation of water dispersions of fats, oils, waxes and resins. Cosmetic creams and lotions made from this

product are said to show exceptionally high stability in respect to color and consistency. Comparable advantages are claimed for automobile cleaner-polishes, shoe and leather dressings, mineral oil emulsions and other textile finishing compounds. The amino-hydroxy derivatives also readily undergo a variety of chemical reactions and are therefore widely used in synthesis.

One of the simplest of chemical compounds—in the borderland between the organic and inorganic kingdoms—is hydroxylamine, NH_2OH . It has been known for many years as a useful, active reagent for chemical synthesis but its application has been restricted because of its high price and limited availability. Now, however, it can be readily made in the form of its salts merely by the

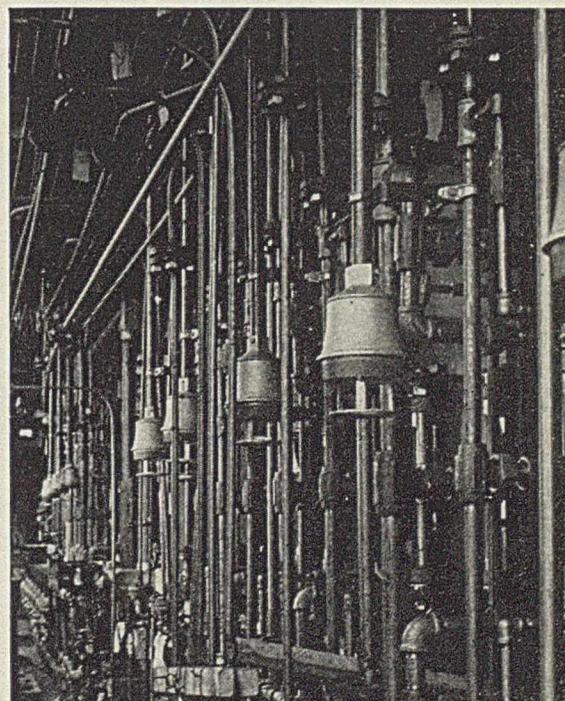
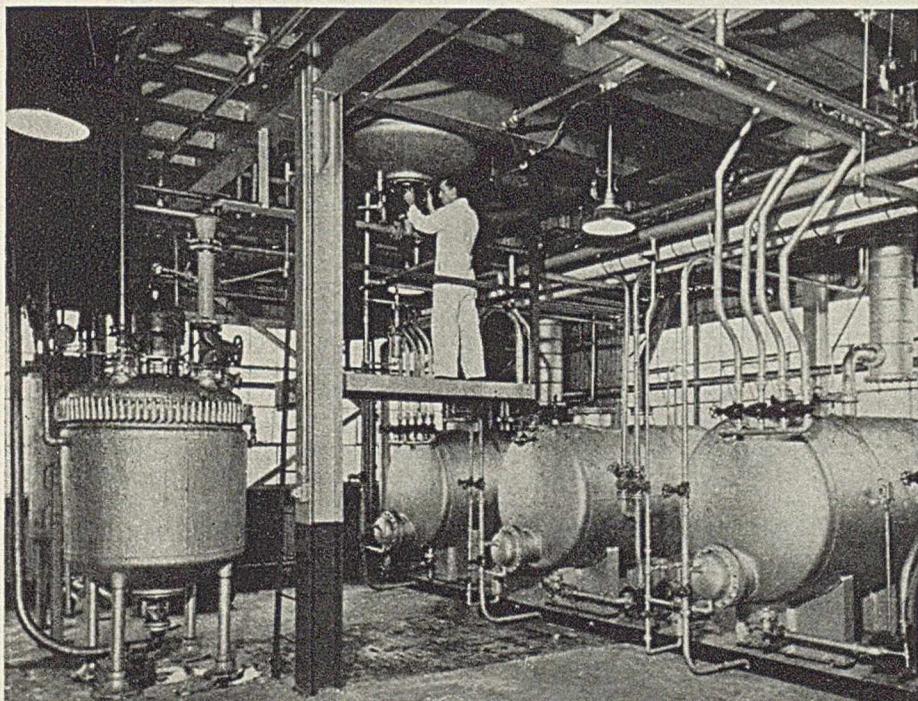
hydration of nitropropane in the presence of an acid (See Fig. 4). The cheapest of these salts now available is hydroxyl ammonium acid sulphate. This is an economical base for the synthesis of dyestuffs, pharmaceuticals, resins, flotation agents and many other organic chemicals. In reactions where high purity is of importance, hydroxyl ammonium sulphate, produced by reaction with methanol (See Fig. 5) is recommended.

These are only a very few of many derivatives of the NP's that are being made at Peoria or in the Terre Haute plant of Commercial Solvents. They will doubtless suggest some of the other processes and applications which are daily extending these products into ever wider fields of usefulness.



Above—Control panel almost 50 ft. long, with 30 controlling devices and over 50 indicating devices

Below—This maze of piping is required to maintain uniform temperature, pressure and flow of materials



Below—Many new nitroparaffin derivatives are made in this model chemical plant

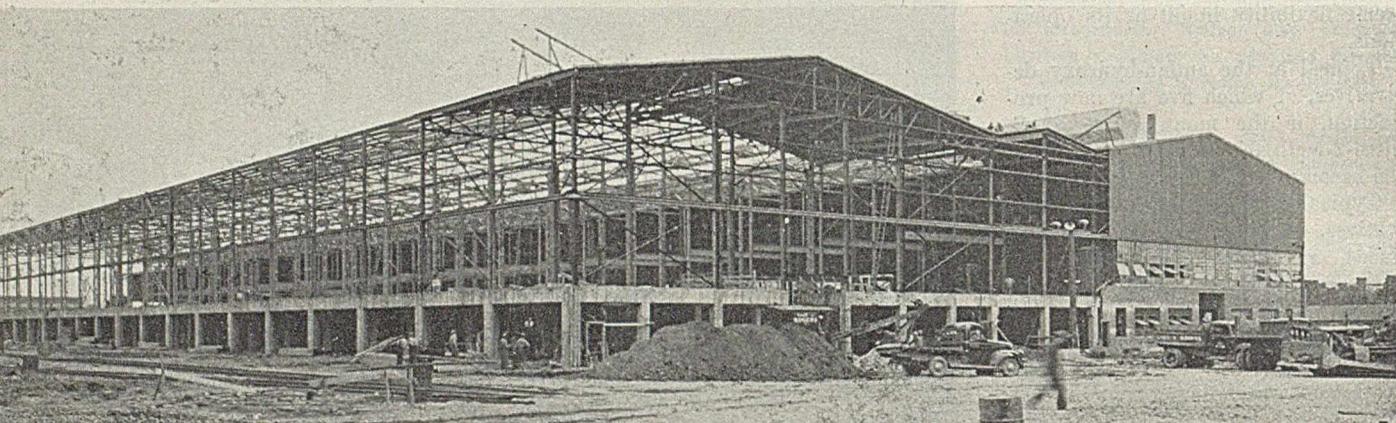
FORD Makes Magnesium

GERALD ELDRIDGE STEDMAN *Webster Hall, Detroit, Mich.*

Chem. & Met. INTERPRETATION

"Somewhere in Michigan" another plant gets under way for the commercial production of the silvery white metal that means so much to our war effort. Behind this development lies the keen personal interest of Mr. Henry Ford, who was among the first to put the new light alloys of magnesium to practical application on a large scale. Behind it also lies the genius and resources of the chemical and metallurgical laboratories of the Ford Motor Co., which accepted the government's challenge to build and operate a plant using the ferro-silicon process recently described in these pages. Within the limits of voluntary censorship, Mr. Stedman tells a story in this article that spells additional trouble for our enemies.—Editors.

Mr. Henry Ford traces his early interest in magnesium to his great friendship for the late Dr. Herbert H. Dow. Many years ago he bought the first automobile trailer to be made of Downmetal. This was finally evolved into a fleet of chassis-less semi-trailers, each weighing 5,700 lb., yet capable of carrying three good-sized automobiles. This same interest in magnesium led ultimately, under the challenge of the Victory Program, to the building and operating of Ford's own foundry for molding magnesium alloy castings. A magneto adapter for aircraft engines was poured on Jan. 14, 1941, as the first magnesium



Under the sheltered section of this building, the first furnace was producing magnesium while roof sections and steel framework were being put in place for the rest of the building. Less than six months after the first construction work began, the first section of the building was virtually completed and workmen were pushing construction of the second

HIGHLIGHTING the importance of aircraft in warfare, the "little World War" stimulated interest in the light alloys. Germany, in particular, went about expanding its capacity for magnesium production. The I. G. Farbenindustrie, A.G., and the Wintershall potash group, who together provide the entire German output, had done so well by 1938 that further extension of productive capacity was prohibited by law. Methods of production varied, but both groups depended primarily upon the electrolysis of fused magnesium chloride obtained either in the waste liquors of the Stassfurt potash industry, or from selected carnallite ores. Japan, too, began to imitate its Axis partner in 1932, when its production

was only 24 tons, but by 1938 the Japs were producing 1,200 tons, most of it by the Nichiman company at its Ube plant in Yamaguchi Prefecture, again using the electrolytic process on magnesium chloride recovered from brines or obtained by chlorinating calcined magnesite.

Our own magnesium industry, as previously reported in *Chem. & Met.* (Nov. 1941, p. 76-85) was started in 1915 by several producers, but since 1927 the major commercial output has come from the Dow Chemical Co. of Midland, Mich. The government has reported that production in 1940 had reached 6,250 tons, and even before Pearl Harbor plans were announced for multiplying this output by fifty fold.

casting of that now mammoth plant. Sad day for Hitler.

Meanwhile, the Ford chemical and metallurgical laboratories continued to explore all phases of magnesium production, as well as its application. As the government magnesium program developed, it had become evident that other magnesium production processes would be needed to furnish quick and certain production with a minimum use of power and critical chlorine. A special committee of the National Academy of Sciences was formed to hunt for other meritorious processes. Its conclusion was that the ferro-silicon process, which had been developed in the Canadian National Research Laboratory (see *Chem. & Met.*, April, 1942, p. 87)

would give the best results with the minimum time-cost risk.

On Dec. 24, 1941, the N.A.S. Magnesium Committee, headed by Dr. Zay Jeffries of the General Electric Co., and Dr. Howard W. Russell, of Battelle Memorial Institute, visited the Ford Motor Co. to find out what it would do about producing magnesium in quantities. Although the work of his own engineers had pointed toward the further development of a carbo-thermic process as the most promising and economic, Mr. Ford agreed to accept the committee's recommendation that the ferro-silicon process should be used. His only desire was to do what the government wanted done to meet its war needs.

Within a week after the N.A.S. Committee's visit, special iron castings were made to serve as a retort and experimental production of magnesium was started by the ferro-silicon process. This convinced Ford engineers that the metal could be produced on a full production basis, and within three days after the letter of intent of the Defense Plant Corp. was received (Jan. 13, 1942) pile drivers were operating on a new plant site. Having no pattern to study in the United States or Canada, Ford engineers originated their own plan and copying the tar-paper cocoon shelter from the Airplane Engine Plant, contractors started to pour cement on January 27, just

First magnesium casting made in Ford foundry Jan. 14, 1941 was this magneto adapter for an airplane engine

Experimental production of magnesium was being conducted in a pilot furnace while construction of the magnesium plant was under way. Retorts of different alloys and various sizes were tested to find a retort that would produce magnesium most efficiently and economically. Water coolers were used at first to condense the metal vapor, but later tests proved air cooling was just as efficient

about a month after the initial approach by the N.A.S. Committee.

