

CHEMICAL & METALLURGICAL ENGINEERING

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S. D. KIRKPATRICK, Editor

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UNCOVER THE UNORTHODOX

COLONEL MAURICE E. BARKER of the Chemical Warfare Service made headlines all over the United States the other day when he said that what this country needs most now is a non-comic-strip ray gun. The wide reaction to his chance remark, before a student group at the College of William and Mary, may reflect only the shallow and wishful thinking of those who would like to see this war won by some of Buck Rogers' 25th century technology. Yet there may be food for more sober thought in the idea that the scientists and engineers of this country have got to do more to help the war program. We are pitted against ruthless enemies that are staking their every resource in a desperate effort to conquer the world. So far they have been getting away with it. And they will continue until we have mustered the scientific brains as well as the manpower and materiel to beat them at their own fiendish game.

Lately some of us had the rare privilege of hearing Canada's commanding officer, Lieutenant General A. G. L. McNaughton, address his fellow engineers on the occasion of his recent return from the other side. He said bluntly and forcefully that this war was not going to be won by orthodox methods or by mere manpower sent as expeditionary forces to do guard duty in various outposts of the British Empire. His plea was for the scientists and engineers of Canada to develop new and more deadly weapons. He was looking for help, not from the politicians or from the brass hats of the army of yesterday, but from his former colleagues and associates in the National Research Council and in the laboratories of Canadian universities and industries. Judging from the fervor with which the General's plea was received, our guess is that great things will be forthcoming—developments as im-

portant now as once were the Banting discoveries of insulin in more peaceful time.

No one can deny that we have made progress here in mobilizing our research and developmental resources for war work. The various agencies and committees included under the broad program of the National Academy of Science have drafted some of our best scientists and most resourceful engineers. Yet many of us have the impression that there is still a discouraging gap between the laboratories and drafting boards of some of our war industries, between research and production of new and better processes, as well as weapons. We still rely too much on the strategy of the past.

Our present need is for output of absolutely necessary equipment—of planes and ships, guns and ammunition. Orthodox methods, standardized designs and other mass production techniques will get quickest results and, of course, there is no time to lose. Nevertheless, we must not be afraid of change and must seek constant improvement—even radical and revolutionary developments in every line of manufacture. Otherwise we are going to be handicapped in fighting better equipped as well as better prepared enemies.

With this in mind we want to urge our government to give more serious and sympathetic consideration to the vital role of research in the war effort. Our Selective Service Director must help to make it clear to the local boards that the man in the laboratory who is working on a new aviation fuel, a more powerful explosive, or a new alloy or plastic is just as important as the man in the plant. And that both, in their present jobs, might conceivably be more important than a whole regiment handicapped with obsolete equipment.

Given opportunity and support, American engi-

neers and research men can help win this war in ways that no one can now foresee or predict. They have what it takes in scientific knowledge and resources. They are already on the job, but they need a little encouragement—especially from those in high quarters who can and will put to test their ideas—however unorthodox.

THEIR BROTHERS' KEEPERS

ALPHA CHI SIGMA, the professional chemical fraternity with 15,000 members, 46 collegiate chapters, and 25 alumni groups in our principal chemical centers, has again contributed a signal service to the advancement of chemistry and chemical engineering. By setting up a comprehensive safety program in cooperation with the National Safety Council, it is going to help get the principles and objectives of the safety movement established in the classrooms and the laboratories of American colleges and universities. Thus will be brought home to the student early in his academic career the vital relation between theory and practice when it comes to accident prevention and the saving of life and property.

Credit for organizing this program goes to H. B. Stevenson of Procter & Gamble, who, as a district counselor of the fraternity, helped to formulate systematic instruction in safety at the University of Cincinnati and at Case School of Applied Science. Now, under the chairmanship of F. R. Holden of Mellon Institute, an active committee is spreading out the program to reach all collegiate chapters. Meanwhile the national organization of Alpha Chi Sigma is helping to finance memberships in the National Safety Council and is otherwise backing up the work of its committee.

In the past our educational institutions have often been severely indicted because graduate chemists and chemical engineers have been permitted to enter industry without intimate knowledge and understanding of the hazards that are involved in the use of high temperatures and pressures and in the handling of toxic and flammable materials. Such indictments have been all too frequent. Let us hope that the new generations of graduates will become so conscious of safety during their college days that they can inculcate among their associates a better understanding of the human principles on which modern industry must operate.

