TITLE OF REPORT Materials of Construction

TO Chemical Engineers and Equipment Designers

FROM Chem. & Met. Editors

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INTERPRETATION ❯ This report serves to bring chemical engineers up to date on the progress that has been made in recent years in the field of construction materials. The significant new developments and trends are summarized in the article commencing on this page. Properties of the ferrous and non-ferrous alloys are presented on the accompanying large wall chart. For each material is given the manufacturer's name and address, physical and mechanical properties, and resistance to corrosion of several of the most commonly encountered chemicals. Comparative prices of stainless steels, an important factor in the selection of a material, are included in this report for reference purposes. Non-metallic materials are grouped according to type; each is accompanied by such important information as manufacturer's name and address, physical and mechanical properties, and in some cases by corrosion resistance data.

New Developments and Trends

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Chemical & Metallurgical Engineering

Preparations for national defense are going to subject materials for the construction of chemical engineering equipment to the most severe test they have ever been called upon to meet. As this is being written government officials and their industrial advisors are working at a feverish pitch making plans and signing contracts. The big "push" is in its formative stage. Shortly the results of this great drive will begin to appear in the form of increasing industrial activity; new manufacturing plants will be built, existing ones will be forced to the limit of their endurance to produce more and more, pressures will be increased, temperatures raised, shut-downs for cleaning, inspection and repair will be reduced, "capacities" will be exceeded. Plant and equipment will be operated far beyond what was thought practical or even possible in normal times.

Can the materials of which the equipment is constructed stand the strain? One thing is certain, this severe service is going to require the best that is available. There will be no time for frequent replacement of the more readily corroded materials. Materials that were once considered economical to use because of their comparatively low initial cost will no longer be tolerated. Shut-downs for replacement will be too costly. The best available will be the most economical and will be demanded.

Far greater pressure on productive activity will be experienced during the next few years than was ever reached during the last World War. Everything will be done on a greater scale. Materials of construction that were adequate in 1917 and 1918 would not be able to stand the demands of 1940 service conditions, but unbelievable progress has been made in the 22 years. The whole field of materials of construction has passed through a transition, the significance of which most engineers have failed to appreciate. Not only have such long established materials as cast iron and steel been subjected to changes by the addition of other elements, but the renowned stainless steels were almost unheard of during the last crisis.

Even a few years ago, the most visionary chemical engineer could not have foreseen that such materials as carbon, glass, silver and synthetic resins would be used so extensively for the construction of large-scale equipment. The synthetic rubber and rubber-like materials were still laboratory curiosities. And great progress has been made in improving the characteristics of chemical stoneware, glass linings, cements, refractories, natural rubber, and other long established materials.

Volumes might be written about the evolution through which materials for the construction of chemical engineering equipment has been passing but it would be dull reading and of little practical value. The chemical engineer is more interested in the materials that are at present available and so we will confine our attention to a discussion of the present trends and new developments in the field of materials.

Cast iron has long been a standard material but the cast iron of today is not the cast iron of five or even three years ago, for the metallurgist has given it new and important characteristics by alloying it with nickel, chromium, molybdenum, copper and other metals. As a result of this modification several of the irons are satisfactory for use in corrosive media and at higher temperatures than heretofore. A small amount of chromium and nickel stabilize the structure of cast iron and then increase its toughness, strength and abrasion resistance. Larger amounts of these alloying materials render the iron truly resistant to attack of many chemicals.

TRENDS AMONG 18-8 ALLOYS

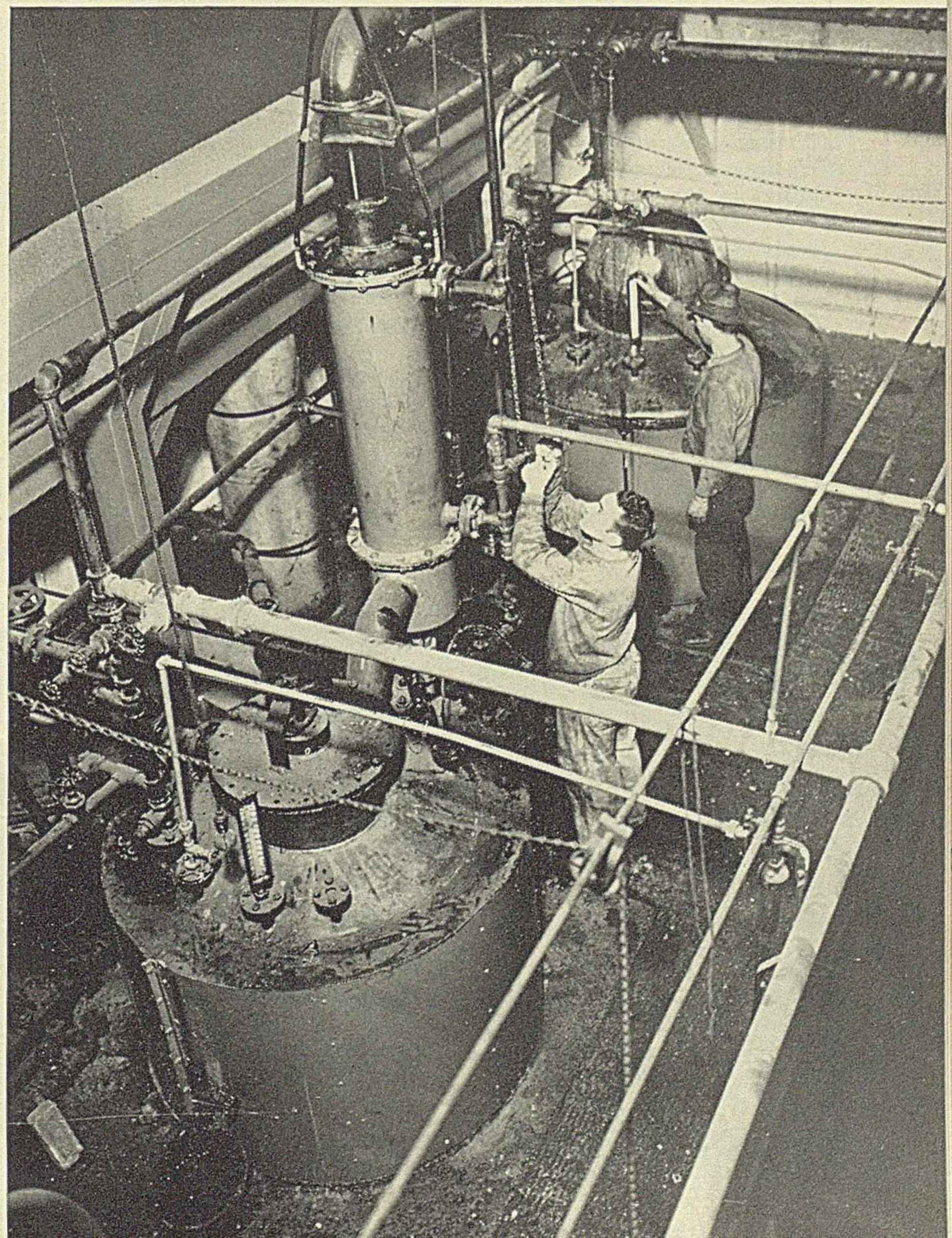
Ever since the 18 per cent chromium-8 per cent nickel alloy containing molybdenum first became available it has been in demand due to the added corrosion resistance conferred by the molybdenum. During the past two years the demand for this material has greatly increased. Since this alloy is susceptible to intergranular corrosion when exposed to a certain temperature range, industry has demanded that it be made immune to intergranular corrosion. This requirement has been met in the straight 18–8 alloys, as is well known, by the addition of columbium or titanium. However, it was only recently that additions of columbium were successfully made to the molybdenum bearing chromium-nickel alloys. These columbium bearing alloys are now available where the chrome-nickel-molybdenum types are necessary and must be free of any susceptibility to intergranular corrosion.

The uses of austenitic chromium-nickel steels which are cold worked to greatly increase their tensile properties for high strength, light weight applications are broadening rapidly. A low-temperature heat treatment below 600 deg. F. (normally practiced between 350-600 deg. F.) has been found materially to improve the elastic properties of the steel.

There is a trend toward raising the manganese in all types of austenitic steels to improve the hot ductility which is important in welding operations. Most of the specifications covering austenitic steels have been rewritten recently to allow 2½ per cent (maximum) manganese. This compares with an old maximum of 0.7 per cent. The increased amount of manganese has no detrimental effect on corrosion resistance, in fact it slightly improves the corrosion resistance with no significant change in physicial properties.

The petroleum refining industry requires alloy castings of the 24 per cent chromium-12 per cent nickel type for high temperature applications such as tube supports. The specifications for this material are unusually severe since they demand a material which has a high creep strength at temperatures as high as 1,800 deg. F. and good ductility after operating within a temperature range which normally tends to drastically reduce ductility. The industry has been aided in meeting these requirements by the addition of manganese in amounts of between 4 and 4½ per cent. It has also been shown that these conditions can be more easily met if part of the carbon is replaced by an equivalent amount of nitrogen.

Early reports that columbium improved the creep strength of the 4 to 6 per cent chromium steels have now been confirmed. This is of enormous importance to the petroleum refineries for they are large users of this



Operating under partial vacuum, these direct-fired, welded Inconel kettles process a high grade of linseed oil metal in the form of tubes and at high temperatures.