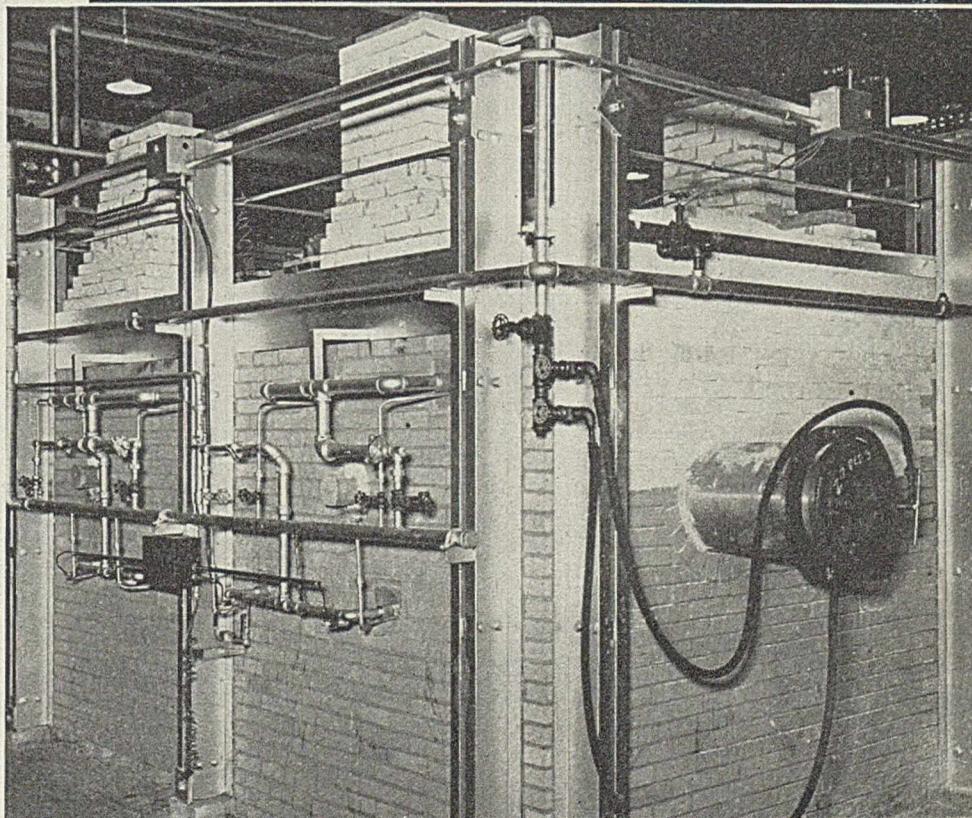
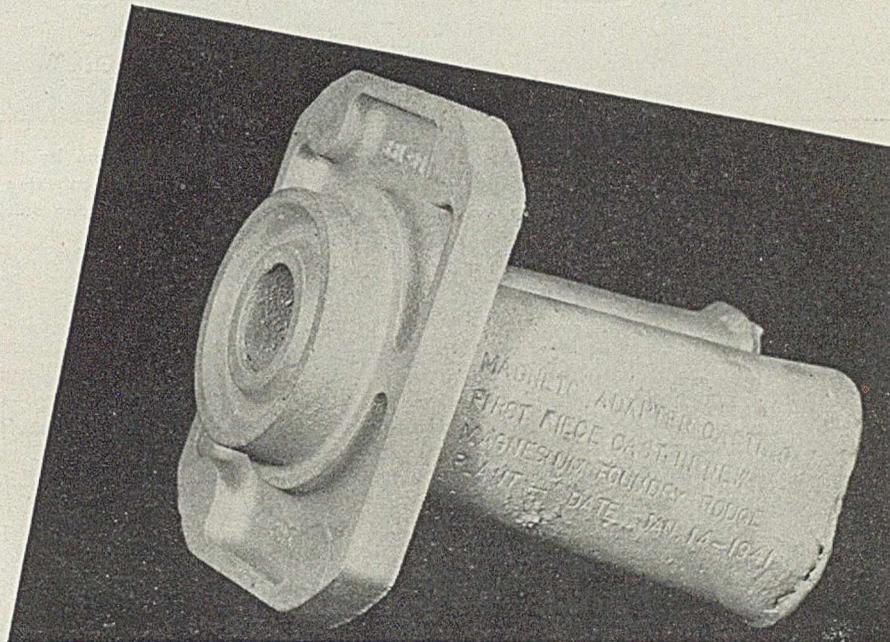
In the Spring of 1942, gas fires were lighted in the first furnace and magnesium was first produced on a commercial basis shortly afterward, less than two months after the first furnace brick were laid. Meanwhile, workmen were pushing construction on the next section of furnaces, and the smelter began its round-the-clock schedule to the Victory effort.

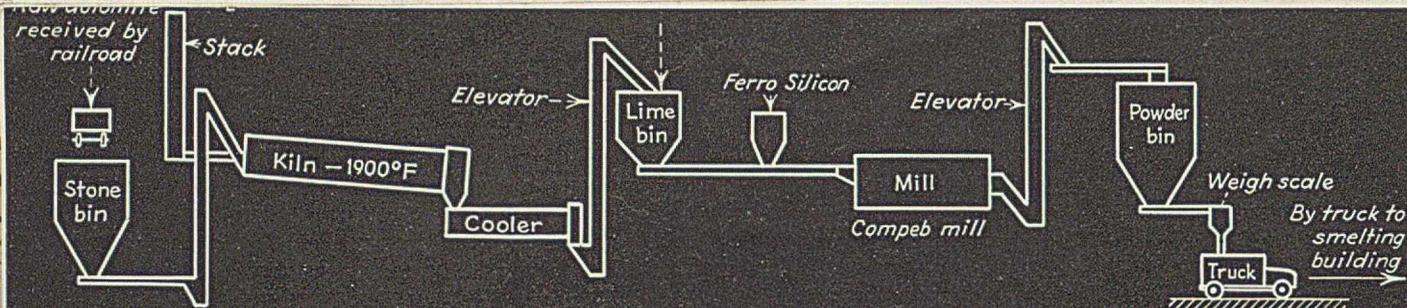
While construction tempo was proceeding, retorts of varying alloys and sizes were tested in a pilot furnace to determine the most efficient mass production set-up. A 20-in. diameter was first tried, but the time required to raise the tube to the proper temperature was too long. Other diameters from 6 in. to 20 in. were experimented with and more than a thousand different runs were concluded to find the most economical methods. Eventually a retort of 22 ft. in length, with 10-in. i.d., made from chrome-nickel steel, proved most satisfactory.

The ferro-silicon process of producing magnesium metal is relatively simple—at least in outline.

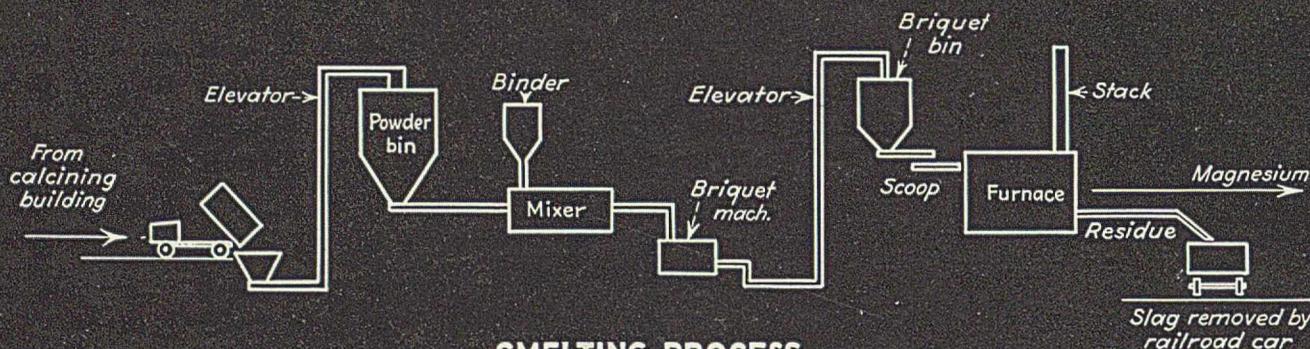
Dolomite, the naturally occurring calcium-magnesium carbonate, is one of the most abundant of our limestones, with deposits widely scattered throughout the United States. Ferro-silicon, of course, is made in the electric furnace from silica, iron and carbon. The combination of the dolomite and ferro-silicon, properly proportioned in a vacuum at a high temperature causes the magnesium to be driven off as a vapor. Coming into contact with a cool surface, this condenses while the iron rides along on the coat-tails of the silicon.

The production flow at the Ford plant proceeds in two stages—calcining and smelting, as shown in the accompanying sketch. From the





CALCINING PROCESS



SMELTING PROCESS

Flowsheet for the production of magnesium from dolomitic limestone by the ferro-silicon process as used by Ford Motor Co. A former cement plant is used for calcining the Michigan dolomite. Half the weight of the stone is removed as CO_2 during calcining

Michigan quarries, dolomitic limestone is brought to a former cement plant to be dehydrated, powdered and calcined. The burning process removes approximately 50 percent of the weight of the raw stone in the form of carbon dioxide.

The calcined dolomite and pre-crushed ferro-silicon are proportioned into large compartment ball mills which have the dual function of powdering and mixing both materials. They further compact the mixture so that there is less tendency for segregation during storage.

This dehydrated dolomitic lime and ferro-silicon mixture is stored, transported by trucks to the magnesium smelting plant, where, in the briquetting unit, the dolomitic lime (mixed with 75 percent of ferro-silicon in a ratio of slightly less than 6-to-1) is compressed into handy shape. The finished briquettes are then ready for the smelter.

Ford's experience in briquetting glass batches was helpful in the production of such enormous quantities of briquettes. The nature of the material caused special design of auxiliary equipment and presses were developed as rolls with briquette-mold recesses in them, the charge being formed into briquettes at the bite of the rolls.

The magnesium smelting furnaces

are arranged in a number of rows. Each furnace is 19 ft. high, 16 ft. wide, and 18 ft. long. Through the middle of each runs two tiers of Nichrome pipe, 11 to each furnace, banked six on the bottom row, and five on the top. These are the retorts. They are 22 ft. long, 13 ft. of which is in the heat zone, and 31 in. of which projects from each end of the furnace. Furnaces are designed to use either 10- or 12-in. i.d. retorts. These are supported inside the furnace by refractory brick arches. Split steel sleeves fit inside each retort on the ends projecting from the furnace. It is on these that the magnesium condenses and crystallizes.

Smelting must be carried out in a high vacuum. This is accomplished by manifolding each retort into a vacuum pump. A 1.5-in. pipe leads from each retort and into one of four furnace manifolds, which, in turn, lead to the floor beneath each furnace where they connect with four vacuum pumps each driven by a 5-hp. electric motor. These pumps, rated at 100 cu.ft. of air per min., remove the air from the retorts. Metal caps placed over the retort ends facilitate in maintaining the high vacuum.

The briquettes are preheated above the furnace proper before loading into the retort. Furnace exhaust gases are circulated through this area on

their journey to the chimney, and the briquettes are thus heated. As the retorts open for charging, these preheated briquettes are loaded into the 22-ft. long tubes, the load weight per retort being 350 lb. The end caps are then attached and the vacuum pumps started.

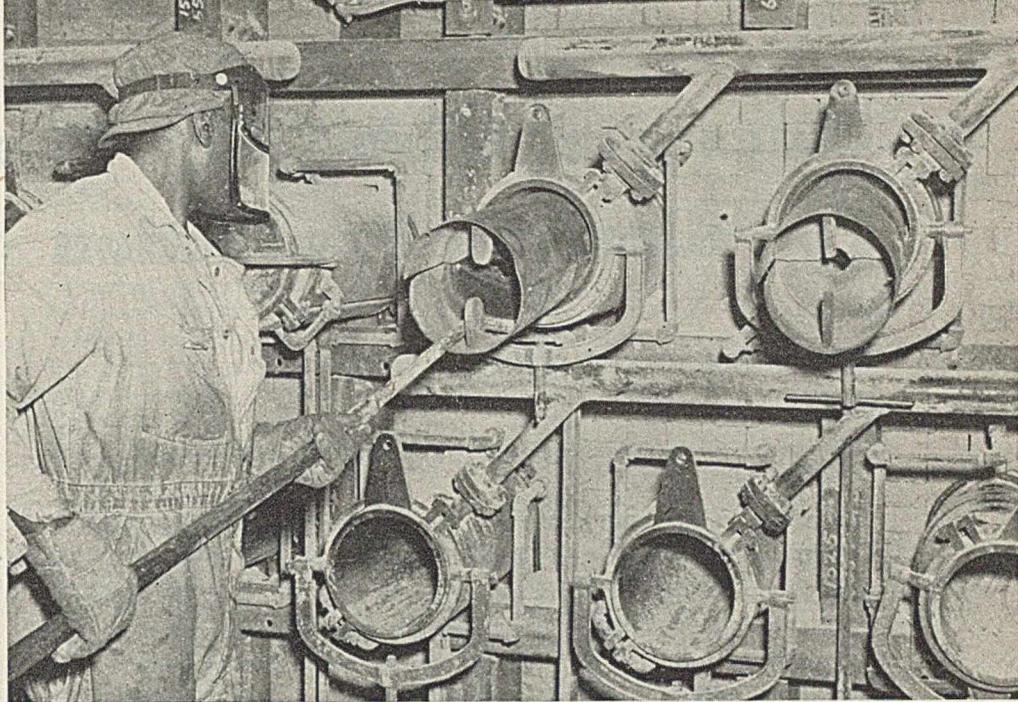
Each furnace is fired by numerous gas jets from each side. They burn purified coke-oven gas and maintain the necessary temperature inside the furnace. This heat, assisted by the vacuum, causes the magnesium to vaporize. An 8-hr. cycle releases the greater proportion of the metal. The vacuum, aside from its necessity in the chemical reaction, tends to draw the magnesium vapors to the ends of the retorts. Here, after some experimenting with water-cooling, it was found that cooler air temperatures at the end-tube portions of the retorts were sufficient to cause the necessary condensation. The metal is deposited on the split iron sleeves lining the extremities of the tubes.

After eight hours of firing, the sleeves, with their magnesium deposits, are withdrawn from the retorts and the crystallized metal removed. Theoretically, 20 percent of briquette weight should be deposited as magnesium. This would represent 70 lb. of metal per charge.