ANY IDLE EQUIPMENT?

TO AID in diverting idle and non-essential chemical engineering equipment to direct war purposes, there has been set up in the Chemical Branch of W.P.B. a new section on Chemical Plant Facilities. Its chief is C. T. Thompson whose office is in Room 2434, Temporary Building R, in Washington, D. C. He will serve as a liaison officer between people who may be able to produce some

essential product and people who may have equipment not engaged in direct war production or have idle facilities. It should be noted, however, that this section is concerned only with equipment already installed and not with new equipment. Also those having such equipment should not only list and describe it and its past usage, but should, if possible, suggest applications for which it might be adapted. Finally, there is the question of whether the equipment can be used in its present place or would be available for relocation. Here, then, are job specifications for an opportunity to serve your country. Mr. Thompson invites your contacts.

IS YOUR SHOP FULL?

EVERY plant in the chemical process industries has a good machine shop for its repair and maintenance work. In some cases these shops may be working on an 8-hour basis only 5 days a week. The other 75 percent of the week should not find them standing idle in emergency times such as these when every minute counts.

Have you made any plans to keep all of the machines in your shop busy on a 168-hour week, turning out a needed item of war material when not actually needed for repair? There is no reason why a subcontracting arrangement cannot be made with a nearby producer of a war item. If the shop is really large, a prime contract may be justified.

Provision must, of course, be made for actual repair and maintenance needed in the plant. But intensive up-grading of present machine shop employees will quickly develop an adequate, skilled staff which can keep the machines running continuously making that extra effort which war necessitates.

Subcontracting exhibits of the contract distribution branch, War Production Board, are now open at the addresses listed below. Visit the nearest office and see what you can do to help.

City	Location
Atlanta, Ga.	Hurt Building
Boston, Mass.	Court Street Branch, First National Bank
Buffalo, N. Y.	White Building
Chicago, Ill.	Civic Opera Building
Cincinnati, Ohio	Union Central Life Building
Cleveland, Ohio	Union Commerce Building
Detroit, Mich.	Boulevard Building
Harrisburg, Pa.	Doehne Building
Helena, Mont.	222 Power Block
Kansas City, Mo.	Mutual State Building
Los Angeles, Calif.	Western Pacific Building
Memphis, Tenn.	Sterick Building
Newark, N. J.	Indemnity Building
New Orleans, La.	Canal Building
New York, N. Y.	Chanin Building
Philadelphia, Pa.	Broad St. Station Building
San Francisco, Calif.	Whitcomb Hotel
St. Louis, Mo.	Boatmen's Bank Building

WASHINGTON HIGHLIGHTS

CONVERSION of industrial plants must be prompt and thorough. This means that metal-working establishments in particular must do something of direct value on the war job, or else. . . . Otherwise, they will certainly be without raw materials because the shortage of metals is truly appalling. For chemical plants it means that the things made must be urgently wanted for war usage or for an absolutely essential civilian activity. Mere comforts or luxuries will no longer qualify.

ERNEST W. REID has been named chief of the Chemical and Allied Products Branch of W.P.B. Thus an outstanding public service rendered by an exceptionally able technical man is signally recognized. E. R. Weidlein, who cannot give full time to Washington activities, continues as an enthusiastic and invaluable consultant, giving particular attention to synthetic rubber. Promotion of Dr. Reid seems to have received unanimous support both within and without the government. In view of the quiet, though very competent job he has done, this is not surprising.

PUBLIC OPINION still has influence. During February it forced reorganization of the Office of Civilian Defense and turned that agency back to its original technical job. That was a good thing. It also compelled Congress to retreat from the proposed retirement annuities for members of Congress, the Cabinet and the President. That may or may not have been so good. It is easy to understand why the general public objected to pensions for politicians. But the public probably does not realize that the naming of lame-duck congressmen to government jobs, lest they be in straitened circumstances, already costs us more than the whole proposed pension system.

TANKER sinkings in dangerous numbers make certain a shortage of petroleum products in many sections of the United States. Mr. Iekes' worst forecasts of last Fall will be exceeded, but not for the reasons then given. This means that some process industries must substitute coal for oil wherever possible. Hence the storage of coal this Spring and Summer is being urged. This is one thing which should be hoarded by industry. Some

firms which require oil may have to establish new processing units near the source of petroleum. Highly desirable projects for the Northeastern States may not be practical there. Making of butadiene, for example, would have to move largely to Texas and the Southwest.