A development of more than passing interest is the approval and setting up of specifications covering certain grades of stainless steels for the construction of unfired pressure vessels by the boiler code committee of the A.S.M.E. The steels specified are types (Iron and Steel Institute numbers) 304, 316, 317, 321, 347. Their chemical composition may be found on page 603-604.

In recent months stainless-clad steel made by a new method was made general available. The Pluramelt process of the Allegheny Ludlum Steel Corp. produces single ingots of two or more compositions, integrally bonded together. These clad materials may be used to advantage for certain types of relatively heavy-wall equipment where solid stainless steel is not necessary or the cost would be prohibitive. Also for many applications where the slight contamination obtained from ordinary carbon steel is objectionable. Any of the corrosion-resistant steels are available on a plain steel base.

Developed originally for the fabrication of thin stainless steel for railroad cars and airplanes, the "Shotweld" process has recently been applied to the production of lightweight, high-strength stainless steel processing equipment. Because of the short time during which the weld area is in the dangerous temperature range, "shot" welded equipment ordinarily does not require subsequent heat treatment to maintain a satisfactory corrosion resistance. Applications include centrifugal baskets, materials handling containers, ducts, fume hoods, lids, kettles, tanks in wide variety, and rayon machinery.

NON-FERROUS METALS AND ALLOYS

The nickel alloys have been keeping up with the progress being made among materials in general. Inconel, Z nickel and K Monel have come into production in a greater variety of shapes. K Monel, a high-strength heat treatable alloy, is now available in the form of seamless tubing. It is useful in such applications as pump shafts, and valve disks and stems for high-temperature steam lines. Another use recently developed is for corrosion-resisting ball, roller and other types of bearings exposed to corrosive attack.

Z nickel is said to combine the corrosion resistance of nickel with the mechanical properties of heat-treated steel, having a strength from 2½ to 4 times that of ordinary structural carbon steel when heat treated.

Illium and Hastelloy C can now be obtained in a variety of rolled forms. And Hastelloy B is available in commercial quantities. Monel has been added to the list of materials available in clad form. Monel-clad steel is being used for drying equipment in salt refineries and for other purposes.

Methods for the attachment of sheet metal to steel surfaces either prior to or following fabrication of equipment are now being applied to the high nickel alloys. Considerable quantities are being used in petroleum refineries. The application of corrosion resistant sheet metal coverings on rolls, originally developed for paper machines, has been extended to covers of rolls for the chemical industry, such as flaker and dryer rolls.

The 70 per cent copper—30 per cent nickel (cupro nickel) condenser tubes used so extensively in marine service are now being applied in the chemical industry to take care of abnormally severe conditions on either the cooling medium or vapor side.

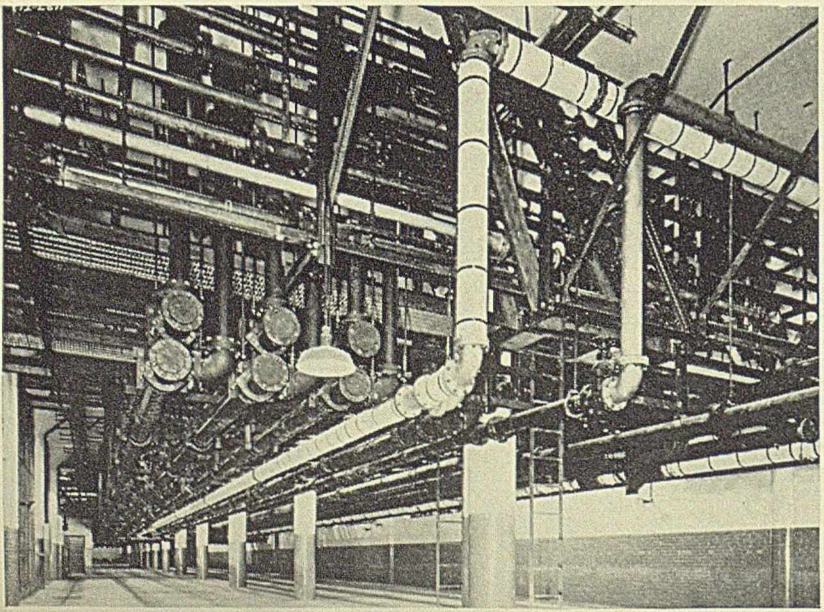
There has been a useful addition to the Ni-Resist family in the form of 30 per cent nickel iron which because of its relatively low expansion is used in process industry equipment which is subjected to thermal shock associated with rapid changes of temperature.

Nickel castings are being made which have improved gall resisting characteristics. They are being used in pumps and other equpiment where it is necessary for moving parts to run in close contact, for example stuffing boxes in autoclaves. There is also increasing use of S Monel castings where resistance to galling is important.

The American Silver Producers' Research Project has concentrated on the development of a pore-free silver plate shipping container. It is said that deposits of 0.001 in. thick on deep drawing steel are readily obtainable.

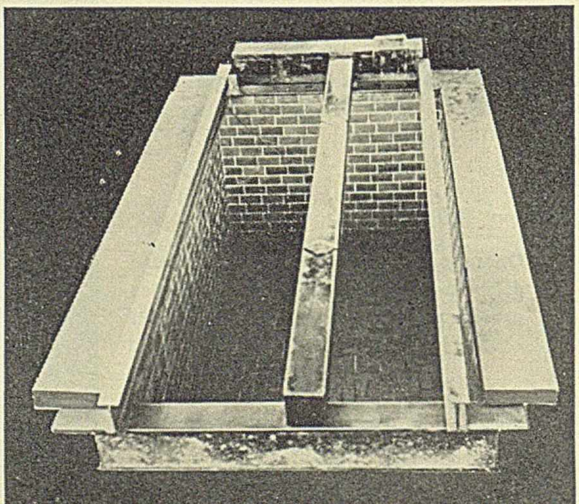
New possibilities in the use of light-weight materials for many purposes have been opened by recently developed methods for the plating of aluminum sheets with nickel and with nickel and chromium. This development makes it possible to utilize the mechanical properties and light weight of aluminum and widens the range of corrosive conditions where aluminum can be used in the chemical industries.

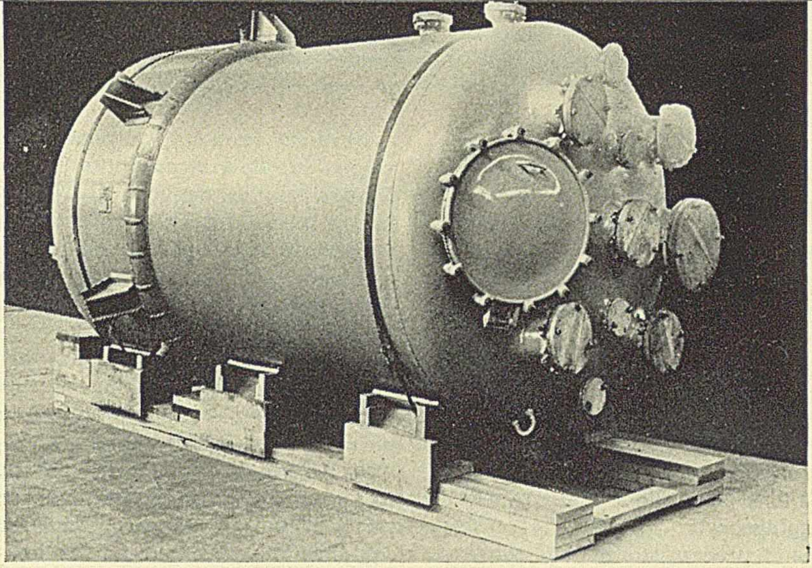
Another development that is just now completed is the hot dipping of steel sheets in molten aluminum to give a coated sheet. It should offer the strength of the base steel with the corrosion resistance of the aluminum.



Over 12 miles of hard rubber pipe and fittings in a rayon plant

Acid-proof brick (laid in acid-proof cement) tank for chromium plating





A 2,000-gal. glass-lined steel tank for high-pressure operation. Note large number of openings in the top head once thought impossible

When long life in hard service and absolute purity of product are required, noble-metal clad material is now available in a variety of forms (rod, wire, seamless tubing, sheet, etc.) and chemical equipment is now being fabricated from these forms.

Seamless composite tubing up to 1¼ in. pipe size and sheet up to 4 ft. x 8 ft. are available; the noble metal layer may be any thickness down to 0.002 in. For larger pipes and vessels liners of noble metal are inserted; the liners may be attached by soldering or welding, or may simply be inserted as a separate liner. The coatings may be platinum, iridio-platinum, palladium, gold, gold-platinum alloys, etc., and the base metals may be copper, brass, nickel and nickel alloys, steel, etc. The original cost of such noble clad materials is naturally somewhat higher than base metal but the high, readily-realizable scrap value makes them a real commercial proposition.

Up to the present time much of this clad material is finding use in heat exchangers and similar equipment; also for valves, frangible disks, thermometer wells, electrodes, autoclaves. Where special purity is needed in certain fine chemicals and pharmaceuticals platinum clad vessels have been found essential.

CHEMICAL STONEWARE AND PORCELAIN

The steady improvement in the long-established equipment materials, while less spectacular, is no less important to the chemical industries. Stoneware has many points in its favor in comparison with other equipment materials and it is almost invariably much less expensive. The common practice in such cases is to use stoneware up to the limit of size that is available. It seems probable that 1,600 gallons is close to the practicable limit of size for stoneware vessels as manufacturing difficulties increase enormously with increased dimensions. However, in regular production the limit is probably between 800 and 1,000 gallons depending on the shape and the purpose for which it is to be used.