After the magnesium covered

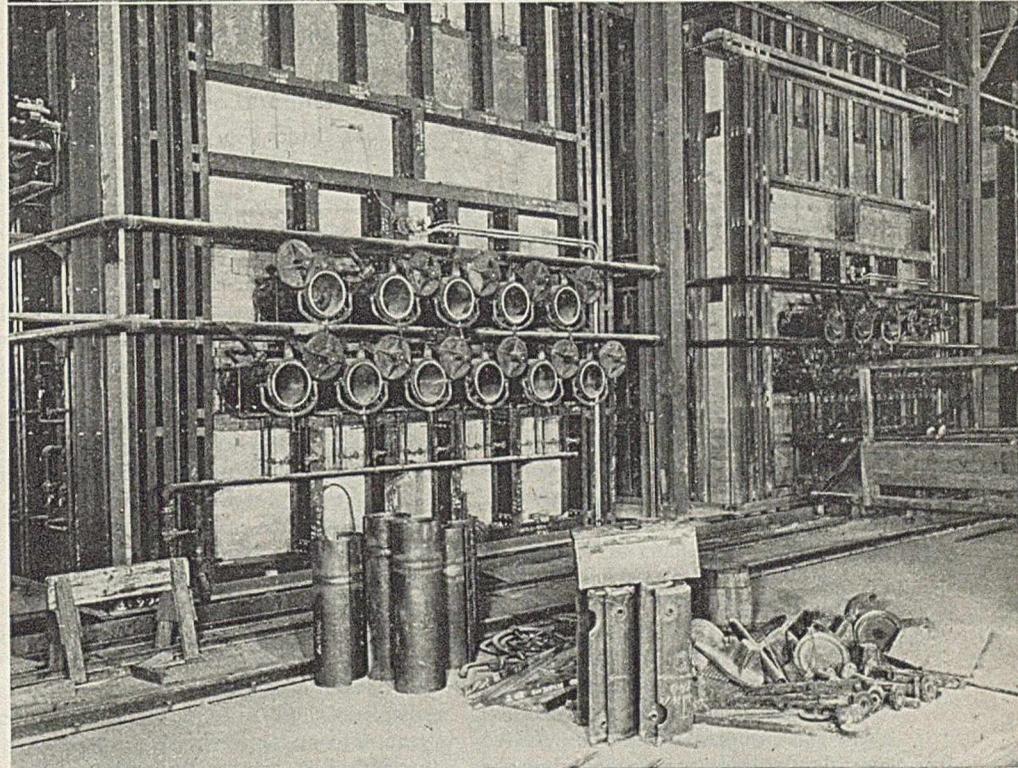
sleeves have been extracted from the retorts, the residue is cleaned out. Because of its high lime content, this could be used for agricultural purposes. Nothing has yet been attempted along this line.

Because of the lack of mechanical equipment, it has been necessary during the first few months of operation to load, tap and clean retorts manually. At first, briquettes were not preheated, but were merely shoveled into a scoop that could be funneled into each retort. Iron sleeves were pulled from tubes by long hooks. Slag was scraped out with long-handled hoes. The mechanization of these tasks is proceeding, and additional daily tonnage per furnace can be expected from such mechanical charging. Censorship prevents disclosure of magnesium smelting production per furnace per day, but it is high, and the furnace operates



Above — Close-up of furnace showing iron sleeves on which the magnesium is deposited

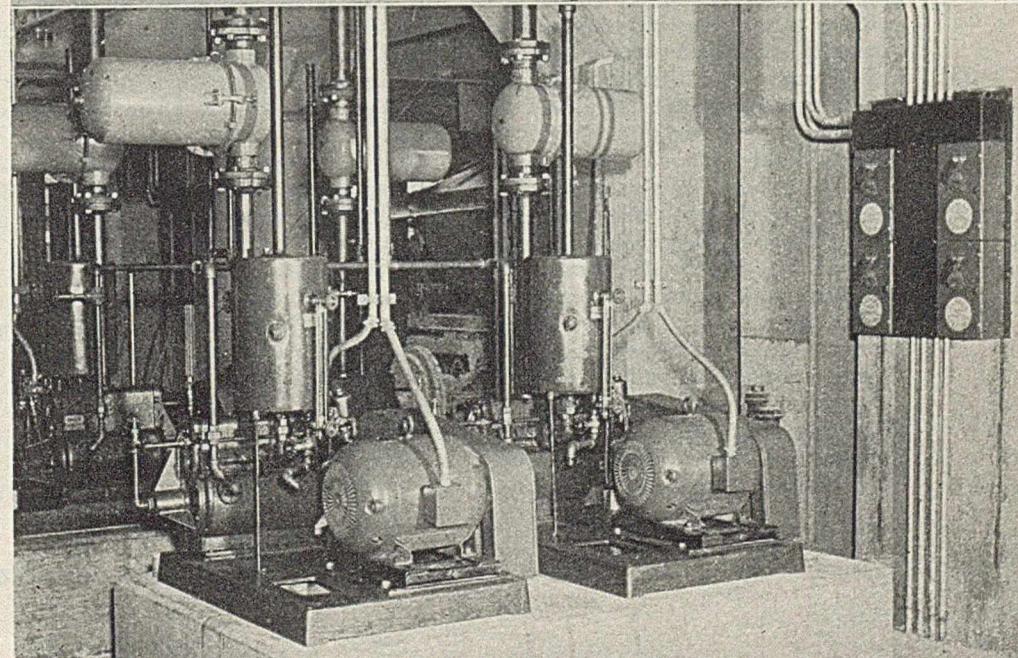
Right — In the smelting of magnesium, briquettes of calcined dolomite and ferro-silicon are charged into long Nichrome retorts. Pure metal is vaporized from the charge and condensed on two-piece iron sleeves lining the ends of the retorts. After eight hours most of the metal is deposited. The sleeves are then withdrawn and the magnesium removed



Below — Four vacuum pumps are required for each furnace. Each is driven by a 5-hp. motor and can remove 100 cu. ft. per min. of air from the retorts

24 hr. each day on eight-hour firing cycles.

This, then, is the story of one of Ford's war achievements, described as closely as censorship permits. The fact that Ford has maintained a mammoth magnesium alloy foundry for better than a year now permits his complete utilization of the advantages of the metal he produces. Ultimately his metallurgists may well develop special alloys of even greater merit than those known. Thus, the completeness of Ford's integrated facilities in producing, casting, machining and fabricating this war metal can give the United States another lifting assurance of ultimate victory. And magnesium is destined to create many revolutions in peacetime mechanical design once its present job is done.



Clays and High-Silica Bauxites For Alumina Production

EDITORIAL STAFF SUMMARY

Chem. & Met. INTERPRETATION

The article below is an abstract of a report prepared by the Advisory Committee on Metals and Minerals at the request of the War Production Board and recently released by the National Academy of Sciences and the National Research Council. The report, signed by Zay Jeffries, reflected the conclusions of the alumina subcommittee, including Francis C. Frary, Oliver C. Ralston, Robert S. Sherwin and John D. Sullivan, and provides an excellent summary of current thinking on the problem of providing sufficient alumina for the war effort without reliance on continued bauxite imports or undue depletion of the known domestic supplies of low-silica bauxite. —Editors.

ABOUT 2 lb. of alumina of high purity is required for the production of each pound of metallic aluminum. Projected production of metallic aluminum in the United States is now seven to ten times the peacetime rate a few years ago.

In the past, all the alumina for the production of aluminum in the United States has been obtained from bauxite. Part of the bauxite was mined in the United States—chiefly in Arkansas—and part was imported from Dutch Guiana. All of it was chemically treated in the United States to separate the greater part of the aluminum oxide from the bauxite. The chemical treatment was effected by alkaline solutions, employing the Bayer process. The ingredients of the bauxite other than alumina, such as the compounds of iron, titanium and silicon, constitute the tailings of the Bayer process, and are called "red mud." Lime and soda, used in the processing, are also present. Varying amounts of alumina remain in the red mud, depending upon the characteristics of the bauxite, the effectiveness of the treatment and, in particular, upon the amount of silica originally present in the bauxite. High-silica bauxites result in high alumina loss in the red mud.

Because of this relationship between the silica content of the bauxite and the alumina lost in the Bayer

process treatment, there has been an incentive in the past to use low-silica bauxites. Much of the Dutch Guiana bauxite is low in silica and hence is a splendid Bayer process feed. In the domestic bauxites the silica content varies all the way up to 25 or 30 percent. Bauxites having a low silica content have been mined here for more than 40 years to provide alumina for the production of aluminum and for other purposes. While some of the higher silica bauxite has been mined for chemical purposes, most of it remains in the ground. Although there is no sharp dividing line between low-silica and high-silica bauxite, a few years ago an upper limit of about 5 percent silica was used to distinguish Bayer-process from high-silica bauxite. In recent years, however, material containing more than 7 percent silica has been used as Bayer process feed.

All the alumina produced in the United States at present is made by the Bayer process. There are three operating plants: two run by the Aluminum Co. of America, and one by the Reynolds Metals Co. One Aluminum Co. plant is in Illinois, the other in Alabama; while the Reynolds plant is also in Alabama. The effective operation of these plants depends on a supply of low-silica bauxite, a substantial part of which at present is imported from Dutch

Guiana. Since there is a possibility that the flow of Dutch Guiana bauxite may entirely cease, and since there are no known available deposits of bauxite in Canada, Mexico or other accessible foreign countries, it seems advisable to consider the steps necessary for the production of our entire alumina requirements from domestic raw materials. It may also be necessary to export some alumina to Canada.

Next to low-silica bauxite, the best raw material for the production of alumina is high-silica bauxite. Certain high-silica bauxites can be treated by a washing process with a recovery of 60 to 80 percent of the original feed in the form of low-silica bauxite. The ashed bauxite is then treated by the Bayer process. Furthermore, high-silica bauxites can be treated by the Bayer process at an additional cost for chemicals and freight and at an additional cost of processing as a result of lower yields. While there may be a possibility of producing low-silica bauxite from high-silica bauxite by flotation or other beneficiation methods, a special Research Council subcommittee which studied the question did not find the prospect very promising.

One process discussed is a lime-soda sintering treatment for high-silica bauxites. Steps are now being taken to put this process into partial operation at a new Defense Plant Corp. plant in Arkansas which is to be operated by the Aluminum Co. The original scheme was to add limestone and soda to the high-silica bauxite and sinter the mixture, but the procedure has now been changed, and it is planned first to put all the bauxite directly through the Bayer plant. The plant will be run entirely on high-silica bauxite. The average silica content is at present unknown but is estimated to be in the neighborhood of 13 percent. The Bayer process treatment will remove about 70 percent of the contained alumina. The tailings, or red mud, will then be sub-

jected to the lime-soda sintering operation.

The Bayer red mud will contain soda, but will contain little, if any, added lime. It will contain practically all the silica of the original bauxite and a considerable amount of alumina. Lime will be added in the form of pulverized limestone and sufficient soda will be added to bring the mixture to the proper composition for sintering. The sintered product will then be leached and the liquors will be added to the Bayer process liquors. The tailings from this operation will contain very little alumina and the weight of alumina recovered from a ton of high-silica bauxite at this plant should be about comparable to the recovery from a ton of low-silica bauxite when treated by the Bayer process alone. Thus it may be said that substantial amounts of alumina will be produced from the clay in the bauxite processed at this plant.

For the purpose of this discussion, the red mud from the Bayer operation at this plant may be considered as clay. If no red mud were available a certain amount of clay could be treated by the lime-soda process and the liquors could be added to the Bayer process liquors and thus, literally, alumina would be produced from clay. How much clay could be used in proportion to the original bauxite is not now known, but laboratory tests indicate that the amount should be substantial. It will be desirable to find out the maximum amount of red mud, clay or red mud-plus-clay that can be utilized by the combination Bayer-lime-soda process.

BAUXITE RESERVES

Although on the basis of simple arithmetic the combined reserves of low- and high-silica bauxite in the United States would appear to be more than adequate for the present war, including some exportation to Canada, still, to mine all the known bauxite would require vast overburden stripping and many underground mining developments. Furthermore, much of the low-silica bauxite is intermingled with high-silica bauxite. This is a problem that must be studied in detail by experts in order to appraise the various factors.

There can be little doubt, however, about the advantage of operating a plant without the need of separating pockets of low-silica bauxite from the high-silica bauxite. For the most effective use of domestic raw materials for the production of alumina, therefore, it would seem desirable to consider having lime-soda sintering

plants constructed at each of the Bayer process plants. At the Illinois plant, in addition to the current production of red mud, there are millions of tons of red mud which has accumulated during the past 30 or more years. The amount of alumina in this red mud is equivalent to that contained in about 1 million tons of bauxite and the alumina is higher in proportion to the silica than in kaolin clay. Lime and soda are also present. To prepare this red mud for the lime-soda sintering operation would require less added lime and soda per pound of alumina than in the treatment of kaolin clay. This red mud is already mined and pulverized. The new soda consumption of this plant would be reduced as a result of the soda recovery from the red mud.

The report therefore suggested that a study be made of the possibility of constructing a lime-soda plant at the Illinois installation to operate in combination with the Bayer equipment. This would enable the plant to use high-silica bauxite and, if more than the current production of red mud could be used in the combination process, the excess could be supplied from the vast accumulation and thus conserve bauxite.

It was also suggested that consideration be given to the construction of a lime-soda sintering plant in Alabama to operate with the Reynolds Bayer plant at that point. High-silica bauxite is easier to obtain than low-silica material at this plant. Hence, if the Reynolds installation is not converted, a supply of low-silica bauxite should be held for it.

Possibly sufficient low-silica bauxite can be obtained in the United States to operate the Aluminum Co.'s Alabama plant. It was suggested, however, that the company be asked to make a study of the possibility of constructing a lime-soda sintering plant, to operate in combination with its Alabama Bayer plant, so that the plant could operate efficiently on high-silica bauxite if necessary.