ALCOHOL making is still the subject of bitter controversy in Washington. The huge new requirements for synthetic rubber and smokeless powder caused most of the trouble. But much more commotion resulted from inaccurate, biased and even erroneous statements that seemed deliberately distorted. There is no question but that the government will give alcohol makers the very minimum quantity of sugar or edible alcohol which is needed for the minimum safe total alcohol production of the country. Preference will be given to every other raw material first. But the narrow margin of corn supply above demand is making it necessary even to substitute wheat as a raw material in some cases. Meanwhile, the "power alcohol" and "chemurgic" politicians from the Middlewest are having a field day with their rumors of a sinister control of alcohol and rubber by international chemical and petroleum interests.

EXPANSION of industrial production is urgently wanted with respect to almost every chemical. But this expansion must be accomplished with present manufacturing facilities if that is humanly possible. Even lower efficiency and makeshift chemical engineering methods are preferred to the spending of time or scarce equipment on plant additions.

DELAYS in synthetic rubber production have already occasioned severe Congressional criticism, and formal inquiry. A lot of folks would like to find out whether the R.F.C. Czar deserves his cocktail party nickname of "Bottleneck" Jones.

BETTER LOAD FACTORS for electrochemical industry are being urged by the engineers of the Federal Power Commission. They ask that peak demands be curtailed, especially at peak-load hours on local utility systems. The curtailment of output of a continuous process industry, if it slows down only two hours each

afternoon five days a week, is not serious. Such slowdown often makes available to the operating company power which otherwise would not be allocated to it. Then, if priorities for equipment can be had, one finds the anomaly of lower power bills, greater production and lower peak loads on the power line. All of these desirable objectives should be investigated by every electrochemical management.

ALUMINUM and possibly magnesium, production from 6-mill power is almost certain to come. Location of such plants in the suburbs of the large metropolitan centers will help to take up the slack in the few areas where a surplus of firm power is still available. All admit that these are "white elephant" plants, erected only to meet the present emergency.

EXPLOSIVES making may be slightly curtailed in order to divert some nitrogen products to the fertilizer business. This queer war-time situation develops from a combination of huge new food demand for our Lease-Lend friends at the same time that import of Chilean nitrate becomes extremely difficult because of ship shortage. We do not dare to tell the British, Russians, or Chinese that we will not help to feed them. But to feed them, we must have more Chilean nitrate or ammonium sulphate for top and side dressing of both sugar and oil-seed crops. The need for more fertilizer nitrogen next year will be much more than an academic factor in military planning.

DONALD NELSON says that this (1942) is the crucial year, not 1943. "We had our golden opportunity to expand capacities in steel, chemicals and other materials and neglected it. That opportunity is gone forever, so far as this war is concerned. This year we have ten silver months ahead. What we produce for ourselves and our Allies now is worth ten times what we produce next January!" Management holds the key. Think what it would mean if every chemical company in the country could improve the efficiency of its management to reach that of the best run enterprises. It is safe to say that output of war production would go up 25 percent without any added equipment or new facilities.

Synthetic Rubber in Industry

H. H. HARKINS, *United States Rubber Co., Providence, R. I.*

Chem. & Met. INTERPRETATION

The rising synthetic rubber production and the rapidly diminishing supply of the natural material give rise to the consideration of how the new types of rubbers can be used for construction of equipment in the process industries. Dr. Harkins discusses the peculiar characteristics of each of the synthetic rubbers that are now being produced commercially with special emphasis on their resistance to heat, oxidation, oil, and chemicals.—*Editors.*

DURING the past two or three years there has been much public discussion of synthetic rubber. Many applications have been found, but the volume of synthetic rubber used thus far compared with the volume of natural rubber consumed is slight. The total production of all synthetic rubber in 1941 was only about 1½ percent of the crude natural rubber consumption. While this may not seem an impressive figure for synthetic rubber, the production has laid the basis for possible further expansion which is of great significance in time of emergency. Much further expansion of the synthetic rubber industry is contemplated. Mr. Jesse Jones recently announced that the Reconstruction Finance Corporation will appropriate \$400,000,000 for the con-

struction of additional synthetic rubber plants to bring the annual production of synthetic rubber up to 400,000 tons per year.