The advantage of stoneware as an equipment material may often be extended to larger units by using it in the form of a protective lining for shapes built of concrete, brick, metal or other base.

In recent years much greater accuracy is possible in making stoneware equipment. The manufacturer is able not only to maintain dimensions within a tolerance of ± 2 per cent but by far the greater part of his products is kept within much closer limits. This uniformity makes possible the fabrication of extremely complicated shapes that were heretofore impracticable and also the grinding and polishing of the finished ware to a precision comparable with that obtainable with metals.

The most noteworthy achievement in the field of chemical stoneware has been the development of new ceramic bodies to meet the increasingly severe operating conditions that the chemical engineering progress has demanded. Ware made from cordierite has a thermal expansion much below that of the average grade of chemical stoneware and consequently will withstand thermal abuse that would be impossible with the regular product. This ware has the further advantage that the absorption is practically nil, it is much stronger than the regular product and has excellent resistance to caustic solutions.

Stoneware containing a large amount of silicon carbide is now available with much higher thermal conductivity, and with an absorption comparable with that of the regular grade of stoneware. It can be glazed either the conventional brown color or white and a method has been developed for grinding it. This new ware is about four times as strong as former products and will withstand almost any kind of thermal abuse between atmospheric temperature and about 400 deg. C.

A development of the last two years is a line of chemical porcelain ware which is now available in numerous types and sizes of plant equipment such as pipe, fittings, valves, jars, kettles, pots, filters and tower packings. Described as a true hard porcelain, the body employed is of extremely high mechanical strength and zero absorption. Being unaffected by all acids except hydrofluoric, and resistant to alkalis, the new ware is being advanced by the manufacturer for a wide variety of severe applications.

GLASS AND GLASS-LININGS

In the process industries glass was once limited to use in the laboratory, but within recent years although it may not be fully realized, glass has become employed to a very considerable extent as a chemical engineering material. This is in part due to the improved technique of manufacture which makes possible shapes and weights of single pieces previously considered impossible.

It is only in recent years that stills, absorbers and columns, valves, pumps, industrial piping and fittings, heat exchangers, filter blankets and a variety of other equipment made of glass have been available for plant service. Glass is perhaps most widely used in the form of piping which is available in 1, 1½, 2, 3, and 4 in. inside diameters, and in lengths of up to 10 ft. Joints are easily assembled and of rugged construction. The assembled piping is suitable for 100 lb. per sq. in. maximum working pressure in the sizes up to 3 in. and 75 lb. per sq. in. for the 4 in. size.

An entirely new method of glass manufacture yielding products which can be heated to cherry red and then plunged into ice water without breaking was announced a year ago. Since then considerable progress has been made with this new ultra-low expansion glass, Vycor, and a limited supply of laboratory ware is now available. The outstanding significance of this glass is that it offers in an economical price range a material similar to fuzed quartz. Its thermal expansion per degree centigrade is 0.080×10^{-5} and the softening temperature is about 2,750 deg. F.

Another recent development is glass fiber for use in filtering liquids and gases or as thermal insulation. Density of packing determines heat transmission.

Glass-lined steel equipment for use in the chemical process industries has made definite progress in development during the past year, particularly as regards a substantial increase in the maximum unit size offered for servere acid conditions. Units of 2,000 gallon capacity are now available as standard equipment and even larger units have been fabricated according to special design.

This increase in size has been accomplished by a broadened range of related working pressures, as permitted by improved technique in fabricating and enameling where greater thickness of steel is concerned.

Yet another comparatively recent improvement is the adoption by at least one manufacturer of a far more drastic test specification than ever before, namely that glass enamel for severe acid service must pass a 20,000 volt electric test. As a result flaws of even microscopic proportions can be discerned and corrected. This results in a greater service life of equipment.

STRUCTURAL CARBON AND GRAPHITE

The use of structural carbon and graphite in recent years has sharply increased for a wide variety of process industry applications. Brick, blocks, tile and special shapes of carbon and graphite are being used for complete towers, for lining of towers, vats, tanks and digesters, for atmospheric condensers and electrostatic precipitators. Tubes and pipes find their applications in the handling of corrosive fluids and in the construction of heat exchangers ranging from simple to complex.

Many carbon and graphite articles are made impervious by special treatments, which change their characteristics to some extent. The product known as Karbate has its porosity reduced to practically zero and permeability eliminated. Its strength is about double that of the base material. To date Karbates are not available in all sizes in which the base materials are made. However, to give some idea of available sizes, tower sections up to 24 in. O. D. can be produced. Large plates, tanks, etc., have been produced by cementing slabs together. Individual slabs run to 6 ft. in length. The widest application of Karbates is in pipe form. A complete line of pipe and fittings from ½ in. I. D. to 6 in. I. D. is available. Threaded or flanged connections are regularly used. With a small amount of practice, a maintenance crew can cut, thread, and fit lines without undue breakage or difficulty.

RUBBER AND SYNTHETIC RUBBER

Since the last World War hard and soft rubber linings for industrial applications have been developed to a point where they are being advantageously applied to many types of process, storage and conveying systems. Rubber compounds capable of meeting more severe conditions of service have been made available to industry. And hard rubber equipment has found an ever increasing demand from chemical engineers in the process industries.

The national emergency is focusing the attention of the entire country on the importance of the synthetic rubber-like products. Pyroflex, neoprene, Koroseal, Pliolite, Resistoflex Buna Ameripol and other such materials are all newcomers. To the chemical engineer these interesting products not only offer substitutes in the event that the United States is cut off from the sources of supply of natural rubber, but also make available materials with certain characteristics not possessed by any other products.

For the most part the synthetic rubbers are useful in the chemical industries where the physical properties of rubber are desirable along with resistance to solvents, hydrocarbons and other chemicals that attack natural rubber. They are being used alone or compounded with rubber. At present they find their widest application in the form of molded articles, hose, hose linings and fabric coatings. Several of these new materials are being used for lining tanks.

While the phenolic resins were developed in 1907 it was not until a few years ago that they were employed for the construction of equipment. Today they are used in the heavy chemical, pulp and paper and other process industry plants. If the story could be told of how extensively this type of material is being used it would surprise many engineers.

The molded resins are resistant to solvents, acids, alkalis, and are tough, hard, and durable. The laminated resins serve many purposes. They resist the attack of most chemicals—acids, solvents and oils. They are unaffected by most organic acids and dilute mineral acids.

Phenolic resinous equipment, Haveg, is supplied in one piece molded construction in single units ranging in size from a quart dipper to a 5,000 gallon tank. The finished vessels have a compact, impervious, homogeneous structure with smooth jointless surfaces. Large equipment is provided by assembling flanged units to provide practically any size or shape of tank required. Other applications include: pipe, valves, absorbing and scrubbing towers, agitators and stirrers, crystallizing dishes, drying trays, evaporating and concentrating equipment, fume duct, and fan housings, rolls, reels and textile dyeing equipment.

Several of the other new plastics are finding uses in the process industries. For example, cellulose nitrate is being used to shield underground pipe lines against soil corrosion. A three-year test on a long line, in a soil known to be highly corrosive, proved very successful. Lucite is used in the fabrication of pumps and is said to be satisfactory for handling some chemicals.

Now that the vinyl resin fiber filter cloth has passed the experimental stage, its application to numerous types of filtration is growing. Because of its acid and alkali resistance the use of Vinyon filter cloth in processes involving strong acid or alkali solutions eliminates the expense of frequent replacements and the cost of idle equipment while changing filter blankets. The synthetic resin filter fabrics are now being used in connection with dyestuffs, bleaches, pigments, pharmaceuticals, concentrated caustics, phosphoric acid and other chemicals that are often handled.

Synthetic resins are being used as protective coatings. The new anticorrosive paints are based, besides general durability, on moisture and alkali resistance and the presence of inhibitors in the pigment.

A MASS ATTACK ON CORROSION

Supplementing the efforts of the metal, stoneware, glass, rubber and other materials of construction producers to develop new materials with improved mechanical properties and greater corrosion resistance is an investigation of the subject of corrosion by numerous technical societies, government bureaus, research laboratories of material producers and other organizations. These bodies are making a mass attack on the fundamental and practical aspects of the causes and prevention of corrosion.

So numerous have these efforts become that two years ago the American Coordinating Committee on Corrosion was formed to coordinate research activities in this extremely interesting field. It is patterned after similar organizations in England, Holland, Belgium and other countries abroad, and is sponsored by and composed of delegates of 20 or more organizations interested in corrosion. The purposes of the Committee are: (1) To serve as a clearing house and coordinating agency for information on experience and work in progress in this country in the field of corrosion and corrosion prevention; (2) To compile a list of the names and addresses of all individuals in America working in the field of corrosion, together with information as to their special interest (This directory has now been completed); (3) To serve as an agency for the exchange of corrosion information and experience with similar foreign agencies such as the Corrosion Committee of the British Iron and Steel Institute, and (4) to serve as a medium through which individual workers may make contact with other investigators here and abroad in specific fields of corrosion work.

The sponsoring organizations are:
American Chemical Society
American Electroplaters Society
American Foundrymen's Association
American Gas Association
American Institute of Chemical Engineers
American Institute of Electrical Engineers
American Institute of Mining and Metallurgical Engineers
American Society of Heating and Ventilating Engineers
American Society of Mechanical Engineers
American Society of Refrigeration Engineers
American Society of Metals
American Society for Testing Materials
American Water Works Association
Battelle Memorial Institute
Electrochemical Society
Mellon Institute of Industrial Research
National Bureau of Standards
National District Heating Association
Society of Automotive Engineers
Technical Association of the Pulp and Paper Industry

In addition to these agencies that are actively engaged in corrosion investigations, many producers of materials of construction have extensive research laboratories which are engaged in corrosion studies in an effort to improve the resistance of the companies' products and to determine their suitability for various corrosive mediums.