If all these plants should be equipped to operate on high-silica bauxite they would, at the same time, be equipped to utilize a substantial amount of clay for the production of alumina. This program would appear to offer the best means of conserving domestic bauxite and at the same time offer the best means of utilizing existing alumina equipment in the manufacture of alumina from clay. It should be made clear, however, that the changing of a Bayer plant to a combination Bayer-lime-soda plant involves much more than the

mere addition of a set of kilns. The use of high-silica bauxite will result in an increased amount of red mud, and the lower lime content may increase filtering difficulties. Among other things, additional mud-handling equipment will be needed, and means must be provided for controlling the moisture content of the mud, for incorporating the lime and soda, for proportioning the kiln feed and controlling the liquors. Although the conversion of a Bayer plant approaches a major operation, no other program seems so promising.

CLAY PROCESSES

From the information now available, it would appear that the lime-soda sintering process can be used effectively on kaolin only in conjunction with a Bayer plant. There should be one or more processes ready for operation for the production of alumina from clay in which there is no dependence on a Bayer plant. The committee gave consideration to this matter and felt that a modified Pedersen process offered the greatest promise for such a process. In skeleton form, this process consists in sintering the clay with lime and subsequently leaching with soda. There are many variations to be studied, not only in the sintering and leaching, but in the treatment of the liquors as well. Results of many laboratory experiments, both in the United States and abroad, give promise that the process will be operable, but it will be desirable to carry out additional work on a test plant basis to obtain data for the construction of a production unit.

In order to gain this needed information as soon as possible, the committee recommended that the War Production Board allocate up to a maximum of \$100,000 to the War Metallurgy Committee for the installation of equipment for a test plant, and for its operation. It was ascertained that the Eastern Experiment Station of the U. S. Bureau of Mines at College Park, Md., would probably have space for the test plant and it was suggested that the test plant be located there, if suitable arrangements could be made. It was also recommended, that the War Production Board assist in the procurement of equipment for this test plant. If the results should be as expected it would be possible in the future to use clay in producing alumina of a suitable grade for the manufacture of aluminum, without the use of acids. This is a goal much to be desired. The construction and operation of a

plant requiring no acids offer many advantages over plants in which acids are required.

The Eastern Experiment Station of the Bureau of Mines is already working on the lime-soda sintering of clay. Work on the modified Pedersen process should be in addition to the other work on alumina at the Experiment Station.

Although the committee prefers the alkaline process in the treatment of high-silica bauxite, red mud or clay, it believes that an acid process is preferable in the treatment of alunite. Kalunite, Inc., is proceeding with a plant for the production of alumina from alunite. The committee suggested that the completion of the first unit be speeded as much as possible so that practical experience can be gained with a minimum loss of time. The Kalunite plant probably can treat 2-3 tons of clay for each ton of alunite without using more sulphuric acid than can be obtained from the sulphur in the alunite.

Kalunite, Inc., also has a pilot plant in Utah, funds for the operation of which were supplied by the Defense Plant Corp. on recommendation of the War Production Board. The report recommended that the War Metallurgy Committee be given the responsibility for the operation of this pilot plant to facilitate coordination of the alumina experimental program.

The committee believes that the Kalunite process, or other processes dependent on the utilization of potassium alum, are the best available acid processes for the production of alumina. The Morenci tailings project, work on which is being sponsored by the Defense Plant Corp. through the War Metallurgy Committee, comes within the classification of a potash alum process.

Another acid process is one which is being worked on in the pilot plant stage by the Tennessee Valley Authority at Wilson Dam, Ala. In the earlier stages of the operation, according to the report, the alumina produced was not nearly pure enough for the manufacture of aluminum. The committee made various suggestions for improving the grade of material produced, but results achieved by these suggestions were not available at the time the report was prepared.

The report noted the fact that the Aluminum Co. now has a pilot plant for investigating the lime-soda sintering process to gain the necessary data for the design and operation of the new Arkansas alumina plant. The

committee considered it advisable that pilot plant work be speeded on the treatment of clay and therefore recommended that the Aluminum Co. be urged to install an additional pilot plant leaching unit for this purpose, if the equipment is obtainable, and suggested that the War Production Board provide assistance. Possibly an even better plan would be to use an available kiln and building at the Aluminum Co.'s Illinois plant, adding to it the equipment needed for a red-mud treating pilot plant. The plant could be in operation soon, after which the company's smaller pilot plant could be turned over to the study of clay.

In conclusion, the report recommended means for the conservation of bauxite. Most alumina abrasives

require substantial amounts of special low-silica bauxite and it may be desirable to earmark the necessary quantities of such domestic material for the production of such abrasives as are essential for the war effort. Furthermore, most aluminum sulphate made in the United States is made from bauxite, but one company at least is making this product from calcined clay. Since large quantities of bauxite could be conserved by restricting its use in alum making, the committee suggested that this matter be considered.

As a final proposal, it was suggested that prospecting for new domestic deposits be carried out vigorously, since a few million dollars spent so would doubtless save tens of millions in the long run.

Guinea Pigs For Tank Cars

TO DETERMINE which chemicals can be carried efficiently in aluminum tank cars, the Aluminum Company of America is employing an adaptation of the traditional laboratory "guinea pig." Developed by A. H. Woollen of the Development Division in New Kensington, Pa., the guinea pigs are neat-looking aluminum cans, about the size of that humidior on your smoking table. Insofar as the proportion of different metals in these containers is concerned, it is the same as an 8,000-gal. tank car built of 17S-T alclad plates, with 17S-T rivets and anchor backup plates.

The small piece of 17S-T sheet riveted to the inside wall of the container is applied with aluminum rivets, and represents the edge of the alclad plates which are exposed to the chemicals carried inside a tank car. The three rivets attaching this piece to the side of the container, as well as the three rivets on the opposite side, are exactly proportionate in area to the rivet heads exposed to the lading in the full-sized tank. The small round disk of 17S-T plate attached by a rivet to the bottom represents the plates which are used in the bottom of the tank car to back up the anchor rivets. Of course, the rivets in the center of this disk are proportionate to the real exposed area for the anchor rivet heads.

Similar cans have been made using 3S alloy, 52S alloy, 53S, and 61S. By placing chemicals in these containers accurate answers are obtainable in a relatively short time as to

whether the chemical will corrode aluminum, or the aluminum will contaminate the chemical. Nitric acid, for example, makes a slight attack on aluminum containers, but this attack is so small that it would take about 30 years to decrease the cross-section of standard aluminum plates to a material degree. Furthermore, the product of the corrosive attack by nitric acid does not contaminate the liquid. It is therefore considered entirely safe to ship the acid in aluminum tank cars.

Through the use of these same guinea pigs, the satisfactory performance of aluminum alloys for I.C.C., 42B drums, barrels, and other containers has been established.

Proportions of various alloys in this "guinea pig" simulate a tank car or other container for corrosion tests



Preventing Heavy Metal Poisoning in Industrial Operations

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Chem. & Met. INTERPRETATION

Last month the author dealt with the general problems that chemical engineers encounter in combating chronic poisoning in chemical operations. Herein he deals with the causes, symptoms and prevention of heavy metal poisoning, as exemplified by lead. Future articles will treat specifically of fibrosis-producing dusts and toxic solvents and with methods of combating hazards from these.—Editors.

ALL OCCUPATIONAL diseases are not caused by poisons. For example, the fibrotic condition of the lungs, caused by silica and asbestos, could not be considered poisoning. In a similar manner, the allergic reaction of certain people to pollen cannot be called true poisoning. However, some of the metals and their salts, such as lead, cadmium, antimony, arsenic, manganese and selenium are true poisons. Their action, quite definite and not limited to a few susceptible individuals, varies. However, the means of entry to the body is similar and the toxicity is of the same order.

Since it would be impossible to discuss all these materials in detail, this paper is limited to a discussion of lead as a typical metal poison. More is known about this metal than the other materials of this group because of its very wide industrial use over a long period of time.

LEAD COLIC

Lead poisoning may occur as colic, arthralgia, palsy, or encephalopathy. The fact that the symptoms of lead poisoning may appear either in the stomach, in the joints, as paralysis, or in the brain, indicates the difficulty of identifying it as the cause of illness. It is so similar to many other complaints that its effects are sometimes masked by another disease. The diagnosis of lead poisoning can be fairly well established by a history of lead exposure, blood examination, urine examination, the existence of the lead line, and colic or other symptoms mentioned.

Symptoms of colic include a severe pain in the abdomen, which may cause the patient to double up or fall to the ground. This attack may come without warning but is generally preceded by gastric discomfort, lack of appetite, constipation and nausea. Old-time smelter men feel that if constipation can be avoided, they will never have lead colic. This form may be the first sign of lead absorption and it increases in intensity after a day or two. It is an indication that poisoning is occurring and that steps should be taken to eliminate the entry of lead into the body.

That the patient appears to be recovered from an attack does not mean that he is cured, since it is possible that lead is being stored in his bones, which will decrease the lead actually circulating in the blood stream. This stored lead is harmless as long as it stays in this inactive state. The serious symptoms of lead poisoning occur as a result of the lead circulating in the blood. This may be increased by a discharge of lead from the bones when the worker is run down and cause serious lead symptoms at a time when the patient is least able to fight it.

Amount of circulating lead is determined by the amount of lead entering the body and also by just what is happening to the stored lead. For example, if considerable lead is being absorbed but is being stored in the bones as rapidly as it enters the body, then the symptoms will not be too severe. If the exposure has been reduced and the lead entering the body is quite small but lead is leaving

the bones from a previous exposure, a person may develop a severe case of lead poisoning with little or no exposure.

It has been said that lead follows calcium. For this reason, a high calcium intake with the use of milk is often used to relieve serious lead symptoms. However, lead which may still be stored up in the bones is potential dynamite. Very possibly this stored lead may never cause any damage, but the trouble which it might cause is so serious that everything possible should be done to avoid this condition. Hence, it is not desirable to depend on the use of milk and a high calcium intake to prevent lead poisoning; everything possible should be done to keep down the lead exposures as much as practical. A bottle of milk a day is not a substitute for an exhaust system.

ARTHRALGIA AND PALSY

Lead workers may complain of muscular cramps and pains in the large joints. The pain may be as severe as in the case of lead colic but often is of short duration. It usually occurs as one of the symptoms of lead poisoning but not as the only one. The description of these joint pains generally occurs in the case history after several attacks of colic.

Palsy generally occurs after several attacks of colic and long exposure to lead. The condition affects those muscles most used. Painters, for example, will be affected in the wrists and fingers of which the condition known as "wrist drop" is a fairly common example. The hand hangs down when the arm is extended nor is it possible for the man to bend his hand back even though there is force left in the hand itself except for the flexing back of the wrist. When this condition occurs, the exposure has gone on for some time and lead poisoning is fairly well advanced. It is an indication that considerable lead is circulating in the blood stream and affecting the various parts of the body.

Encephalopathy is the type of lead

poisoning that involves the brain. The symptoms are mental confusion, delirium, hallucinations and faulty speech. Death may result from apoplexy during delirium. Blindness and loss of color perception have also been reported. After the violent mental signs have disappeared, the patient may be sluggish mentally. The symptoms described are alarming and leave no doubt that everything possible should be done to control the hazards.

OCCURRENCE OF HAZARDS

It is, of course, important to know where to look for lead poisoning and how to identify exposure in potentially dangerous occupations. Although lead is generally considered an occupational hazard, it is interesting that nearly 60 percent of the cases reported in a recent survey were non-occupational. This particular survey indicated a number of cases resulting from the use of storage battery casings for fuel. Another large group were children who acquired lead poisoning by chewing objects painted with lead pigment.

Use of lead is widespread and consequently the operations where lead poisoning occurs are also numerous. It appears that, at the present, the more serious forms of lead poisoning occur in occupations where apparently no exposure exists. A typical example of this was an epidemic of lead poisoning resulting from the use of lead-coated nails by shinglers. These men held the nails in their mouths and, in this way, absorbed the lead. The symptoms which were complained of were severe muscular pains in the forearm and calf of the leg. There was also a dead and numb feeling, similar to paralysis. Cramps and abdominal pains were also present. If the manufacturer of the nails had given consideration to this practice of the shinglers, the product would not have been put on the market. Also, if the men had realized that the nails were coated with lead, they would not have exposed themselves to the hazard.

Operations where lead poisoning may exist are too numerous to list, but Table I indicates some of the more common occupations where there is a definite lead exposure.

LEAD DETECTION

In determining the extent of the hazards in any of these potentially dangerous industries or others which may be suspected, an accurate determination should be made of lead in the air. The sample which is to be

analyzed may be taken by the Greenburg Smith impinger for lead dust and collected with an electric precipitator for fumes. Descriptions of the sampling methods and the analysis are given by Jacobs.¹

Table I—Some Common Occupations Having Definite Lead Hazards

Painters
Red lead workers
Storage battery makers
Printers
Insecticide makers
Lead burners
Glaze dippers
White lead workers
Putty makers

Some work has been done in this laboratory using a respirator with replaceable filter as a sampling device. An approved type respirator is worn for a day or two. The replaceable filters are then removed and their lead content determined. The value is converted to milligrams of lead per day, equivalent to milligrams per 10 cubic meters used for impinger samples.

This method gives the entire exposure as compared to only the exposure during the sampling period given by the impinger. Operations may vary so that the average exposure may differ widely from that indicated by an impinger or precipitator sample. This method has value as an economical means of checking atmospheric contamination in plants which do not have enough work to warrant the investment in an impinger or precipitator.