One of the principal reasons why the use of synthetic rubber has lagged so far behind natural rubber is due to its being produced in the Far East with cheap labor at a price so low that synthetic rubber cannot compete. Hence, the only uses for synthetic rubber thus far have been for purposes for which it is superior in performance to the natural product. With the sources of natural rubber imperiled, or cut off entirely, synthetic rubber becomes a subject of vital interest to all of us.

Rubber manufacturers are keenly aware of their responsibilities to industries using this material. Under

instructions from the government and also on their own initiative rubber manufacturers are endeavoring to (1) conserve natural rubber wherever possible, (2) see that rubber is allocated to the essential needs of industry, (3) use substitute materials where warranted; for example, reclaimed rubber, (4) study intensively the processing and the properties of synthetic rubbers with the idea of using them wherever possible when they are available in sufficient quantity.

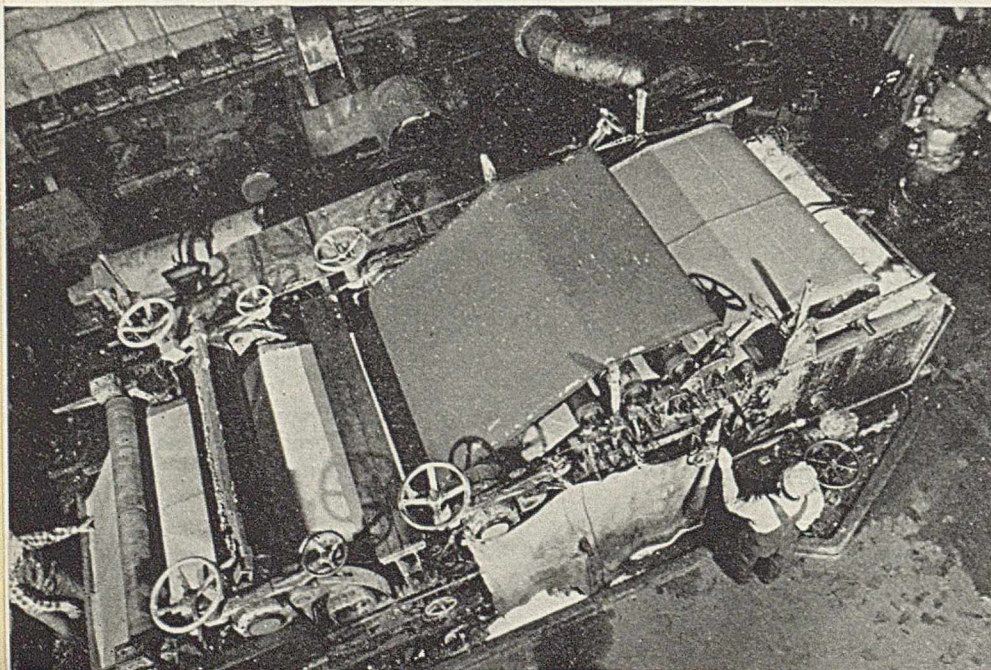
On the assumption then that in the immediate future we will have little natural rubber, but a moderately good supply of synthetic rubber, to what extent can our basic needs be satisfied? This question is too big for any one to answer definitely at the present time. However, we may consider the fundamental properties of the synthetic rubbers and thereby gain some insight into the possibilities of using them for various applications in industry.

Before discussing "synthetic rubber," it is advisable to define this term. Many attempts have been made to build up high molecular weight hydrocarbons to yield a product like natural rubber. None of these efforts has been successful. Therefore, synthetic rubber does not mean a product identical with natural rubber. It has been possible to build up or polymerize various substances or mixture of substances which can be made to yield materials of high strength and elasticity resembling natural rubber in physical properties. There are many synthetic products which exhibit these properties in some degree. It is in this rather loose sense then that the term synthetic rubber will be used.

The more important synthetic rubbers, their chemical and mechanical properties, will be discussed and some of their possible uses will be mentioned.

For detailed information on any particular synthetic rubber the manufacturer should be consulted. The statements which will be made are based to a large extent on information received from the manufacturers

Buna S can be bonded to metal satisfactorily and hence may prove useful as a lining material to replace rubber in the paper and other process industries



Based on a paper presented before the recent annual meeting in New York, N. Y., of the Technical Association of the Pulp & Paper Industry.

coupled with the author's own observations. They do not necessarily represent the views of the company with which he is connected or of the manufacturer of the synthetic rubber. In comparing these synthetic rubbers, every effort has been made to be fair. This comparison is made difficult by the fact that the properties of any one are largely dependent upon the processing, compounding, and curing it has received.