Many of the plants of the process industries are constantly engaged in research and development of their own. The larger companies have staffs who devote their entire time to the consideration of the corrosion of equipment and to the application of the recently introduced materials that are offered to prevent attack from acids and other chemicals.

METALS AND ALLOYS

Of all available materials of construction, the group composed of metals and alloys is by far the most extensively used. Many of the physical and chemical data and much trade information which chemical engineers need to know about those corrosion, heat and abrasion resisting materials have been condensed for the large wall which has been folded and inserted under the front cover of this issue of *Chem & Met*.

PRICES OF STAINLESS STEELS

One of the determining factors in the selection of a material from which to construct equipment for use in the chemical industries is price. When several materials are of equal suitability from all other considerations the engineer naturally chooses the one that is obtainable at the lowest cost. For the purpose of assisting in the selection, the current prices of some of the stainless steels in wrought form are given in the accompanying table. While these prices may change slightly from time to time it is probable that their relation, one to another, will continue as at present. It is essential to keep in mind that these are base prices of the steels in the form of plates, sheets, cold rolled, strip, and so forth. And while the prices are comparable and therefore offer a useful guide, when selecting materials of construction other factors enter into the delivered cost of the alloy steel sheet, bar, wire, or other form. To the base price of the steel must be added extra charges that are due to such factors as quantity of the material ordered, the degree of surface finished specified and whether one or both sides are polished, width, length and thickness. It is sometimes necessary to specify other requirements that add to the cost. Among those that should be mentioned are: close tolerance, testing, packing, machining, perforation, cutting to size, and in the case of bars, shape. While this list of extras may appear to be long the average added cost for extras rarely prohibits the use of the steel for the purpose in mind.

COMPARATIVE PRICES OF STAINLESS STEELS

Type No.	Carbon	Chrome	Nickel	Other Elements	Bars Drawn Wire Structurals	Plates	Sheets	Hot Rolled Strip	Cold Rolled Strip	Forging Billets
301	.09-.20	16.00-18.00	7.00- 9.00	Mn. 1.25 Max.	24c	27c	34c	20¼c	25½c	20.40c
302	Over .08-.20	17.50-20.00	8.00-10.00	Mn. 1.25 Max.	24c	27c	34c	21½c	28c	20.40c
302B	Over .08	17.50-20.00	8.00-10.00	Si 2.00-3.00 Mn 1.25 Max.	24c	27c	34c	21½c	28c	20.40c
303	.20 Max.	17.50-20.00	8.00-10.00	S or Se .07 Min or Mo .60 Max.	26c	29c	36c	27c	33c	22.10c
304	.08 Max.	18.00-20.00	8.00-10.00	Mn. 2.00 Max.	25c	29c	36c	23½c	30c	21.25c
308	.08 Max.	19.00-22.00	10.00-12.00	Mn. 2.00 Max.	29c	34c	41c	28½c	35c	24.65c
309	.20 Max.	22.00-26.00	12.00-14.00	....	36c	40c	47c	37c	47c	30.60c
309S	.08 Max.	22.00-26.00	12.00-14.00	....	40c	44c	51c	41c	51c	34.00c
310	.25 Max.	24.00-26.00	19.00-21.00	....	49c	52c	53c	48¾c	56c	41.65c
311	.25 Max.	19.00-21.00	24.00-26.00	....	49c	52c	53c	48¾c	56c	41.65c
312	.25 Max.	27.00-31.00	8.00-10.00	....	36c	40c	49c	....	....	30.60c
315	.15 Max.	17.00-19.00	7.00- 9.50	Cu. 1.00-1.50 Mo 1.00-1.50	36c	42c	46c	....	....	....
316	.10 Max.	16.00-18.00	10.00-14.00	Mo 2.00-3.00	40c	44c	48c	40c	48c	34.00c

COMPARATIVE PRICES OF STAINLESS STEELS (Continued)

Type No.	Carbon	Chrome	Nickel	Other Elements	Bars Drawn Wire Structurals	Plates	Sheets	Hot Rolled Strip	Cold Rolled Strip	Forging Billets
317	.10 Max.	18.00-20.00	10.00-14.00	Mo 3.00-4.00	50c	54c	58c	50c	58c	42.50c
321	.10 Max.	17.00-20.00	7.00-10.00	Ti Min 4xC	29c	34c	41c	29¼c	38c	24.65c
325	.25 Max.	7.00-10.00	19.00-23.00	Cu 1.00-1.50	26c	30c	37c	26¼c	34c	22.10c
327	.25 Max.	25.00-30.00	3.00- 5.00	....	31c	36c	42c	30¾c	41c	26.35c
329	.10 Max.	25.00-30.00	3.00- 5.00	Mo 1.00-1.50	36c	40c	44c	36c	45c	30.60c
330	.25 Max.	14.00-16.00	33.00-36.00	....	49c	52c	53c	....	....	41.65c
347	.10 Max.	17.00-20.00	8.00-12.00	Cb 10xC	33c	38c	45c	33c	42c	28.05c
403	.15 Max.	11.50-13.00	....	Turbine Quality	21½c	24½c	29½c	21¼c	27c	18.275c
405	.08 Max.	11.50-13.50	....	Al .10-.20	20c	23c	28c	19¾c	25½c	17.00c
406	.15 Max.	12.00-14.00	....	Al 4.00-4.50	23c	26c	31c	22¾c	31c	19.55c
410	.15 Max.	10.00-14.00	....	....	18½c	21½c	26½c	17c	22c	15.725c
414	.15 Max.	10.00-14.00	2.00 Max.	....	18½c	21½c	26½c	17c	22c	15.725c
416	.15 Max.	12.00-14.00	....	S or Se .07 Min or Mo .60 Max.	19c	22c	27c	18¼c	23½c	16.15c
418	.15 Max.	12.00-14.00	....	W 2.50-3.50	Prices	quoted upon	application			
420	Over .15	12.00-14.00	....	....	24c	28½c	33½c	23¾c	36½c	20.40c
420F	Over .15	12.00-14.00	....	S or Se .07 Min or Mo .60 Max.	24½c	....	....	....	....	....
430	.12 Max.	14.00-18.00	....	....	19c	22c	29c	17½c	22½c	16.15c
430F	.12 Max.	14.00-18.00	....	S or Se .07 Min or Mo .60 Max.	19½c	22½c	29½c	18¾c	24½c	16.575c
431	.15 Max.	14.00-18.00	2.00 Max.	....	19c	22c	29c	17½c	22½c	16.15c
438	.12 Max.	16.00-18.00	....	W 2.50-3.50	Prices	quoted upon	application			
439	.50-.65	8.00	....	W 8.00	Prices	quoted upon	application			
440	Over .12	14.00-18.00	....	....	24c	28½c	33½c	23¾c	36½c	20.40c
441	Over .15	14.00-18.00	2.00 Max.	....	24c	28½c	33½c	23¾c	36½c	20.40c
442	.35 Max.	18.00-23.00	....	....	22½c	25½c	32½c	24c	32c	19.125c
446	.35 Max.	23.00-30.00	....	....	27½c	30½c	36½c	35c	52c	23.375c
501	Over .10	4.00-6.00	....	....	8c	12c	15¾c	12c	17c	7.20c
502	.10 Max.	4.00-6.00	....	....	9c	13c	16¾c	13c	18c	8.10c

When carbon content .11 or under is specified or required in Types 301, 302 and 302B, the price of Type 304 applies.
No specific composition limits within the above ranges may be placed on Types 301, 302, 302B and 303 except that carbon may be specified to a four point range within the above limits.

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 10^5)	Hardness*	Thermal Expansion Per °C. (Multiply by 10^{-5})	Thermal Cond., Cal. per sec., cm.², °C., cm. (Multiply by 10^{-4})	Specific Heat, Cal. per °C., gm.	Softening Point, °F.	Breakdown Voltage, 60 cycles, v. per mil	Dielectric Constant, 60 cycles	Refractive Index, n_{AD}	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	35	0.25	2,600	500 (¼ in.)	Approx. 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 (¼ 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
Alsop Engineering Co., Milldale, Conn.	Glass-lined steel tanks and mixers
Amersil Corp., Hillside, N. J.	Fused silica ware such as pans, pipes, gas coolers, absorbers
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
Ertel Engineering Co., New York, N. Y.	Glass-enameled tanks
General Electric Co., Schenectady, N. Y.	Transparent fused quartz in various small sized articles
Glascote Products, Inc., Euclid, Ohio	Glass-enameled steel equipment
Hanovia Chemical & Mfg. Co., Newark, N. J.	Transparent fused quartz in all shapes
Metal-Glass Products Co., Belding, Mich.	Glass-enameled steel equipment
Owens-Corning Fiberglas Corp., Toledo, Ohio	Fibrous glass filter cloths and dust filters
The Pfaudler Co., Rochester, N. Y.	Wide variety of standard and special glass-enameled steel equipment—various formulas
A. O. Smith Corp., Milwaukee, Wis.	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

CHEMICAL STONEWARE, PORCELAIN, CEMENTS

PHYSICAL PROPERTIES OF CHEMICAL STONEWARE AND PORCELAINWARE

Chemical Stoneware

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.