In the case of (2), the worker did a job of dismantling some old duct work which was not picked up by the impinger as the work was not carried on during the sampling period. In the case of (4), the correct

Table II—Comparison of Impinger and Respirator as Sampling Instruments for Lead

Operation	Respirator mg/day	Impinger mg/10 cubic meters
(1) Lead burning.....	7	6
(2) Repair work in lead plant	65	5
(3) Repair work in lead plant	4	4
(4) Putty manufacturing	3	12
(5) Sweeping	10	15

Milligrams per day = Milligrams per 10 cubic meters.

weighting was not given to the intermittent nature of the work. The impinger sample was taken during a period of high concentration, and this was not representative of true conditions. Although the results do not check with those of the impinger,

it is felt that they represent the actual conditions at the time of exposure, which is most important.

It is generally considered that if the air contains lead in excess of two milligrams per 10 cubic meters of air, which represents a day's exposure, there is definite danger of lead poisoning. Of course, if the lead concentration is below this amount, it is still necessary to give the utmost care to sanitation regarding drinking water, washing facilities, proper type of lunch rooms and every type of precaution to prevent ingestion. The fact that the lead in the air is within a safe limit does not eliminate the hazard from ingestion through carelessness by the employees.

DANGER FROM FUMES

One of the more common types of lead exposure which occurs in several of the occupations named is the production of fumes from the melting of lead. When this metal is melted and exposed to the air, there is a scum of lead oxide formed on the surface which may get into the air by air currents or by mechanical agitation of the surface. Calculation of the vapor pressure of lead indicates that theoretically, no injurious concentration would be given off below 900 deg. F. We have found, however, that if there is considerable mechanical agitation, such as exists in certain dipping or pouring operations, the concentrations of lead may be 100 times that which would otherwise be expected at the same temperature.

The proper respiratory protection from the fine lead oxide which results from the heated metal is a lead fume respirator of the mechanical filter type. Masks depending on charcoal are useless, as the fumes are not a gas but are extremely fine particular matter.

It is desirable to detect signs of lead absorption before this condition develops into serious poisoning. It is possible to get an indication of possible absorption by an examination of the blood of workers. If this examination is conducted at regular intervals, it will serve as a check on the engineering control methods and also on the care taken by the workers to prevent the entry of lead into the body. Absorption results in an increase in the number of basophilic cells. This condition may not be specific, but it does offer a fairly simple method of checking on changes in the circulating blood. Another method which has been suggested for checking on incipient lead

poisoning is the determination of lead in the urine by use of the polarograph.

METHODS OF CONTROL

Steps in dealing with control of lead poisoning are as follows:

1. Determine chemically the amount of lead in the air if there is any question of exposure.

2. Reduce the lead content in the air by means of exhaust equipment to the lowest practical point. This can be done by enclosing the dust producer and exhausting so that a slight negative pressure is maintained. Local exhaust hoods are preferred to general ventilation.

3. If there is any question about the efficiency of the exhaust equipment, protective equipment such as respirators approved by the Bureau of Mines should be furnished. In the case of metallizing employing lead, a positive pressure helmet should be used.

4. Hazardous operations should be isolated so as to expose as few employees as possible.

5. The employer should see that the men wear suitable clothing, such as overalls and jumpers. These should be thoroughly washed at least weekly. The employer should provide a suitable place for the men to change their clothes.

6. Sanitary drinking fountains should be used and no other supply of water should be permitted in work rooms where any lead process is in operation.

7. The employer should provide suitably heated and lighted wash rooms, separate from the work or eating rooms. These wash rooms should be provided with running hot and cold water and be adequate for the number of employees.

8. Shower baths should be provided with running hot and cold water. The employer should provide a sufficient supply of soap, bath towels, and hand towels for each employee.

9. The employer should require each man to wash his hands and face before eating lunch and at the close of the day's work.

10. Men should be required to take a shower bath before leaving the plant.

11. A suitable place must be provided for the employees to leave their lunches. No one should be allowed to eat in any room where lead operations are being carried on. It has been found that special lunch rooms, equipped with suitable tables and benches, are an excellent method of control.

12. Use of tobacco in any form should be prohibited during working hours due to the possibility of the tobacco becoming contaminated with lead dust or fumes.

13. Sweeping, if done at all, should be performed wet and at the end of the shift.

14. Wherever possible, cleaning operations should be by vacuum system. Floors and walls should be so constructed that there would be little accumulation of dust and dirt. Rafters and beams which might catch suspended materials should be cut down as far as possible. In some plants triangular pieces of metal are placed on the rafters so that dust will not be retained.

15. Periodic physical examinations, together with blood tests, should be made to check on the efficiency of the control methods.

This list of control measures is not complete, but it does indicate the consideration which has been given to the problem. It is the result of long experience acquired by the lead industry. It is because of control measures such as these that the number of lead poisoning cases in occupations which are known to be definitely hazardous have been nearly eliminated. Although at the present time stress is being placed on control of lead dust, the importance of personal cleanliness and the limitation of ingestion cannot be overemphasized.

The purpose of this article is not to emphasize the hazards of lead but to point out that it can be used with safety if certain of its properties are recognized.

If the question of chronic lead poisoning arise, it is desirable to contact those authorities who have knowledge regarding these hazards. The State Department of Industrial Hygiene, or in some states the State Labor Department, the National Safety Council or representatives of insurance companies all have considerable information regarding toxic limits and the control of hazards. These agencies are glad to cooperate in any way toward furnishing information or making studies. Such information and services are available without charge to practically any plant.

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Torch cutting of metal which has been coated with lead paint has frequently resulted in cases of acute lead poisoning. Lead fume respirators should always be used in such hazardous operations



Managing New Product Development in Chemical Industry—II

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Chem. & Met. INTERPRETATION

Last month the author introduced the subject of management of new product development in the chemical industry by discussing the problems, technique and management of the research stage, including sources of ideas, preliminary screening of ideas and initial technical-economic investigations. In this concluding article the problems connected with the pilot plant, semi-commercial plant and transfer to full scale production are all discussed.—Editors.

THERE IS a fairly sharp dividing line between the research and the development stages of a new chemical product. In the former, the general object is to find out if the product can be made and if it should be made, while in the development stage an effort is made to work out a satisfactory commercial process and to prepare for full-scale marketing.

Technical development takes the form of making the product in small-scale production units. The words "pilot plant" and "semi-commercial plant" are sometimes used synonymously. In this article the distinction is made that the product from the pilot plant is not sold to the market, while a part of the output of the semi-commercial plant is sold on a small scale.

PILOT PLANT

The pilot plant is a small-scale production unit set up for the following purposes:

1. To determine if the laboratory process for making the chemical will work on a larger scale in industrial equipment.

2. To raise yields, improve quality and lower costs by refining the process. Pilot plants are frequently used for this purpose by the production departments of chemical firms to improve present full-scale operations. However, the pilot plant discussed here is understood to be one used in the development of new products.

3. To gather engineering data for use in designing the full-scale plant.

4. To make a sufficient quantity of the product for testing and distributing as samples.

5. To obtain more accurate estimates of manufacturing costs.

6. To train personnel for operating the full-scale plant.

There is usually a change of personnel when the product is transferred from the laboratory to the pilot plant. Chemical engineers often form an integral part of the group operating and observing pilot plant operations. However, in many companies the pilot plant group is headed by the research chemist previously in charge of the laboratory research, since he is most familiar with all of the details of the process. The study of the product and process by chemical engineers constitutes an evaluation from a different point of view than that of the research chemists. Many executives emphasize the importance of the pilot plant for this reason.

The semi-commercial plant, larger than the pilot plant, has as its primary purpose the production of sufficient quantities of the new chemical to permit sales in small lots. However, the semi-commercial plant is still experimental, and its purposes also include all those listed under the pilot plant.

SEMI-COMMERCIAL PLANT

A distinction is sometimes made between new chemicals already made by competitors and those which are entirely new and must be introduced to the market. For the former, a pilot plant just large enough for experimental purposes is used. For entirely new products, a semi-commercial plant is designed larger than necessary for a purely experimental pilot plant and yet large enough to permit fairly economical production

so that the product can be sold at the cost of manufacture. This permits the company to "break even" on the costs of operation.

Data for the design of the semi-commercial plant are gathered in the laboratory. The size of the semi-commercial plant is estimated by the director of development, who has previously conducted market surveys and customer tests. The output is introduced to the market by a staff of market development men who specialize in such work. The price is naturally higher than that ultimately possible, but it is low enough to permit limited sales to users who have the greatest need for it. As the demand grows, the semi-commercial plant is operated at an increasing percent of its capacity. When full capacity is reached, preparations are made to transfer the product to a large, full-scale plant.

MARKET DEVELOPMENT

Desirability of using a semi-commercial plant after, or in place of, a pilot plant depends on many factors, including the economics of production costs, possibilities of getting necessary design data in the laboratory, and importance of introducing the new chemical to the market.

Market development, the preliminary introduction of new chemicals to the trade, is another activity carried on during the development stage. It is closely associated with evaluation of new products by customers and with application studies. Such work is carried on by different staffs in different companies: by salesmen, by sales service men, or by special market development staffs attached either to the sales or to the research department.

The use of specialized market development men in chemical companies seems to be increasing. These men are technically trained and industrially experienced. They do most of their work in the field, talking with customers' research and production men. They are usually responsible for handling new products from the time of chemical development

until they are turned over to the regular salesmen for full-scale marketing. In essence, they do "experimental marketing." Their job is to "educate" customers, to adapt new products to customer needs, and to uncover uses for new products. In one company, there is a staff of five market development men, each of whom specializes in one customer industry and handles all new products intended for use in that industry.

Exact organizational set-up and functions performed by market development staffs vary considerably, but there is a recognized need for a specialized group with the patience and technical knowledge of the research men plus the sales ability of the salesmen.

CUSTOMER EVALUATION

Customer evaluation is the process of testing and evaluating new chemical products by potential customers or in customers' plants. The conduct of this seems to be a very controversial and perplexing question in the chemical industry. Practice varies from avoiding it as much as possible until the product is placed on the market to distributing samples while the product is still in the laboratory stage. The following are objections to customer evaluation expressed by executives:

1. Samples of new chemicals are a nuisance to customers, who may feel that they are being asked to do research for the distributing company.

2. The customer may decide that the product is excellent and that he would like to purchase quantities of it, only to find it not yet available in commercial lots.

3. The customer may get a bad impression of the new chemical while it is still in the experimental stage and retain that prejudice even after it has been improved.

4. Patent protection of the manufacturing process and product uses may not be complete.

5. If the product is given only to a few companies, this constitutes discrimination in favor of those concerns, which may bring repercussions later.

On the other hand, there are important reasons and advantages for customer evaluation:

1. It constitutes an evaluation of the product by the ultimate user, who is expected to buy it in large quantities later.

2. Difficulties and "bugs" not foreseen in research and development studies are brought to light.

3. Information for improvements necessary or desirable before the product is placed on the market is developed.

4. Information for establishing different grades of products can be obtained.

5. Data are usually provided for a check on market surveys.

Because of these advantages, chemical companies have sought ways to secure customer evaluation without the disadvantages. Three general methods have been tried:

1. Evaluation within the producing company from the point of view of the customer is being used as far as possible by many concerns. This is accomplished by specialized application laboratories and by market development men and sales engineers well acquainted with the needs and desires of customer industries.

2. Cultivating a few friendly customers who will be glad to cooperate is actually only a modification of the original concept of customer evaluation. By careful selection and cultivation of a few customers, many of the disadvantages may be minimized. The cultivation may include adhering to careful policies on distributing samples, offering the customer something in return, having men from the producing company conduct the tests in the customer's plant, or purchasing an interest in the customer concern.

3. Some companies submit a sample to chemical consultants, asking them to determine if it is applicable to particular "customer" industries. The experience of chemical consultants with chemical consuming industries is valuable in making such evaluations.

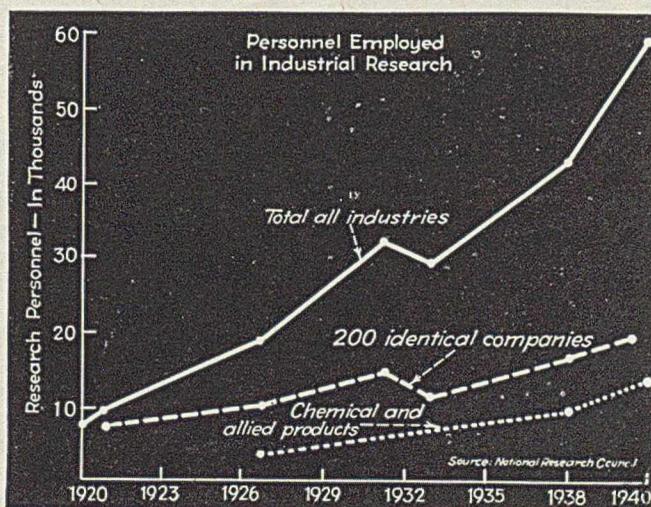
An interesting problem that arises in application research is determining how many uses should be studied, developed, and patented before the new chemical is released generally to the market. By continuing research and application study many of these possible uses may be investigated, but this takes time and delays the introduction to the market. On the

other hand, the developer will suffer if other companies should investigate and patent uses for the chemical. The patent department naturally wants all possible uses explored before the product is placed on the market. The usual practice is to investigate and patent only the most important uses before the product is announced.