It must be made clear at the outset that no one synthetic rubber is satisfactory for all purposes for which a rubber-like material is required. But by taking advantage of all of the various synthetics it may be possible, by making use of the best property of each, to satisfy most needs.

According to one authority 29 varieties of synthetic rubbers were studied in 1941, and that one manufacturer has made over 200 synthetic rubbers. It would be impossible to discuss all of these, even if complete information were available, which it is not,—therefore consideration will be confined to the few types that are now commercially available. It is necessary to point out that in the discussion to follow there are numerous products under each heading, and therefore no generalizations are valid. The rubber technologists have been busy formulating compounds which would accomplish certain things which were not supposed to be possible for rubber. Exactly the same possibilities exist for compounding each of the synthetic rubbers. Consequently, any iron-clad rule concerning synthetics today may prove to be erroneous tomorrow in view of the development activity which is sure to take place in the field because of present conditions.

The first commercially successful, and best known synthetic rubber is neoprene which is made by the duPont company (polymers of chloroprene—several important commercial varieties are being produced). Neoprene can be processed on rubber machinery with nearly as much ease as natural rubber. When properly compounded and heated, it polymerizes or "vulcanizes" to a product resembling natural soft rubber. It is better than rubber with respect to:

- (a) Oils
- (b) Deterioration by heat, oxygen, and sunlight
- (c) Flexing life
- (d) Gas diffusion

Usually it is less resistant to water than is rubber, but it can be formulated to yield products that are bet-

ter than rubber is in resistance to hot water. These properties of neoprene make it useful (sometimes preferable to rubber) for certain products such as,—

- (a) Hose, gaskets, packings
- (b) Transmission and conveyor belts
- (c) Boots where oil is a factor
- (d) Soles and heels where an oil condition exists
- (e) Tank linings where oil or high temperatures are encountered, or both
- (f) Soft roll cover, especially printers' rolls

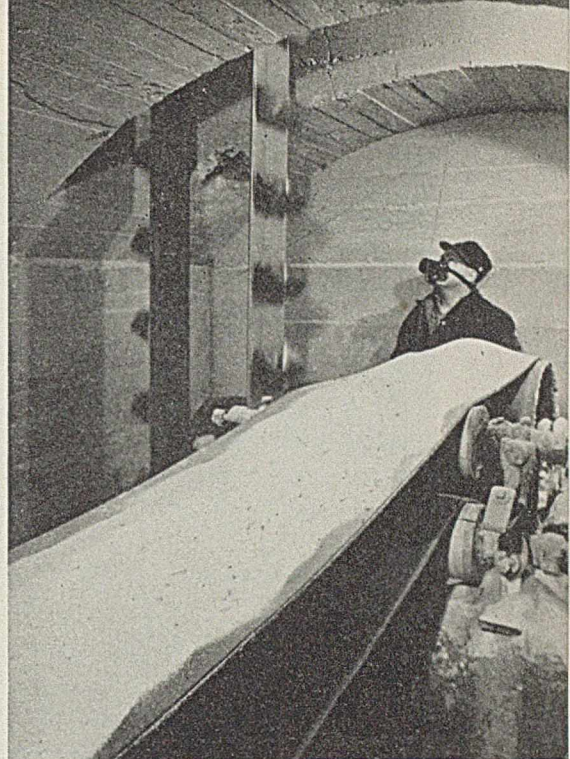
Quite recently neoprene has been made available in semi-liquid condition so that it may be used as a high solids paint or as a troweling compound. This type of plasticized neoprene may be of value for various corrosive conditions in the pulp and paper and other process industries.

One very important characteristic of neoprene is that a good product can be made which is light in color or even white. This is not true of some of the other synthetic rubbers.

Butadiene, a hydrocarbon obtainable from petroleum or other sources, will polymerize to yield a rubber-like material. However, much better rubbers are obtained by interpolymerizing butadiene with other compounds containing an active vinyl group, such as styrene, acrylonitrile, vinylidene chloride, or other vinyl compounds (E. R. Bridgwater, *Chem. & Met.* p. 139, Oct. 1941).