Specific gravity	2.2	Modulus of elasticity, lb. per sq. in.	8,000,000
Hardness, scleroscope	100	Specific heat	0.2
Ultimate tensile strength, lb. per sq. in.	2,000	Thermal cond., B.t.u. per hr., sq. ft.,°F., in.	10.0
Ultimate compressive strength, lb. per sq. in.	80,000	Linear thermal expansion, per °F	0.0000020
Modulus of rupture, lb. per sq. in.	5,000	Water absorption, per cent	0-4

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	0.0000023
Water absorption, per cent	0

MAKERS OF CHEMICAL STONEWARE, PORCELAIN, ACIDPROOF BRICK AND STONE

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

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; 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 all acidproof construction
Charlotte Chemical Labs., Charlotte, N. C.	Charlab, Acipruf, Carolina	Standard and chemical-setting silicate cements; acidproof putty
Chemical Construction Corp., New York, N. Y.	Acipruf	Acidproof cement
Custodis Construction Co., Inc., New York, N. Y.	Custodis resin cement, Penchlor, Asplit	Synthetic resin, sodium silicate & phenolic base cements, resp.
Electro-Chemical Supply & Engineering Co., Paoli, Pa.	Duro Standard, Triple X	Cements for all acid 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	Self-hardening phenolic resin cements for acids
M. W. Kellogg Co., New York, N. Y.	.....	Acidproof cement
Maurice A. Knight, Akron, Ohio	Knight	Silicate cements for strong acids
Nukem Products Co., New York, N. Y.	Basolit, Nu-Mastic asphalt, Plasul-Basolit	Sulphur-base cement for acids, resin cements
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

MAKERS OF CEMENTS AND PUTTIES (Continued)

MANUFACTURER	Trade Names	Compositions, Applications, Types
Quigley Co., New York, N. Y.	Acidproof Nos. 1 and 2	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	U. S. Standard, Pre-Mixt, Calktite and others	Silicate cements of all types, resin cements, putties, etc.

CORROSION-RESISTANT PLASTICS

REPRESENTATIVE MAKERS OF MOLDING AND CASTING RESINS FOR CHEMICAL PLANT USE

MANUFACTURER	Trade Name and Type
MOLDING AND EXTRUSION MATERIALS	
American Cyanamid Co., New York, N. Y.	**Melamac**, melamine
Bakelite Corp.*, New York, N. Y.	**Bakelite**, phenolic and polystyrene
Carbide & Carbon Chem. Corp.*, New York	**Vinylite**, vinyl chloride and acetate
Continental Diamond Fibre Co., Newark, Del.	**Celeron**, phenolic
Dow Chemical Co., Midland, Mich.	**Ethocel**, ethyl cellulose **Styron**, polystyrene **Saran**, vinylidene chloride
E. I. duPont de Nemours & Co., Wilmington, Del.	**Lucite**, methacrylate
Durez Plastics & Chem. Inc., N. Tonawanda, N. Y.	**Durez**, phenolics
General Electric Co., Pittsfield, Mass.	**Textolite**, phenolic
Hercules Powder Co., Wilmington, Del.	**Hercules**, ethyl cellulose
Heresite & Chemical Co., Manitowoc, Wis.	**Heresite**, phenolic
Irvington Varnish & Ins. Co., Irvington, N. J.	**Cardolite**, cashew nut derivative
Monsanto Chemical Co., Indian Orchard, Mass.	**Monsanto**, polystyrene **Resinox**, phenolic
Reichhold Chemicals, Inc., Detroit, Mich.	**Beckacite**, phenolics
Reilly Tar & Chemical Co., Indianapolis, Ind.	**Indur**, phenolic
Rohm & Haas Co., Philadelphia, Pa.	**Crystalite**, acrylate
CAST RESINOIDS	
Bakelite Corp.*, New York, N. Y.	**Bakelite**, phenolic
Catalin Corp., New York, N. Y.	**Catalin**, phenolic
E. I. duPont de Nemours & Co., Wilmington, Del.	**Lucite**, methacrylate
Haveg Corp., Newark, Del.	**Haveg**, phenolic equipment
Marblette Corp., Long Island City, N. Y.	**Marblette**, phenolic
Monsanto Chemical Co., Indian Orchard, Mass.	**Monsanto**, phenolic
Rohm & Haas Co., Philadelphia, Pa.	**Plexiglas**, acrylate

* Unit of Union Carbide & Carbon Corp.

REFRACTORY MATERIALS

PHYSICAL PROPERTIES OF REFRACTORY MATERIALS

(Complete revision of earlier Chem. & Met. data, compiled by L. J. Trostel, General Refractories Co., Baltimore)

Type of Brick	Silica	High Heat Duty (No. 1) Fireclay	High Heat Duty (No. 1) Kaolin	Super Duty Fireclay	Alumina-Diaspore, 70 PerCent Al_2O_3	Sillimanite (Mullite)	Chrome	Unburned Chrome	Magnesite	Unburned Magnesite	Bonded Silicon Carbide (Grade A)	Bonded Fused Alumina	Insul. Firebrick (2,600°F.)
Typical composition, per cent													
SiO_2	96	50-57 [1]	53	52 [1]	22-26	35	6	5	3	5	7-9	8-10	50-57
Fe_2O_3	1	1.5-2.5	2	1	1-1.5	0.5	......	......	6	8.5	0.3-1	1-1.5	1.5-2.5
FeO	......	......	......	......	......	......	15	12	......	......	......	......	......
Al_2O_3	1	36-42	42	43	68-72	62	23	18	2	7.5	2-4	85-90	36-42
TiO_2	......	1.5-2.5	2	2	3.5	1.5	......	......	......	......	1	1.5-2.2	1.5-2.5
CaO	2	......	......	......	......	......	......	......	3	2	......	......	......
MgO	......	......	......	......	......	......	17	32	86	64	......	......	......
Cr_2O_3	......	......	......	......	......	......	38	30	......	10	......	......	......
SiC	......	......	......	......	......	......	......	......	......	......	85-90	......	......
Flux[2]	......	1-3.5	1	2	1-1.5	0.5	......	......	......	......	1.5	0.8-1.3	1-3.5
P.C.E. (with approx. equivalent temp., °F.)[3]	31-32 (3,056-3,092°)	31-33 (3,056-3,173°)	33-34 (3,173-3,200°)	33-34 (3,173-3,200°)	36-37 (3,290°)	37-38 (3,308-3,335°)	41+ (3,578°+)	41+ (3,578°+)	41+ (3,578°+)	41+ (3,578°+)	39 (3,389°)	39+ (3,389°+)	29-30 (2,984-3,002°)
Deformation under load,[4] per cent (at lb. per sq. in. and temp., °F., shown)	Shears 25 p.s.i. 2,900°	2.5-10* 25 p.s.i 2,460°	6-7 25 p.s.i. 2,640°	2-4† 25 p.s.i. 2,640°	1-4† 25 p.s.i. 2,640°	0.0-0.5† 25 p.s.i. 2,640°	Shears 28 p.s.i. 2,740°	Shears 28 p.s.i. 2,955°	Shears 28 p.s.i. 2,765°	Shears 28 p.s.i. 2,940°	0-1 50 p.s.i. 2,730°	1 50 p.s.i. 2,730°	0.3 10 p.s.i. 2,200°
Resistance to spalling, per cent[9]	Poor	5-20	5-15	0-4	No loss	No loss	Poor	Fair	Poor	Fair	Good	Good	Good
Permanent linear change on reheating[5] (after 5 hr. at temp., °F., shown)	(+) 0.5-.8 2,640°	(±) 0-1.5 2,550°	(−)0-1.5 2,550°	(±) 0-1.5 2,910°	(−) 2-4 2,910°	(−) 0-0.8 2,910°	(−) 0.5-1 3,000°	(−) 0.5-1.0 3,000°	(−) 1-2 3,000°	(−) 0.5-1.5 3,000°	(+) 2 [6] 2,910°	(+) 0.5 2,910°	(−) 1.5 [8] 2,550°
Porosity (as open pores), per cent	20-30	15-25	24-28	12-15	27-36	20-25	20-26	10-12	20-26	10-12	13-28	20-26	75
Weight per brick (std. 9 in. straight), lb.	6-6.5	7.5	7-7.5	8.5	7.5-8.5	8.5	11	11.3	10	10.7	8-9.3	9-10.6	2.25-3
Specific heat (60-1,200°F.)	0.23	0.23	0.22	0.23	0.23	0.23	0.20	0.21	0.27	0.26	0.20	0.20	0.22
Relative slag resistance[7]													
Acid steel slag	Good	Fair	Fair	Fair	Good	Good	Poor	Poor	Poor	Poor	Good	Good	Poor
Basic steel slag	Poor	Poor	Poor	Poor	Fair	Fair	Good	Good	Good	Good	Good	Good	Poor
Mill scale	Fair	Poor	Fair	Good	Fair	Fair	Good	Good	Good	Good	Fair	Fair	Poor
Coal ash slag	Poor	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Good	Good	Good	Good	Poor

[1] Higher in some districts. [2] Includes CaO + MgO + alkalis. [3] Pyrometric Cone Equivalent; terms "fusion," "softening," "deformation," and "melting" points heretofore loosely used. [4] Data marked (*) are from A.S.T.M. test C 16-36 with High Heat Duty time-temperature schedule; those marked (†) are from same test with Super Duty time-temperature schedule; others determined by other commonly used tests. [5] (+) means expansion; (−) means shrinkage. [6] Oxidizing atmosphere. [7] Ratings affected somewhat by varying temperatures and type of atmosphere prevailing. Resistance to coal ash slag affected by furnace temperature as well as analysis and fusion point of slag. [8] After 24 hr. [9] Loss in appropriate A.S.T.M. Panel Test.