While the new product is in the pilot plant, studies of other economic factors are continued so that these are completely understood by the time the product is transferred to semi-commercial or full-scale production. Estimates of the cost of manufacture are further refined, checked by development men and sometimes by cost accountants. The raw materials situation is scrutinized thoroughly, data being gathered on prices, quantities available, locations of important suppliers, transportation costs, and other factors.

Specifications for containers are carefully checked to make sure they are adequate for shipping large quantities of the commercial commodity. The problem of pricing is ironed out at this stage. This is extraordinarily complicated, for the selling price must be related to the cost of manufacture, competitive prices, geographical distribution of customers, quantities purchased, cost of marketing, amounts which will be purchased at various prices, and many other factors. Executives from several departments of the company frequently cooperate in the task of setting prices. One common practice is to inform the customer that the price of the new product will be lowered later when the demand increases.

A financial appraisal is usually made just before the transfer from the pilot plant to full-scale produc-



tion, or before a semi-commercial plant is built. This appraisal is usually comprehensive because of the considerable investment in equipment that is necessary. In one company, a complete report on each project must be submitted to a budget committee before a product can be transferred from the pilot plant to full-scale production.

FULL-SCALE OPERATIONS

Final stage in the development of a new chemical product is the transfer to full-scale operations. This includes design, construction, and preliminary operation of a full-scale plant and transfer to full-scale marketing.

Detailed design and construction of the plant is usually handled by a separate design or mechanical engineering department, although much of the data may have been gathered by the chemical engineers working on the pilot plant. For radically new products made by complicated processes, design and construction require a great deal of time and effort; while for other products which are similar to those previously produced by the company, such activities may consist only of adapting present equipment to the manufacture of the new product. If the development is "big" enough to require a separate plant, then all factors of plant location have to be considered before construction is undertaken.

A compromise must sometimes be made between the size of plant required for optimum production costs and the size dictated by the probable market demand. The most economical plant, production-wise, will often have a larger capacity than the present market demands. This may result in the construction of a large but economical plant with the hope that demand will increase sufficiently to permit operation at a reasonable percent of capacity.

After the plant has been constructed, there follows a period of preliminary operation during which members of the research and development staff are present to study and remedy any problems that arise. In one company, a radically new product was recently developed and the management felt that the plant should be located within a reasonable distance of the research laboratories so that the research personnel would be available to study and remedy all difficulties.

Operators are often trained for the full-scale plant by having them operate the pilot plant. In one com-

pany, the pilot plant is operated by a selected group of regular production workers who thus become familiar with the production technique on a small scale. Usually a few of these "payroll" workers will stand out as being most adept, and one of them is selected as foreman of the full-scale plant.

On the marketing side, a transfer is made from the market development men to the regular salesmen in those companies which have specialized market development staffs. If the technical characteristics of the product are important, this involves training the salesmen and a gradual transfer from special, "experimental" marketing to a more extensive selling program.

Transfer of the product from experimental operations to full-scale production and marketing present many problems of coordination, cooperation, and balance. Various methods which are used by chemical companies to accomplish a smooth transfer include: (1) use of market development staffs for experimental marketing, (2) use of a semi-commercial plant between pilot plant and full-scale production, and (3) use of special liaison officers to coordinate the efforts of research, production, and sales.

GENERAL MANAGEMENT

Evaluation of monetary returns from the research and development program are very difficult, primarily because results cannot be measured accurately in dollars and cents. Executives have indicated that this difficulty lies in the fact that in each new development contributions are made by the sales, production, legal, and financial staffs as well as by the research and development departments. In most companies arrangements are made to charge research expenses to specific projects, and to compare the sales and profits on new products to the expenses incurred during research and development. However, most executives feel that these figures do not tell the whole story. A sound evaluation of the results of research can be made only in a qualitative way by pointing out the importance in the company's activities of new products contributed by research and development.

Executives emphasized the importance of "knowing when to stop," of being able to recognize "dead-end" projects. It is difficult to foresee what may be discovered "just around the corner" if research work should be continued. Usually research and de-

velopment workers want to continue work on new projects, feeling that the obstacles encountered will be overcome by more research; but research executives must exercise restraint to keep from "throwing good money after bad" by continuing projects which will never be productive. Various techniques have been used to assist in making decisions on whether or not to continue a given project. Many companies apportion funds to projects in such a way that when one allotment has been spent, then the whole project must be reviewed.

TIME FACTOR

The time necessary to develop a new chemical commodity varies considerably from product to product. Most executives agree that for a basically new chemical, from seven to twelve years are required for complete development. For products similar to those already being made by the company, this time is considerably shorter.

Executives of one concern have found that for new chemicals quite similar to present ones, only about a year for complete development is sometimes necessary. In another company, one new chemical was developed within two weeks from the time the sales department reported a demand to the time drums were being shipped to the customer.

The relatively long periods of time required for development present quite a challenge to aggressive management in the chemical industry. Most executives admit that they are continually trying to find short-cuts. Many managerial methods discussed previously are intended to shorten this development period. Among those specifically mentioned were:

1. Conducting "high-spot" studies to find crucial factors, then completely investigating these factors.
2. Making market surveys before projects are undertaken.
3. Providing a staff of market development men to introduce new products to the trade.
4. Not adhering to any standard procedure in development, but in each specific case selecting only those steps absolutely necessary.
5. "Promoting" each project by bringing it to the attention of the proper executives at the right time.

One company has an assistant to the president who acts as a liaison officer and whose duties include the "promotion" of new developments. As that officer expressed it, "The time it takes to develop a new product is an inverse function of the 'oomph' behind it."

Timesaving Ideas for Engineers

NOMOGRAPH FOR QUICK SOLUTION OF EFFICIENCY EQUATIONS OF ELECTROLYTIC ALKALI AND CHLORINE CELLS

J. C. COLE Engineer, Diamond Alkali Co., Painesville, Ohio

MANY different types of electrolytic caustic and chlorine cells are now in commercial operation, but in order to analyze each cell critically several efficiencies must be calculated. These calculations, although relatively simple, may require considerable review work by the engineer who has not been called upon to make such calculations for several years. Also the engineer who is familiar with electrolytic cell operation will spend considerable time in calculating these efficiencies,

and often in certain cases the engineer must calculate the efficiencies of a number of cells each day.

Probably no series of equations offer themselves more adaptably to nomographic or alignment chart solution than do the electrolytic alkali cell calculations. Very important in the economics involved in cell operation characteristics are these three efficiencies—percent current efficiency, percent voltage efficiency, and percent energy or power efficiency. For the executive who wants something concrete and realistic, the energy efficiency is expressed in a different way, that is, kilowatt-hours of electricity required to produce 1 lb. of NaOH, which may readily be converted from units of caustic to units

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of chlorine or hydrogen produced, or the NaCl decomposed.

According to Faraday's Law, one of the most exact laws known, one Faraday or 96,480 coulombs will deposit, liberate, or is equivalent to 1 gram equivalent of any substance at each electrode. Since 1 coulomb is defined as the quantity of electricity passing when 1 ampere flows for 1 second, it is pos-

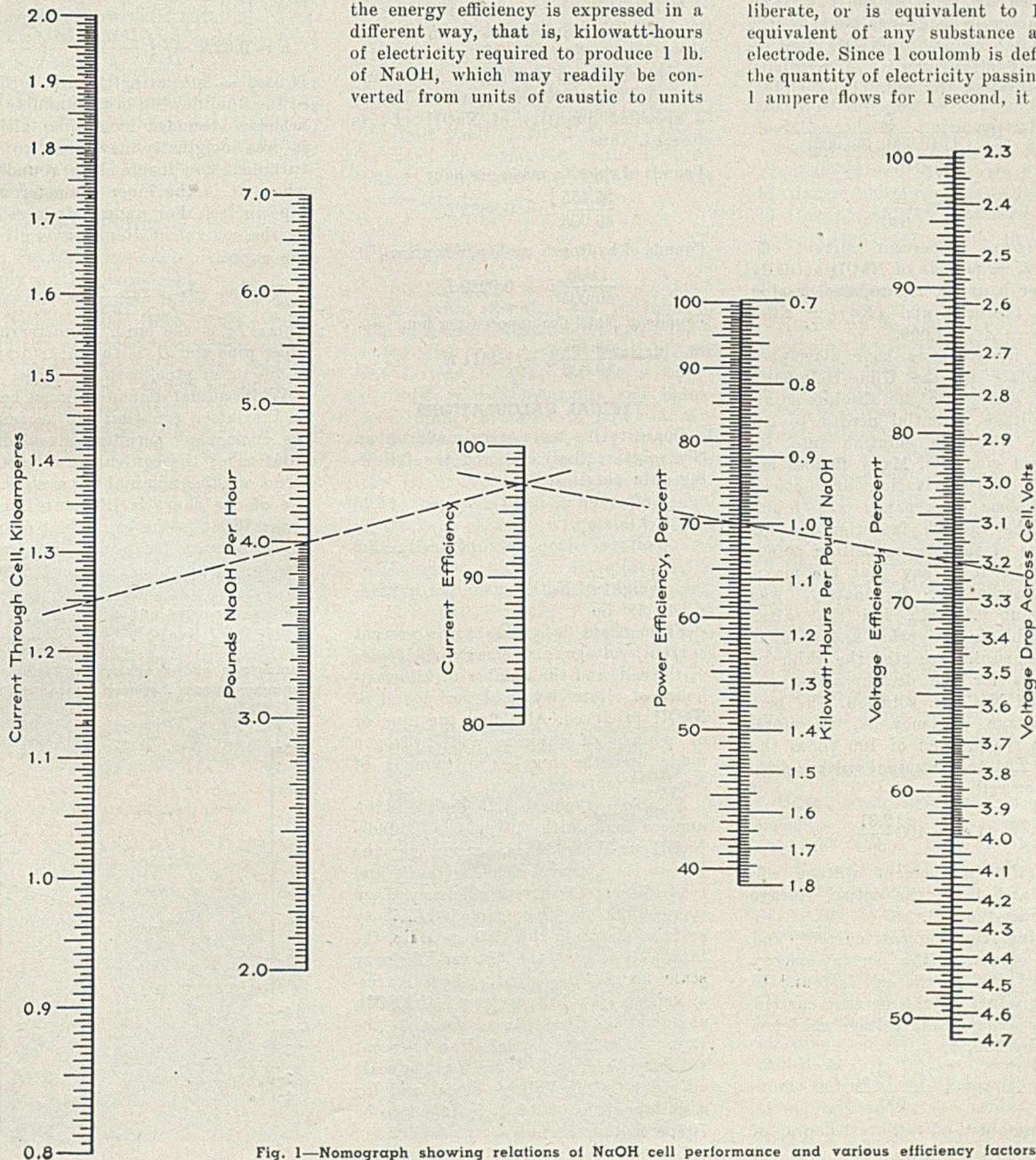


Fig. 1—Nomograph showing relations of NaOH cell performance and various efficiency factors

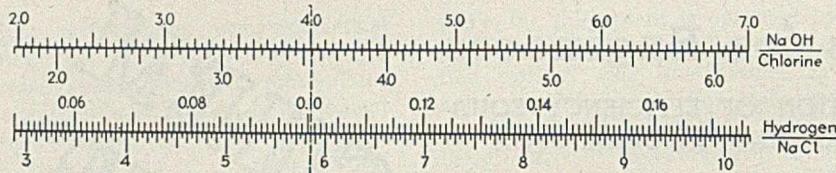


Fig. 2—Chemical equivalent diagram relating NaCl decomposed with NaOH, chlorine and hydrogen produced

sible to calculate the theoretical quantity of NaOH that should be formed when a specific quantity of electricity is passed through the cell. Because of certain definite and numerous reasons that will not be discussed here, it is found in commercial practice that the actual weight of caustic made is always less than the theoretical quantity as calculated from the quantity of electricity passed through the cell. By definition then, the percent current efficiency is defined as the product of 100 times the ratio of the pounds of NaOH actually made per hour, to the theoretical weight of NaOH that is equivalent to the quantity of electricity passed through the cell. Then

$$(Ce) = 100 \frac{L}{\frac{(A)(3,600)(40.005)}{(96,480)(453.6)}} = 3.039 \frac{L}{(Ka)}$$

where (Ce) = percent current efficiency; L = pounds of NaOH actually made per hour; A = amperes passing through the cell; and (Ka) = Kilo-amperes = $A \div 1,000$.

Many investigators have attempted to calculate by the Gibbs-Helmholtz equation and prove the absolute minimum voltage potential needed to decompose NaCl in solution into its component elements. Many factors enter into this derivation and consequently some discrepancy was found among the various investigators for the value of this decomposition potential. Suffice it to say that the maximum discrepancy, fortunately, was only about 0.1 volt, and that after considerable investigation and thought many companies accepted the value of 2.31 volts for the decomposition potential of NaCl in solution. The percent voltage efficiency is, therefore, equal to the product of 100 times the ratio of 2.31 to the actual voltage drop across the cell, or

$$(Ve) = 100 \frac{2.31}{V}$$

where (Ve) = percent voltage efficiency; and V = the actual voltage drop across the cell.