Perbunan or Buna N is a copolymer of butadiene and acrylonitrile. Next to neoprene it is the best known synthetic rubber. Perbunan will vulcanize with sulphur just as natural rubber will, and can be made to yield compounds of all degrees of hardness ranging from soft inking-roll stocks of 5-10 durometer up to a very hard ebonite. This synthetic rubber is characterized by the fact that carbon black must be incorporated if high tensile strength is demanded. Any so-called Perbunan stock which is light colored is likely to have low tensile strength and the other properties will be poor also.

Perbunan vulcanizates are very resistant to aliphatic oils, quite resistant to heat, and have low permanent set or good cold flow resistance. These properties, coupled with the fact that a wide range of hardnesses can be made, indicate that Perbunan could be used as a press roll covering material for paper machines. A good roll cover must be well bonded to the metal core, must be resilient and resistant to cold flow, and have the proper hardness. Methods have been



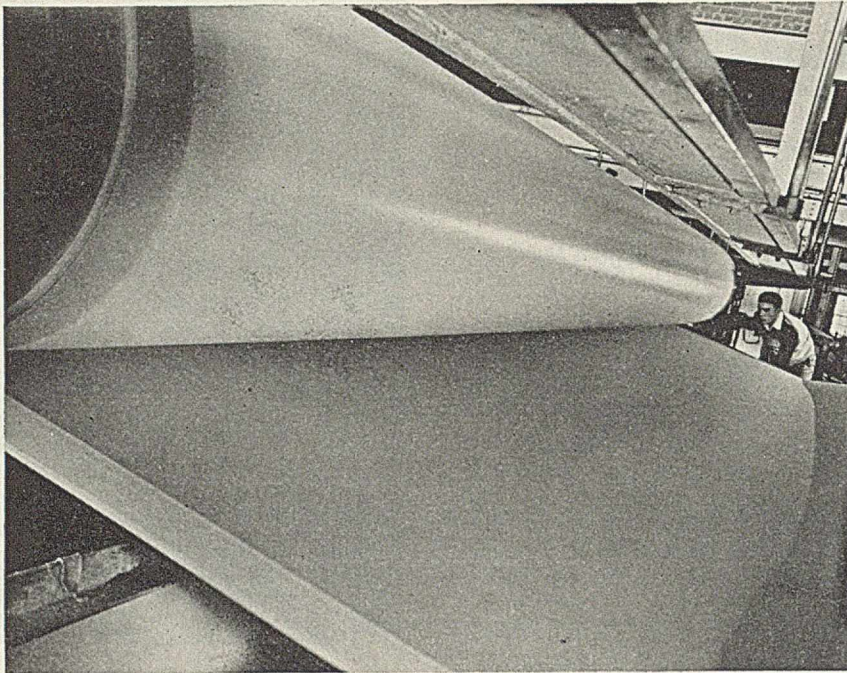
Synthetic rubbers might be considered by chemical engineers for many uses where natural rubber has sufficed

devised for adhering this rubber to metal. Numerous rolls have been made of the material, but it has not been used as a press roll cover for the reason that rubber is satisfactory, and also because Perbunan is more expensive, more difficult to process, and adhesion of plies presents a problem.

Decker couch rolls covered with Perbunan have worked very satisfactorily. Possibly the same technique would be applicable to large press rolls. It must be appreciated, however, that if attempts are made to use Perbunan or any other synthetic rubber in large rolls there will be numerous delays in delivery. No doubt many mistakes will be made before a synthetic rubber used as a press roll cover can approach the present high standard of performance of rubber covered press rolls.

It will take much time and effort to adopt the synthetic rubbers to all of the services of the process industries, meanwhile it is hoped that engineers will be sympathetic with rubber manufacturers. Real cooperation will be needed between the producer and user in order to solve the problems.

Perbunan has been used as a tank lining material as it is resistant to acids, alkalis, and water. Its electrical properties are not outstanding, but are good enough for many purposes. This rubber may be used for printers' rolls, motor mountings, conveyor belts, gasoline hose, packing, gaskets, and other products. The



Decker couch rolls covered with Perbunan have worked very satisfactorily. Possibly the same technique would be applicable to large press rolls

Germans say Buna reinforced with wire makes gaskets which seal better than asbestos and work well up to 350 deg. F. No doubt further uses can be made of it as more experience is gained. From the rubber manufacturer's standpoint, the chief drawback to this material is the difficulty in processing it, since it does not "break down" on a rubber mill in the same manner as rubber. Nevertheless, methods have been devised for handling it. It has excellent molding qualities.