REPRESENTATIVE MAKERS OF REFRACTORIES AND HIGH TEMPERATURE MORTARS

MANUFACTURER	Principal Types
Acme Brick Co., Ft. Worth, Tex	Firebrick and clay, h.t. cements, plastic refrs.
Alberene Stone Corp. of Va., New York, N. Y.	Refractory linings
American Crucible Co., Shelton, Conn	Graphite crucibles, silica and mullite refrs.
Armstrong Cork Co., Lancaster, Pa	Refr. insul. brick, h.t. mortars, 1,800 deg. insul. block and cement
Atlas Lumnite Cement Co., New York, N. Y.	Cement for refr., heat-resisting and insul. concrete
Babcock & Wilcox Co., New York, N. Y	Glass plant refrs., h.t. mortars, plastic refrs., insulating and kaolin refrs.
Bartley Crucible & Refr. Co., Trenton, N. J.	Graphite crucibles, firebrick, magnesite refrs.
Betson Plastic Fire Brick Co., Buffalo, N. Y.	H.t. mortars, plastic refrs.
Botfield Refractories Co., Philadelphia, Pa	Chrome, firebrick, plastic refrs., h.t. mortars
Philip Carey Co., Lockland, Ohio	H.t. mortars, insulations
Carborundum Co., Perth Amboy, N. J	Silicon carbide, aluminum oxide, mullite and fused cast refrs. and h.t. mortars
Champion Spark Plug Co., Detroit, Mich	Sillimanite plastic refrs., electric furnace refrs.
Corhart Refractories Co., Louisville, Ky	H.t. mortars, electro-cast mullite refrs.
Corundite Refractories, Inc., Massillon, Ohio	Firebrick, h.t. mortars, plastic refrs, alumina, silica and mullite refrs.
Denver Fire Clay Co., Denver, Colo	Firebrick, diaspore and sillimanite refrs., h.t. mortars, plastic refrs., fireclays
W. S. Dickey Clay Mfg. Co., Kansas City, Mo.	Fireclay refrs.
Joseph Dixon Crucible Co., Jersey City, N. J.	Graphite crucibles
Ehret Magnesia Mfg. Co., Valley Forge, Pa	H.t. mortar
Electro Refrs. & Alloys Corp., Buffalo, N. Y	Mullite, fused alumina, silicon carbide and magnesia refrs.
Emsco Refractories Co., Vernon, Calif	Firebrick, glass plant refrs., h.t. mortars
The Exolon Co., Blasdell, N. Y	Silicon carbide, alumina refrs.
General Abrasive Co., Niagara Falls, N. Y	Alumina and silicon carbide
General Ceramics Co., New York, N. Y	Special refrs.
General Refractories Co., Philadelphia, Pa	Fired and unfired chrome and magnesite, firebrick, h.t. mortars, plastic and silica refrs.
Gladding, McBean & Co., Los Angeles, Calif.	Firebrick, insul. brick and plastics, h.t. mortars, plastic refrs., fireclays
A. P. Green Fire Brick Co., Mexico, Mo	Firebrick, insul. f.b., h.t. mortars, plastic and castable refrs., fireclays
Harbison-Walker Refrs. Co., Pittsburgh, Pa	Refrs. of most types incl. reg. and super fireclay, high-alumina, silica, chrome, magnesite, Fosterite brick; clays; insul. firebrick and mortars; h.t. mortars
Haws Refractories Co., Johnstown, Pa	Firebrick of all kinds, silica brick, fireclays
Illinois Clay Products Co., Joliet, Ill	Firebrick, h.t mortars, insulating cements coatings and brick
Ironton Fire Brick Co., Ironton, Ohio	Fireclay refrs., refr. cements, fireclays
Johns-Manville, New York, N. Y	Bonding mortars, castables, ramming mixtures, plastic and insul. refrs.
Laclede-Christy Clay Prod. Co., St. Louis, Mo.	Firebrick, h.t. mortars, plastic refrs., glass plant refrs., fireclays
E. J. Lavino & Co., Philadelphia, Pa	Chrome and magnesite refrs., h.t. mortars, silica refrs., fireclays
Massillon Refractories Co., Massillon, Ohio	Firebrick, h.t. mortars, plastic refrs., special, compositions
McLain Fire Brick Co., Pittsburgh, Pa	Various
McLeod & Henry Co., Troy, N. Y	Firebrick, h.t. mortars, plastic refrs., fireclays
Mullite Refractories Co., Shelton, Conn	H.t. mortars, plastic refrs., mullite refrs.
National Carbon Co., Inc., Cleveland, Ohio	Carbon refrs.
Niles Fire Brick Co., Niles, Ohio	Firebrick, insulating refrs.
North American Refrs. Co., Cleveland, Ohio	Fireclay, super, insul. and silica brick, h.t. mortars, plastic refrs., fireclays
Norton Co., Worcester, Mass	H.t. mortars, silicon carbide, fused alumina and magnesia, raw materials, cements, refr. shapes
Pacific Clay Products Co., Los Angeles, Calif.	Plastic refrs.
Pyro Clay Products Co., Oak Hill, Ohio	Glass plant refrs.
Quigley Co., Inc., New York, N. Y	Firebrick, insulating refrs., super firebrick, h.t. mortars, plastic refrs.
Ramtite Co., Chicago, Ill	H.t. mortars
Refractory&Insulation Corp., NewYork, N. Y	H.t. mortars
Robinson Clay Product Co. of N. Y., New York, N. Y	H.t. mortars, firebrick and clay, insulating refrs.
Ross Tacony Crucible Co., Philadelphia, Pa	Graphite crucibles and stopper heads, magnesite refrs.
St. Louis Fire Brick & Insulation Co., Huntington Park, Calif	Various
Seaboard Refrs. Co., Perth Amboy, N. J	Firebrick, h.t. mortars, plastic and insulating refrs., silicon carbide and mullite refrs.
Chas. Taylor Sons Co., Cincinnati, Ohio	Firebrick, glass plant and insulating refrs., sillimanite
The United States Stoneware Co., Akron, Ohio	Plastic and castable refrs.
M. D. Valentine & Bro. Co., Woodbridge, N. J.	Firebrick
Vitrefrax Corp., Los Angeles, Calif	Glass plant refrs. firebrick, h.t. mortars, plastic refrs., fireclays

STRUCTURAL CARBON AND GRAPHITE

CHEMICAL RESISTANCE OF IMPERVIOUS CARBON AND IMPERVIOUS GRAPHITE

Resistant to These Reagents	Concentration Per cent	Temp. Deg. C.
Acetic acid	Glacial	B. Pt.
Acetic anhydride	100	B. Pt.
Acetone	100	B. Pt.
Air	...	175
(S) Air	...	200
Ammonia	20	R. T.
Ammonium thiocyanate	25	95
Amyl alcohol	100	B. Pt.
Aniline	100	110
Arsenic acid	75	125
Benzene	100	B. Pt.
Boric acid	25	B. Pt.
(S) Bromine water	Sat'd.	65
Butyl alcohol	100	B. Pt.
Butyl cellosolve	100	110
Camphor	.08	50
Camphor and Sodium hydroxide	.08 3	50 50
Carbon dioxide — water	Sat'd.	to 100
Carbon monoxide — water	Sat'd.	to 100
Carbon tetrachloride	100	B. Pt.
Cellosolve	100	110
Cellosolve	25	110
(S) Chlorethylbenzene	Tech.	125
Chlorine, dry	Gas	R. T.
(S) Chlorine water	Sat'd.	R. T.
Chloroform	100	B. Pt.
Citric acid	25	B. Pt.
Cupric chloride	10	95
Dioxan	100	B. Pt.
Ethyl alcohol	95	B. Pt.
Ethyl mercaptan — water	Sat'd.	to 100
Ethylene dichloride	100	B. Pt.
Ferric chloride	15	to B. Pt.
(S) Ferric chloride	25	B. Pt.
Ferrous chloride	40	B. Pt.
Ferrous sulphate	25	B. Pt.
Formic acid	90	B. Pt.
Formic acid and, Potassium dichromate	3 1	70 70
Freon - 11 ($CFCl_3$)	100	R. T.
Freon - 12 ($CF_2 Cl_2$)	100	R. T.
Gasoline	100	B. Pt.
Glycerine	100	135
Hydrobromic acid	40	B. Pt.