Knowing the percent current and voltage efficiency, the percent energy efficiency (Pe) of the cell is found to be the product of the percent current efficiency and percent voltage efficiency divided by 100, or

$$(Pe) = \frac{(Ce)(Ve)}{100}$$

The number of kilowatt-hours of

electricity needed to make 1 lb. of NaOH is found by the following:

$$E = 2.31 \frac{(453.6)(96,480)}{(40.005)(3,600)(1,000)} \frac{(Pe)}{(100)}$$

$$\text{or } E = \frac{70.195}{(Pe)}$$

where (Pe) = percent energy efficiency; and E = kilowatt-hours per pound of NaOH¹ produced. These relations appear in the nomographic chart, Fig. 1.

The horizontal lines of Fig. 2 give the chemical equivalents of caustic, or in other words they give the quantity of chlorine and hydrogen made and the quantity of NaCl decomposed when a specified quantity of NaOH (L) is formed, thus

Pounds of chlorine made per hour =

$$\frac{35.455}{40.005} L = 0.8863 L$$

Pounds of hydrogen made per hour =

$$\frac{1.008}{40.005} L = 0.0252 L$$

Pounds of NaCl decomposed per hour =

$$\frac{58.452}{40.005} L = 1.4611 L$$

TYPICAL CALCULATIONS

Quantitative tests were made on an electrolytic alkali cell and the following data obtained:

Amperage = 1,250 amp. (1.25 kiloamp.)

Voltage drop across cell = 3.2 volts

Weight of NaOH made per hour = 4.0 lb.

From these data obtain the percent current, voltage, and energy efficiencies of the cell, and the number of kilowatt-hours of electricity used per pound of NaOH produced. Also find the number of pounds of chlorine and hydrogen made and the number of pounds of NaCl decomposed.

Solution—Connect 1.25 on the Kilo-ampere scale with 4.0 on the Pounds-NaOH-per-Hour scale, extending the line to the Current Efficiency scale and read 97 percent current efficiency. Then connect 97 on the Current-Efficiency scale with 3.2 on the Voltage scale, the intersection on the Power-Efficiency scale being 70 percent, which corresponds to 1 kw-hr. per pound of NaOH, as found on the scale adjacent to the Power-Efficiency scale. The percent voltage efficiency is found on the scale adjacent to the Voltage scale, and for a voltage drop of 3.2 it is found to be 70 percent.

To find the equivalent for 4.0 lb. of caustic per hour, a vertical line is drawn through the 4.0 on the NaOH top horizontal scale of Fig. 2 and extended to intersect the lower horizontal scales. Reading the various scales we find that when 4.0 lb. of NaOH is made per hour, there is also 3.55 lb. of chlorine and 0.1004 lb. of hydrogen made per hour, and that 5.85 lb. of NaCl is decomposed per hour.

Nomograph for Equivalent Diameters of Annuli

D. S. DAVIS, Chemical Engineering Dept. Wayne University, Detroit, Mich.

THE Dittus-Boelter equation [Univ. Calif. Pub. Eng., 2, 443 (1930); McAdams, "Heat Transmission", p. 169 (1933) and "Elements of Chemical Engineering", p. 134, New York, McGraw-Hill Book Co.]:

$$h = 0.0225 \frac{k}{D} \left(\frac{D u \rho}{\mu} \right)^{0.8} \left(\frac{c \mu}{k} \right)^{0.4}$$

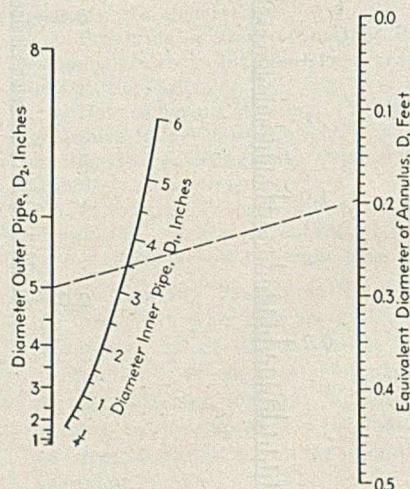
is used in estimating the film coefficient of the fluid flowing in the annular space between standard iron pipes although it was originally developed to cover turbulent flow inside clean, round pipes where D is the inner diameter of the pipe in feet. For annuli, D is replaced by the equivalent diameter as given by the expression,

$$D = \frac{D_2^2 - D_1^2}{12 D_1}$$

where D_1 is the outer diameter of the inner pipe and D_2 is the inner diameter of the outer pipe, both in inches.

While actual diameters must be used in the latter equation the accompanying nomograph permits convenient calculation of the equivalent diameter in terms of the nominal pipe sizes. The use of the chart is illustrated as follows: What is the equivalent diameter of the annulus between 3½-in. and 5-in. standard iron pipes? Connect 5 on the D_2 scale with 3½ on the D_1 scale and read the equivalent diameter as 0.197 ft. on the D scale.

Nomograph giving equivalent diameters for annular spaces between concentric pipes



Machinery, Materials and Products

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PROCESS EQUIPMENT NEWS

Blackout Blinds

New industrial blackout blinds, manufactured of heavy crepe fiber, have been announced by Clopay, 1207 Clopay Square, Cincinnati, Ohio. These blinds, claimed to be completely lightproof, are said to be available at one-seventh the cost of opaque cloth. They are of the cord type, raising and lowering readily, when the control cords are pulled. A practical method of overlapping is employed, which makes the blinds adaptable to windows of any size or number. A flameproofing process makes them incapable of supporting combustion. The same crepe fiber material is available for outside installation on skylights and for effectively blacking out sawtooth buildings without the usual reflections resulting from most methods.

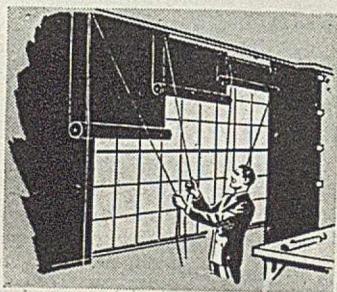
According to the manufacturer, the original installation cost of such blinds is about the same as paint which, of course, becomes ineffective when the glass is broken.

Coal-Fired Heater

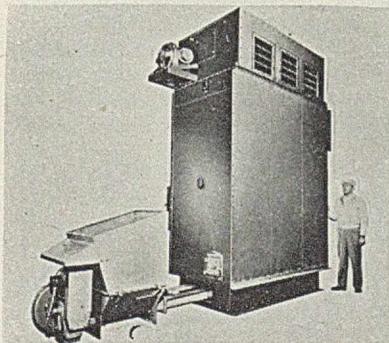
To ENABLE industrial concerns to comply with government requests for conversion from oil to coal for heating purposes, the Dravo Corp., Pittsburgh, Pa., has designed a new direct-fired coal-burning unit heater made in eight sizes from 750,000 to 4,000,000 B.t.u. output per hour.

As in the case with other direct-fired heaters made by this company,

Fiber blackout blinds



Stoker-equipped unit heater



the unit is entirely self-contained, having its own combustion chamber, and distributing warm air either directly from outlet vents into the area to be heated, or when partitions or obstructions make it necessary, through a simple duct system. An underfeed stoker for either bituminous or anthracite coal is available in both hopper and bin-feed types. The unit is also obtainable for hand-firing. A corrugated combustion chamber is employed, having fins and deflectors which make possible heat transfer to a moving air stream at about the same rate per square foot of surface as is obtained in a boiler, according to the manufacturers.

The new unit may be installed during plant construction and used for temporary heat, after which it is retained as a permanent system. Owing to the simple method of warm air distribution, and to the construction of the unit itself, a 40-50 percent saving in steel as compared with a boiler plant is affected, according to the manufacturer.

Plastic Window

DEVELOPED by the Plastics Division of Monsanto Chemical Co., Springfield, Mass., a new transparent plastic, laminated with wire mesh, is available for use instead of glass in the windows of military establishments and industrial plants situated in potential air raid zones. This material, developed by the company in cooperation with the U. S. Navy, is claimed to withstand the explosion of a 150-lb. bomb 8 ft. away and to withstand a 28-in vacuum without appreciable damage. Although a 1-lb. ball dropped from a height of 20 in. smashes ordinary glass, a 2-lb. ball dropped from 42 in. is necessary to penetrate a pane of the new material.

Hydraulic pipe bender



Pipe Bender

BENDS up to 180 deg. in iron and steel pipe, as well as in solid bars of mild steel from $\frac{3}{8}$ to 2 in., can readily be made without heating or filling by means of a new portable hydraulic pipe bender introduced by Tal's Prestal Bender, Inc., Milwaukee, Wis. The machine comes equipped with seven different sizes of formers, the total weighing 158 lb. The machine alone, with the 2 in. former shown in operation in the accompanying view, weighs but 98 lb. The machine consists of a pipe holder frame, hydraulic jack, and a former attached to the plunger of the jack. Three minutes or less is required to produce bends in any size of pipe up to the capacity of the machine, according to the manufacturer.

High Pressure Meter

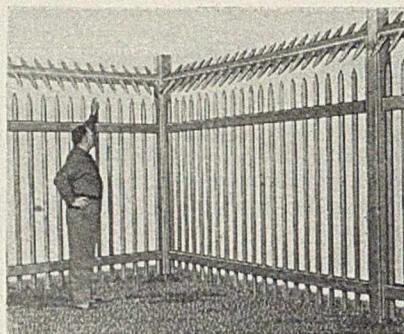
ULTRA HIGH-PRESSURE flow measurement is possible, according to the Cochrane Corp., 17th St. and Allegheny Ave., with a new high-pressure flowmeter manometer of the ring balance type which has recently been introduced. A manometer of this type requires no stuffing box, float or pressure-tight bearing. A stainless steel ring, 15 in. in diameter, balanced on a knife edge, contains mercury as the manometer fluid. The ring is partitioned at the top, connections being made to the two sides by nickel torsion tubes, located at the center of rotation. The ring tilts 10 deg. for the

full differential which may be between 4 and 9 in. of mercury, depending on the cam weight supplied. As in other ring balance meters of this company's design, a cam and weight arrangement is provided to extract the square root relationship so as to express the flow directly in uniform increments on a 36-in. indicating scale and/or 12-in. circular chart.

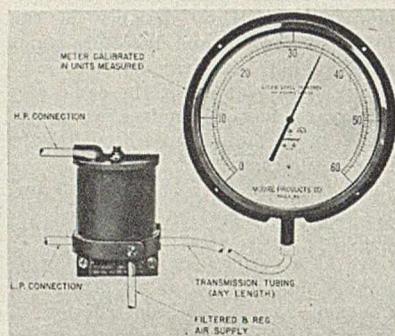
Such meters are tested under 7,500 lb. per sq.in. pressure and are being employed in several synthetic ammonia plants at pressures above 5,000 lb. per sq.in.

Industrial Wood Fence

To comply with steel restrictions in fencing, the Rock Island Sash & Door Works, Rock Island, Ill., is manufacturing a new industrial wooden fence, which weighs 20.4 lb. per lin.ft., permitting the shipment of 2,000 lin.ft. per car. According to the manufacturer, this fence has the approval of the Army Engineering Corps and has been given a thorough tryout.



Industrial wooden fence



Differential pressure transmitter

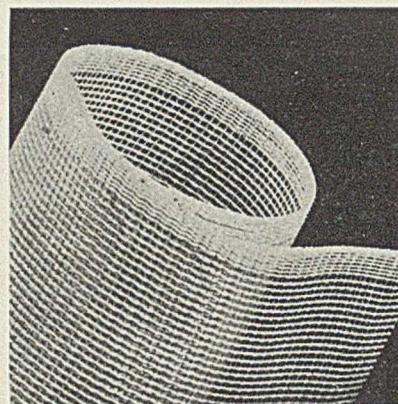
It is suitable for transmission of indications in connection with liquid level, interface level, flow in pipes, ratio flow control, specific gravity, temperature compensation of specific gravity, or temperature measurement.

Plastic-Mesh Fabric

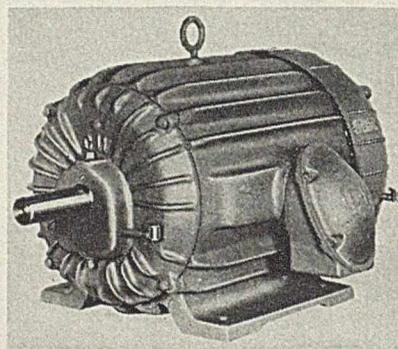
TEN-MESH FABRIC, the openings of which are filled with a transparent plastic, is available under the name of Ceco safety cloth from Colloid Equipment Co., 50 Church St., New York, N. Y. This material, which is non-shattering in the event of bombing, may be used instead of window glass, or may be applied inside, over the regular window glass, to minimize the shattering effect of a nearby explosion. The safety cloth is said to transmit 89 percent of the light of 4,000 angstrom units range and 76 percent of the ultra-violet light of 3,600 angstrom units range. It is weatherproof, flexible and easy to handle. It can be cut with scissors and tacked up on a wooden sash, using unskilled labor. For use over steel sash, the material may be set up in special frames or secured by metal strips screwed into holes drilled in the sash. The cloth comes in rolls of 300 ft., 28 in. wide.