Perbunan Extra is similar to Perbunan except that it is more oil resistant. It is a copolymer of butadiene and acrylonitrile in which a larger amount of the latter is used.

Hycar O.R. is derived from butadiene and an undisclosed ingredient. This synthetic rubber is similar to Perbunan, except that it is more resistant to oil. Like Perbunan it will

yield vulcanizates with a wide range of hardness (Garey, Juve, Sauser, *Ind. & Eng. Chem.*, p. 602, 1941).

Specially compounded Hycar O.R. yields soft vulcanizates with excellent resistance to heat, both wet and dry. Hycar is less resilient than rubber but is sufficiently "rubbery" for many purposes. In spite of its low resiliency (in general), the stocks properly formulated show excellent resistance to cold flow. It tends to stiffen at low temperatures but can be formulated to give compounds which have good flexibility under this condition. Hycar O.R. is reported to give better wear value as a tire tread than natural rubber. It is outstanding in resistance to aliphatic oils. It has excellent molding qualities, can be calendered quite easily, and can be bonded to metal. This material has good resistance to acids, alkalis, and salt solutions (except strong oxidizing

agents). Hence it can be used for all the applications previously given for Perbunan.

Buna S is a copolymer of butadiene and styrene and resembles natural rubber to some extent. It is not oil resistant, but does have good resistance to abrasion and chemicals, and good electrical properties. This synthetic rubber has been very little used for mechanical rubber goods, since it is not oil resistant, the principal attraction of synthetic rubbers heretofore. With a shortage of natural rubber, Buna S may become a very important synthetic rubber. It is capable of yielding vulcanizates of all degrees of hardness. These vulcanizates resemble compounds of similar hardness made from rubber with respect to chemical resistance and electrical properties. The electrical properties are superior to compounds of similar hardness made from Perbunan, Perbunan Extra, Hycar O.R., and the neoprenes.

Hard Buna S or Buna S-S could perhaps replace the usual products made of hard rubber such as combs, trays, bowling balls, syringe fittings, battery containers, etc.

Buna S can be bonded to metal satisfactorily and hence may prove useful as a tank or pipe lining material to replace rubber for all chemical solutions where rubber is now used, namely:

(a) All inorganic acids except strong oxidizing acids such as nitric and chromic

(b) All inorganic salt solutions except those which are strongly oxidizing

(c) Plating solutions

(d) Inorganic bases, such as sodium hydroxide

(e) Many organic acids, such as acetic, tartaric

(f) Pickling solutions

(g) Chlorine water and hypochlorite solutions

These possibilities for synthetic rubber are of interest to many industries. For example, rubber-lined tanks are widely used for pickling steel. The rubber is protected by a brick lining. In the case of stainless steel pickling where nitric acid is used special rubber compounds are required, and rubber coated with plasticized polyvinyl chloride is considered superior in performance to the conventional types of rubber lining. Synthetic rubbers, especially neoprene and Buna S could perhaps be adapted to this service either alone or in combination with other materials.

Transportation and storage of various acids now handled with rubber-

Comparison of Properties of Synthetic Rubbers

Rubber	Yields soft or hard rubber	Chemical Resistance	Oil Resistance	Electrical Properties	Abrasion Resistance	Heat Resistance	Cold Flow Resistance	Aging
Natural	All hardnesses	Good	Very poor	Good	Good	Medium	Good	Fair
Neoprene	Soft only	Good	Fair	Fair	Good	Good	Fair	Good
Perbunan	All hardnesses	Fair	Excellent to aliphatic hydrocarbons	Fair	Good	Good	Good	Good
Hycar O.R.	All hardnesses	Fair	Outstanding toward aliphatic oils	Fair	Good	Good	Good	Good
Thiokol	Soft only	Good	Excellent toward aro. and all.	Fair	Poor	Poor	Poor	Excellent
Butyl	Soft only	Excellent	Poor, fair to vegetable oils and fatty acids	Excellent	Fair	Excellent	Fair	Excellent
Buna S	All hardnesses	Good	Poor	Excellent	Good	Good	Good	Good