(Continued next page)

STRUCTURAL CARBON AND GRAPHITE (Continued)

Resistant to These Reagents	Concentration Per cent	Temp. Deg. C.
(Continued from preceding page)		
Hydrochloric acid	20	B. Pt.
Hydrofluoric acid	15	B. Pt.
Hydrogen peroxide and	8	
Mercuric nitrate and	10	R T.
Nitric acid	5	
Hydrogen sulphide — water	Sat'd.	to 100
Isopropyl acetate	100	B. Pt.
Isopropyl alcohol	100	B. Pt.
Isopropyl ether	100	B. Pt.
Kerosene	100	to 160
Lactic acid	25	B. Pt.
Manganous sulphate	15	95
Mannitol	25	B. Pt.
Methyl alcohol	100	B. Pt.
Methyl isobutyl ketone	100	B. Pt.
Monochlorbenzene	100	B. Pt.
Monoethanolamine	10	96
Nickel chloride $6H_2O$ and	300 g./l. 30 g./l.	50
Boric acid	30 g./l.	50
Nickel sulphate $6H_2O$ and	318 g./l.	
Nickel chloride $6H_2O$ and	16.5 g./l.	75
Boric acid	30 g./l.	
(S) Nitric acid	2	R. T.
(S) Nitric acid	10	R. T.
Nitrobenzene	100	135
Octyl alcohol	Tech.	B. Pt.
Oleic acid	100	135
Oxalic acid	25	135
Oxalic acid and	Sat'd.	R. T.
Nitric acid	0.3	R. T.
Paraldehyde	100	110
Paraldehyde — water	Sat'd.	110
Paradichlorbenzene	100	125
Petroleum oil	100	160
Phenol	100	110
Phenol	25	110
Phosphoric acid	25	B. Pt.
Phosphoric acid	50	135
Phosphoric acid	85	135
(S) Potassium permanganate and	3	R. T.
Sulphuric acid	10	R. T.
Rayon Solutions		
Na_2SO_4	12–20	60
H_2SO_4	8–12	...
$MgSO_4$	4–6	...
$ZnSO_4$	1	...
Sodium chloride	25	B. Pt.
(S) Sodium dichromate and	5	R. T.
Sulphuric acid	10	R. T.
(S) Sodium hydroxide	to 80	to 135
Sodium hydroxide and	3	50
Camphor	.08	50
Sodium hydrosulphite	3	R. T.
Sodium hydrosulphite and	3	R. T.
Hydrochloric acid	0.1	R. T.
Sodium hydrosulphite and	3	R. T.
Sodium hydroxide	0.1	R. T.
(S) Sodium hypochlorite	5	R. T.
Sodium nitrate and	Sat'd.	110
Sodium carbonate	5	110
Sodium nitrate and	25	110
Sodium carbonate	5	110
Sodium sulphate and	30	121
Sulphuric acid	15	121
Stannic chloride	15	B. Pt.
Stearic acid	100	135
Sulphuric acid	to 75	to 135
Sulphuric acid	96	to 80
(S) Sulphuric acid	96	to 150
Sulphuric acid and	96	
Chlorine and	Sat'd.	45
Hydrogen chloride	Sat'd.	
Sulphurous acid	7	R. T.
Tartaric acid	25	B. Pt.
Tetramine C	10	96
Water	100	to 100
Zinc chloride	53	120

Note: These resistances are for Karbate No. 1 (Impervious Carbon) and Karbate No. 2 (Impervious Graphite) except for reagents marked (S) where specially treated Karbate is required.

PHYSICAL CHARACTERISTICS OF CARBON AND GRAPHITE PRODUCTS

	Apparent Density	Weight Lb./cu.ft.	Strength, Lb. per Sq. In			Elastic Modulus Lb./sq.in. Multiply by 10^5	Specific Resistance Ohms./In.^{3}	K (Thermal Expansion, See Note)	Thermal Conductivity B.t.u./hr./sq.ft./°F per ft.
			Tensile	Compressive	Transverse				
Carbon Cylinders									
8 inch dia.	1.54	96.0	660	2,920	1,320	5.5	0.0013	13	6.0
10–14 inch. dia. inc.	1.525	95.0	470	2,120	950	5.4	0.0013	12	6.0
17–24 inch. dia. inc.	1.54	96.0	400	2,200	790	5.4	0.0014	13	6.0
30–40 inch. dia. inc.	1.54	96.0	400	1,910	810	4.3	0.0026	12	6.0
Carbon Blocks									
4x4 inch to 6x6 inch inc.	1.57	97.8	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	96.0	400	1,910	810	4.3	0.0026	12	4.0
Carbon 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									
Dependent on Application	1.56	96.7–97.8	970–1,530	5,340–8,320	1,950–3,070	8.9–10.3	0.0015–0.0016	13–14	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	95.3	580	3,180	1,490	6.7	0.00039	8–12	79.0
16 & 18 inch dia.	1.53	95.3	500	3,180	1,490	6.7	0.00040	8–12	70.0
20 inch dia.	1.53	95.3	440	3,180	1,490	6.7	0.00040	8–12	70.0
Graphite Squares and Slabs									
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	95.3	570	3,180	1,490	6.7	0.00039	8–12	79.0

STRUCTURAL CARBON AND GRAPHITE (Continued)

	Apparent Density	Weght Lb./cu.ft.	Strength Lb. per Sq. In. Tensile	Compressive	Transverse	Elastic Modulus Lb./sq. in. Multiply by 10⁹	Specific Resistance Ohms./In.[1]	K (Thermal Expansion, See Note)	Thermal Conductivity B.t.u./hr. sqf't./°F per ft.
Graphite Tubes									
½-4 inch. I. D. inc.	1.68	104.7	780	4,550	2,820	14.0	0.0003	12	94.0
5-10 inch. I. D. inc.	1.67	104.0	870	5,100	2,980	13.0	0.0003	12	84.0
Graphite Brick, Standard sizes	1.56	97.3	700	3,050	1,750	8.8	0.00036	5-12	84.0
Karbate No. 1 (Impervious Carbon)*									
Tubes 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	4,040	26.0	0.0016	33	2.8
Karbate No. 2 (Impervious Graphite)*									
Tubes 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	84.0	500	1,530	2,700	>1.2	0.0020	6	3.0
Grade 60	1.05	69.0	190	600	850	>1.2	0.0070	27	1.5
Grade 50	1.05	69.0	180	500	830	>1.2	0.0070	27	1.4
Grade 40	1.04	69.0	120	320	900	>1.2	0.0057	27	1.0
Grade 30	1.04	69.0	100	250	770	>1.2	0.0070	27	1.0
Grade 20	1.03	68.0	90	240	700	>1.2	0.0070	27	1.0
Grade 10	1.03	68.0	80	160	300	>1.2	0.0080	27	1.0
Graphicell (Porous Graphite)**									
Grade C (Finest)	1.35	84.0	600	1,080	1,680	.....	0.00045	6	60.0
Grade 60	1.05	69.0	110	250	500	.....	0.0012	21	50.0
Grade 50	1.05	69.0	110	250	500	.....	0.0012	21	45.0
Grade 40	1.04	69.0	100	190	500	.....	0.0013	21	45.0
Grade 30	1.04	69.0	80	200	520	.....	0.0017	21	40.0
Grade 20	1.03	68.0	60	140	310	.....	0.0020	21	30.0
Grade 10	1.03	68.0	50	140	270	.....	0.0020	22	20.0

Carbon and graphite products are resistant to most acids and alkalis. * See preceding table for chemical resistance. ** See following table for additional data.
NOTE: Coefficient of Thermal Expansion: To Temperature t°F = (K = 0.003 (t°F), 10^{-7}; to Temperature t°C 9 = (1.8 K + 0.007 (t°C), 10^{-7}.

PHYSICAL PROPERTIES OF POROUS CARBON AND POROUS GRAPHITE

	Porosity Per Cent	Average Pore Diameter Inches	Microns	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_2O Pressure Cu.ft./sq.ft./min.
Carbocell						
Grade C	36.0	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
Graphicell						
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	0.00178	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 can be treated so as to be wettable for use in caustic filtration. Both 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.

MAKERS OF STRUCTURAL CARBON AND GRAPHITE PRODUCTS

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

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

RUBBER and LIKE PRODUCTS

CHEMICAL PROPERTIES OF RUBBER-LIKE MATERIALS

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.

NEOPRENE

Neoprene is a basic thermosetting (not thermoplastic) 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 (see table of physical properties for broad range). 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.

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 per cent 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, ozone 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 far to exceed natural rubber in both strength and abrasion resistance when in contact with gasoline and oils. Since it has extremely low permeability, there is practically no diffusion loss through Thiokol when conducting volatile solvents. In certain compositions it can be made into molding powder and liquid dispersions.

Thiokol can be used at temperatures ranging from 200 to −40 deg. F. In addition to being used as rubber, it can be used to plasticize other rubbers and similar materials where an insoluble plasticizer is desired.

Solvent Resistance of Thiokol F

(Immersion tests at room temperature for one year. Percentage swell determined from increase in length of 1/4 x 1/16 x 4-in. test strips.)

Solvent	Per Cent Swell	Condition
Motor gasoline	1.0	OK
80/20 gasoline/benzol (by vol.)	3.0	OK
50/50 gasoline/benzol (by vol.)	6.3	OK
Benzol	25.0	Firm
Kerosene	0.8	OK
SAE No. 30 motor oil	0.5	OK
No. 4 fuel oil	3.5	OK
Drip oil	13.8	OK
Linseed oil (raw)	1.3	Surface hardened
Cottonseed oil	0.0	OK
Acetone	2.5	OK
Methyl alcohol	1.3	Surface slightly affected
Carbon tetrachloride	8.8	OK
Ethylene dichloride	Destroyed	

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. It can be used at temperatures up to 300 deg. F., and will remain flexible at temperatures as low as −45 deg. F.

Perbunan is unaffected by water, dilute acids or alkalis, or salt solutions of any

Solvent Resistance of Chemigum

(Samples immersed at room temperature for 12 days)

Solvent	Per Cent Swell	Condition
80/20 gasoline/benzol	0.80	OK
Lacquer thinner	100	OK
Turpentine	27	OK
Benzol	105	OK
Kerosene (room temp.)	0.20	OK
Kerosene (212 deg. F.)	1.50	OK

Solvent Resistance of Perbunan

(Samples immersed at room temperature for 24 days.)