Inclosed Motor

COWL-COOLED is the name of the latest fan-cooled motor developed by Crocker-Wheeler Electric Mfg. Co., Ampere, N. J. The motor is totally inclosed, and especially adapted for use in dusty locations. As appears from the accompanying illustration, the frame carries a number of heavy



Ceco safety cloth



External-cooled inclosed motor

ribs parallel to the shaft. At the right hand side, a cowl ring covering the fan wheel will be observed. Air is drawn into the fan at the center of the cowl ring and then blown over the external ribs. There are no internal passages for cooling air, and thus the motor is claimed to be particularly suitable for service in destructive fumes, abrasive dusts, oil or dirt.

This motor is built with either sleeve or ball bearings, in the same frame sizes used for open motors of corresponding horsepower ratings and speeds, and in sizes up to 20 hp.

Blackout Light Control

SWITCHING EQUIPMENT intended to provide low intensity light during blackouts has recently been made available by Automatic Switch Co., 41 East 11th St., New York, N. Y. In many applications it is desirable to provide low intensity light for essential movement with safety, whenever the main lighting is turned off during a blackout. The new equipment consists of a switching arrangement having two sets of contacts so arranged that, being operated by the same mechanism, when the contacts for normal lighting are closed, the special blackout lights are disconnected, whereas when the normal lighting contacts are disconnected, the blackout lights go into operation. The unit can be controlled either manually, or remotely from one or more push-button stations. Customarily a second source of power should be provided for

the blackout light, for control and communications. Automatic transfer switches should be provided to insure continuity of operation from either available source.

Standard Bearing Covers

WITH THE APPROVAL of all leading manufacturers of ball and roller bearings, R-S Products Corp., 4530 Germantown Ave., Philadelphia, Pa., has commenced the marketing of a line of standard covers designed to form a dust- and grease-tight closure to the bearing housing. These covers, available in a complete range of types and sizes, are low in cost and are said to simplify materially the problems of the designer and draftsman and to eliminate the costs of patterns, fixtures, gages, etc.

Fast-Stabilizing Control

HYPER-RESET is the name of a new control function which is now available in the newly designed Model 30 Stabilog controller, manufactured by The Foxboro Co., Foxboro, Mass. In tests of instruments in which this function was incorporated, it is claimed that process stabilization following an upset was reestablished in one-quarter of the time, and with only one-half of the upset effect, as compared with a

similar controller having only the usual reset. Hyper-Reset is said to reduce the effect of a process disturbance by making initial temporary additional corrections which are proportional to the rate of change of the measured variable caused by the disturbance. The normal reset follows, establishing stabilization. However, the several control functions carried out by the device are simultaneously and automatically adjusted. No tuning-in is necessary, and no more than two process adjustments are required, proportional and Hyper-Reset.

Check Valve

IMPROVEMENTS in a new line of check valves have been announced by the Williams Gauge Co., 2018 Pennsylvania Ave., Pittsburgh, Pa. These valves are available in a wide variety of metals and sizes. Designated as the Williams-Hager Flanged Silent Check Valve, their rated pressures range from 150 to 2,500 lb., their sizes from 1 to 20 in. Simple, compact and rugged design has been employed. Only two parts are subject to wear, the valve disk and the seat, both of which are easily removable and renewable, reseating being possible without special tools. As appears from the accompanying illustration, the spring ring is built as an integral part of the body.

According to the manufacturer, these valves are particularly suited for use in water service, oil refining, chemical manufacture and other non-return flow lines. In general, they can be used in all pump lines handling water, oil, gas, certain acids, alkalis, and other liquids.

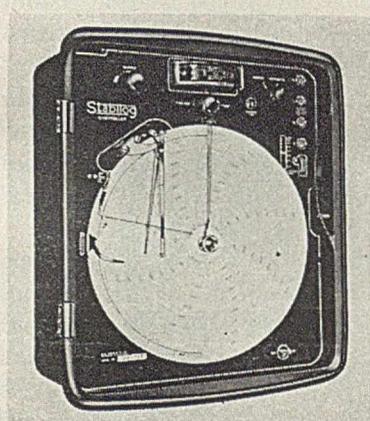
Axial Flow Fan

A RECENT ANNOUNCEMENT of the B. F. Sturtevant Co., Hyde Park, Boston, Mass., describes the company's new Victory Axiflo fan which is claimed to offer features in performance, quietness of operation, saving of weight, space and power, which have never before been approached in fans of the axial flow type. The fan is not yet available for industrial use, since the entire production at present is required by the U. S. Navy for use in heating, ventilating and mechanical draft service.

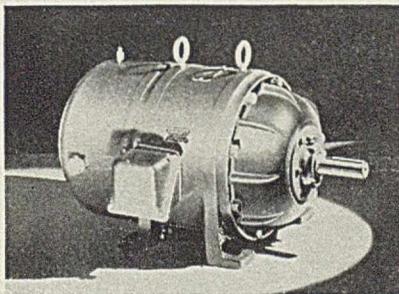
The new fan is claimed to have an exceptionally high mechanical efficiency of 90 percent, and to be extremely quiet in operation, as well as light in weight and small in size. It weighs only about 60 percent as much as other fans for comparable service. Pressures range from $\frac{1}{2}$ to 6 in. w.g. in the motor-driven type, with turbine-drive models available for pressures as high as 60 in. w.g. After the emergency, a wide range of sizes will be available for industrial use.

Several novel features characterize the design of the new fan. A special motor is supported in the center of the duct section by a number of "Streamvanes" which are welded to the motor and the inside of the fan housing, serving not only to cool the motor, but also to straighten the air flow from the rotor, reducing turbulence and resistance in connected ducts. The rotor itself is of a novel stream-lined design, the blades being shaped in such a fashion that the same amount of work is performed at every radius, thus giving great flexibility of volume without change in pressure.

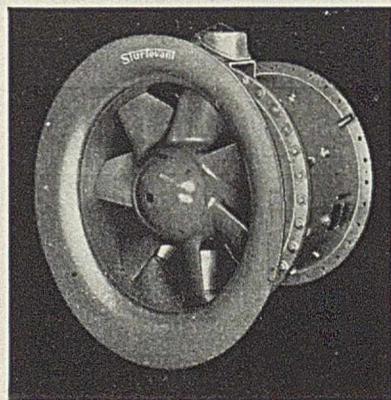
Model 30 Stabilog with Hyper-Reset



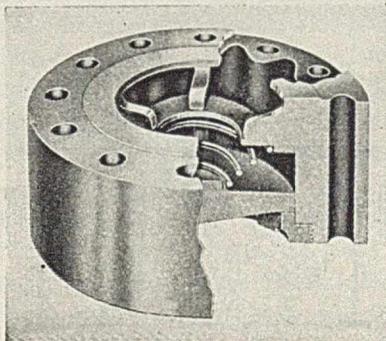
Motor for magnesium-dust locations



Victory Axiflo fan



Flat-disk check valve



Magnesium-Dust Motor

SUITABLE for use under magnesium-dust conditions, a new motor labelled as acceptable for Class II, Group E hazardous locations has been announced by General Electric Co., Schenectady, N. Y. These new polyphase induction motors are made in sizes from 1 to 20 hp. and are intended particularly for use in plants handling fine magnesium powders, as in the manufacture of incendiary bombs. The motors are totally enclosed, with a non-ventilated construction in the smaller ratings, and a fan-cooled construction above 2 hp. Dust-tightness is said to be achieved without complications. The motors feature non-sparking bronze external fans; relatively straight and smooth external ventilating passages in the fan-cooled motors; permanently sealed-in leads; and a rotating labyrinth seal at the shaft opening.

Equipment Briefs

A BUILT-IN chain reducer, with the output shaft in exact alignment with the input shaft, is now being offered in combination with a variable speed

transmission, in a special design manufactured by the Reeves Pulley Co., Columbus, Ind. Output speeds may either be increased or decreased, as compared to the variable speed shaft of the transmission. They are, of course, infinitely variable within predetermined limits by turning the speed control hand wheel. The chain drive operates in a bath of oil.

FOR USE where electric operation seems best fitted to the job, Clark Tractor Division of Clark Equipment Co., Battle Creek, Mich., is now prepared to supply electric-powered fork trucks, platform trucks and tractors. Formerly this company manufactured only gas-powered trucks. The new machines lift from 2,000 to 7,000 lb. using a hydraulic vane-type pump driven by a special series-wound motor. The same pump operates the tilting unit which enables the operator to tilt the load back 10 deg. in 5 second for safe riding, or tilt it forward 3 deg. in 1 second for tiering. Four speeds in either direction up to 6 m.p.h. under full load are standard.

A USEFUL ACCESSORY for heavy welding is a new holding magnet or magnetic welding clamp now available from Stearns Magnetic Mfg. Co., Milwaukee, Wis. The magnet is available in various sizes. For example, one of 10 in. diameter, weighing about 70 lb., exerts a pull of 2,000 lb. on $\frac{3}{4}$ and 1 in. steel plates. Through use of such a clamp it is said to be possible to draw the plates to level alignment with the edges brought flush against the perfect surface of the magnet. By tacking welds to the plates on either side of the magnet, the welder is able to maintain alignment readily and achieve quick results.

TWO NEW PIECES of air raid equipment are available from Specialties Mfg. Co., 35 Farrand St., Bloomfield, N. J. One is a 20-gal. barrel pump extinguisher mounted on wooden wheels, with carrying handles to permit its being carried upstairs by two people. The barrel is provided with a tight cover to prevent evaporation and a stirrup pump with a 12-ft. length of hose. An ax is included in the assembly. The other unit is a portable sand barrel for the extinguishment of incendiary bombs. Like the pump barrel, this consists of an open top barrel of approximately $2\frac{1}{2}$ cu.ft. capacity, mounted on wheels and equipped with handles for carrying upstairs. A long-handled shovel and an ax are part of the assembly.

Packing Material

RESILIENT packing material made of kraft paper stock, expanded into a honeycomb pattern so as to resemble expanded metal, has been introduced as a shipping packing material by Research Products Corp., Madison, Wis.

The material is light, uniform and easy to handle. The expansion process gives it a third dimension, and hence resilience. As shown in the accompanying view, it can be wrapped around double-curved objects, such as the chimney and bulb shown.

Motor-Operated Valve

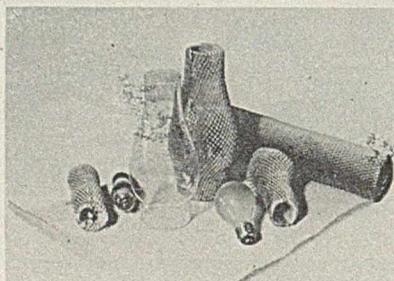
FOR PROCESS WORK where close regulation is required in the handling of steam, water, oil or gas, Barber-Colman Co., Rockford, Ill., has introduced the new Microvalve, a motor-operated valve with a proportioning type operator. The valve operator consists of one of this company's Microtrols, with the addition of an eccentric cam which operates the valve plunger. Valves are built in single-seat V-ported, double-seat V-ported, and double-seat, three-way designs.

Impact Crusher

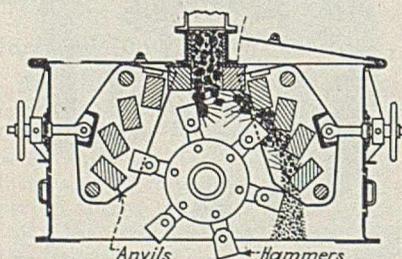
A NEW CRUSHER designed to operate almost entirely by impact, with a minimum of attrition and abrasion, has been introduced under the name of Reversible Impactor by the Pennsylvania Crusher Co., Liberty Trust Bldg., Philadelphia, Pa. According to the manufacturer, such a mill causes a particle rupture much like that produced by an internal explosion, normally giving a different particle shape than is obtained by plain, slow compression breaking. It is claimed to minimize over-grinding and to permit high reduction ratios.

The new mill consists of a rotor carrying swing hammers, on either side of which are arranged a group of heavy anvils against which the feed is batted by the hammers. The mill has no cage and thus material cannot be held in the mill and subjected to attrition. The larger pieces rebound into

Kraft paper packing material



New reversible impact mill



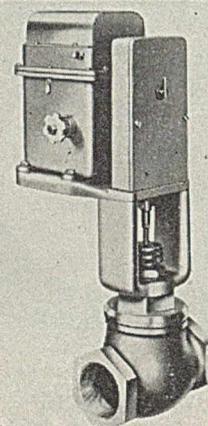
the beater circle and are repeatedly thrown against the anvils. Fines are removed from the mill by an air stream, and for best results the mill should be operated in closed circuit.

The novel feature of this design is the use of two groups of anvils, one arranged on either side of the machine. Feed enters at the center over the rotor and the direction of rotation determines which group of anvils is active. A reversing switch is provided so that the direction of rotation can be selected and either set of anvils used, in effect, giving two mills in one. Handwheels are provided at either side for quick adjustment of the anvils.

Automatic Scale

SEVERAL interesting features are obtainable in a new automatic weighing scale designed for rapid and accurate handling of coal and other free-flowing bulk materials, and manufactured by Beaumont Birch Co., Philadelphia, Pa. Material is conveyed from the feed hopper to a weighing hopper by means of a vibrating metal feeder deck which eliminates all rubber belts, pulleys and other rotating mechanisms. The scale is totally enclosed in a dust-tight, welded steel case, and is built in three standard sizes for handling quantities ranging from 1 to 30 tons per hour. On special order, larger sizes having weighing capacities up to 60 tons per hour can be furnished.

Electric-operated control valve



Automatic weighing scale