Solvent	Per Cent Weight Increase	Tear Resistance
n-Heptane	No effect	Good
Varsol (heavy naphtha)	20	Good
Turpentine	25	Good
SAE 30 Motor oil	No effect	Good
Nujol	No effect	Good
Cottonseed oil	No effect	Good
Acetone	97	Very poor
Benzene	214	Very poor
Carbon disulphide	97	Poor
Amyl acetate	53	Poor
Methyl alcohol	No effect	Good
Diethyl ether	23	Good
Carbon tetrachloride	160	Very poor
Ethylene dichloride	387	Very poor
Aniline	280	Very poor
Glacial acetic acid	No effect	Good

Solvent Resistance of Extruded Resistoflex PVA

(Samples immersed at room temperature for 240 hours.)

Solvent	Specific Gravity at 72° F.	Per Cent Shrinkage or Expansion in 6 in.	Tensile Strength, Lb./sq. in.	Per Cent Elongation in 2 in.	Hardness (Durometer)
Before immersion	1.259	......	5,236	213	85
66% Gasoline, 24% ethanol, 10% benzene, by volume	1.195	−1.0	5,057	180	86
Gasoline (leaded)	1.260	−0.30	5,255	220	85
Kerosene	1.255	+0.30	5,247	220	84
Benzol	1.251	+0.30	5,290	225	84
Xylol	1.260	+0.20	5,351	220	84
Acetylene gas	1.256	+0.10	5,340	220	85
Methylene dichloride	1.261	−0.40	5,110	225	84
Trichlorethylene	1.253	+0.10	5,140	225	86
Carbon tetrachloride	1.259	0.00	5,084	145	84
Monochlorbenzol	1.258	+0.10	5,026	190	84
Methanol (anhydrous)	1.203	−6.50	5,980	195	86
Ethanol (anhydrous)	1.181	−4.30	5,779	190	87
Ethylene glycol	1.186	+4.70	4,335	185	77
Acetone	1.246	−1.20	5,203	175	87
Petrohol	1.224	−1.30	5,971	165	89
Furfural	1.250	−2.00	5,890	175	88
Methyl acetate	1.269	−0.70	5,403	185	85
Ethyl acetoacetate	1.258	−0.50	5,491	205	85
Diethyl ether	1.260	−0.30	4,980	230	86
Dioxane	1.271	−1.30	5,272	195	85
Freon gas	1.270	−0.50	5,636	205	86
Butane gas	1.268	+0.30	5,352	200	86
Propane gas	1.267	+0.20	5,529	200	87
Sulphur dioxide	1.269	+0.50	5,497	215	86
Aniline	1.256	−0.70	5,557	185	86
Formamide	1.201	−4.00	3,845	195	77

RUBBER and LIKE PRODUCTS (Continued)

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. In aromatic hydrocarbons, Perbunan swells to an extent comparable to natural rubber, but it is superior to natural rubber for gasoline-benzol mixtures. 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.

It should be pointed out that the behavior of Perbunan in most practical applications depends upon proper compounding and processing, and definite conclusions should only be drawn from actual service tests.

PHYSICAL PROPERTIES OF RUBBER AND RUBBER-LIKE MATERIALS

PROPERTY	Ameripol, Oil-resisting, Soft	Ameripol, Tire Type, Soft	Ameripol Hard	Chemigum Tire Cpd.	Koroseal		Neoprene (all forms)	Perbunan	Pliolite No. 40	Resistoflex Molded & Ext.	Natural Rubber	
					Hard	Soft					Hard	Soft
Specific gravity	0.99–1.6	0.96–1.20	1.1–1.3	1.19	1.3–1.4	1.2–1.3	1.27–1.30	0.96	1.06	1.26	1.17–1.18	0.93–1.17
Tensile strength, lb. per sq. in.	1,000–4,500	1,000–4,000	4,000–10,000	4,000	2,000–9,000	500–2,500	1,000–4,000	500–5,000	4,000–5,000	2,000–5,000	4,000–11,000	1,000–6,000
Hardness, Shore durometer	15–90	50–80	80–100	65	80–100	30–80	15–95	30–90	....	....	70–100	30–80
Maximum temperature for use, °F.	260–300	240–280	260–300	450+	212	190	300	300	160–248	250	220	150–180
Dielectric strength, volts per mm.	....	....	....	....	30,000–50,000	15,000–30,000	....	....	....	6,000–10,000	40,000–150,000	40,000–55,000
Effect of heat	Stiffens slightly		....	Stiffens	Softens	Softens	Stiffens slightly	Stiffens	Softens	Softens	Softens	Softens & Det.
Abrasion resistance	Excellent		Good	Excellent	Good	Good	Equal to rubber	Excellent	....	Good	Good	Excellent
Effect of sunlight	Discolors, cracks less than rubber		....	Deteriorates	None	None	None	Slight	None	None	Discolors	Deteriorates
Effect of aging	Highly resistant, stiffens slightly		None	None	None	None	Better than rubber	Highly resistant	None	None	None	Highly resistant
Machining qualities	Can be ground		Excellent	Excellent	Good	Can be ground	Can be ground	Can be ground	....	....	Excellent	Can be ground

REPRESENTATIVE MAKERS OF INDUSTRIAL RUBBER PRODUCTS AND RUBBER-LIKE MATERIALS

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, etc.
Atlas Mineral Products Co. of Pa., Merzetown, Pa.	Rewbon seamless rubber linings and Zerok synthetic resin linings
Boston Woven Hose & Rubber Co., Boston, Mass.	Conveyor and transmission belts, hose, mechanical rubber goods
Crane Packing Co., Chicago, Ill.	Rubber and synthetic rubber packings
Custodis Construction Co., New York, N. Y.	Custoplast soft rubber and neoprene tank linings
Dayton Rubber Mfg. Co., Dayton, Ohio	Oilproof rubber belts, transmission belting, synthetic rubber products
E. I. du Pont de Nemours & Co., Neoprene Div., Wilmington, Del.	Neoprene polymerized chloroprene rubber
Firestone Tire & Rubber Co., Akron, Ohio	Perbunan synthetic rubber
Garlock Packing Co., Palmyra, N. Y.	Rubber packings, transmission belting, molded goods
Gates Rubber Co., Denver, Colo.	Transmission and conveyor belting
L. H. Gilmer Co., Tacony, Philadelphia, Pa.	Transmission belting
B. F. Goodrich Co., Akron, Ohio	Acid- and abrasion-resistant linings, hose, conveyor and transmission belting, packings, hard-rubber pipe and molded goods, rubber paints, Koroseal plastic, Anode process, Ameripol tires and mechanical goods
Goodyear Tire & Rubber Co., Akron, Ohio	Hose, conveyor and transmission belting, packings, linings, mechanical rubber goods, Pliolite modified rubber plastic, Chemigum
Hewitt Rubber Corp., Buffalo, N. Y.	Hose, transmission and conveyor belting, packings
Hydrocarbon Chemical & Rubber Co., Akron, Ohio	Synthetic rubbers (Ameripol)
Jenkins Bros. Rubber Div., Bridgeport, Conn.	Mechanical rubber goods, packings, molded and extruded shapes
The Osborn Mfg. Co., Johns Conveyor Div., Cleveland, Ohio	Johns rubber and synthetic rubber "moving pipe-line" conveyors
Maurice A. Knight, Akron, Ohio	Rubber and neoprene-lined rubber drums, Pyroflex resin-base tank linings
Linear Packing & Rubber Co., Philadelphia, Pa.	Rubber and synthetic rubber packings
Luzerne Rubber Co., Trenton, N. J.	Hard rubber pipe, fittings, valves, shapes, tanks, rayon apparatus and other equipment
Manhattan Rubber Mfg. Div., Passaic, N. J.	Transmission and conveyor belting, blocks, hose, piping, rolls, brake lining, bearings
Miller Rubber Co., Akron, Ohio	Hose, molded products, linings and coverings
Paramount Rubber Service, Inc., Detroit, Mich.	Seamless rubber linings, rubber paint, molds, coatings and insulations
Resistoflex Corp., Belleville, N. J.	Rubber-like oil-resisting resin — tubing, hose, sheets, molded shapes, gloves
Self-Vulcanizing Rubber Co., Chicago, Ill.	Liquid and plastic rubber self-vulcanizing coatings and lining materials
Standard Oil Development Co., Elizabeth, N.J.	Perbunan synthetic rubber
Jos. Stokes Rubber Co., Trenton, N. J.	Molded hard rubber products of all kinds
Thermoid Rubber Co., Trenton, N. J.	Hose, belting, packing, mechanical rubber goods
Thiokol Corp., Trenton, N. J.	Thiokol olefine polysulphide synthetic rubber — crude sheet, molding powder and liquid dispersions
U. S. Rubber Co., New York, N. Y.	Rubber-lined pipe, hard, semi-hard and soft linings, abrasion-resistant linings, hard rubber pipe, acid hose, packings, mechanical rubber goods and belting
U. S. Stoneware Co., Akron, Ohio	Resilon and Tygon polymer tank linings, rubber latex linings
Vulcanized Rubber Co., New York, N. Y.	Hard and semi-hard rubber molded products

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 ¼ 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

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

Representative Makers of Wood Tanks and Pipe for Chemical Applications

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