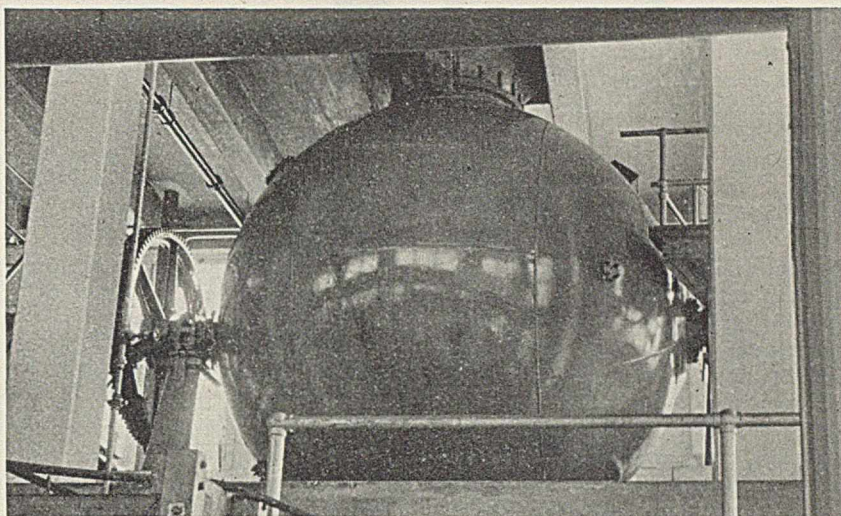
lined equipment could be handled with synthetic rubber. Discoloration of certain acids by contact with the synthetics is a problem which should receive special attention.

The plating industry makes extensive use of rubber-lined tanks, while the synthetic rubbers appear to have been little used for these tanks, some of the synthetics especially neoprene and Buna S have the necessary resistance to water and to the plating solutions. Adapting one or more of the synthetics would involve test to determine whether or not plating baths would be "poisoned." It seems probable that in most cases the synthetics could be so compounded as to avoid harmful contamination of the bath.

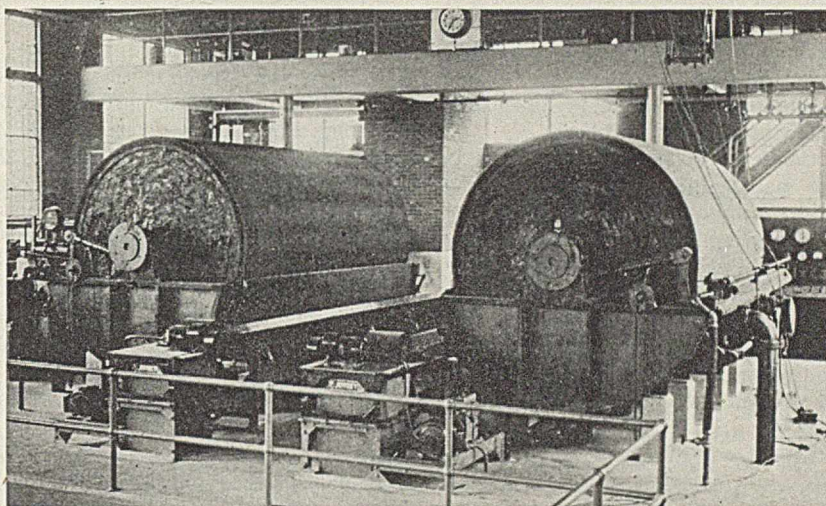
In general, synthetics have been used in the chemical industry only where an oil or severe heat condition exists. Obviously, they might be considered in many instances where natural rubber has sufficed. For best resistance to hot aqueous solutions, where oil is not a factor, neoprene (specially formulated) or Buna S would be preferable to the oil resistant Buna types. Due to its better aging characteristics it is possible that Buna S might prove superior to rubber in certain of the possible applications indicated.

There are a number of polysulphide rubbers known under the trade name of Thiokol. They are made from an organic dihalide and sodium polysulphide. This group is best known for its exceptional resistance to oils—both aliphatic and aromatic. They are quite resilient but have poor resistance to high temperatures and severe mechanical stresses. Thiokols are excellent for hose, printers' rolls, gaskets, self-sealing gasoline tanks, and many other mechanical goods where good resistance to oil is demanded. Their use can be greatly extended if necessary during the present emergency. They are not good at high temperatures and will not withstand severe mechanical stresses.

From this discussion of the commercial varieties of synthetic rubber it is apparent that if all were available in quantity, rubber manufacturers could make many of the articles which are now made of rubber. Some of the synthetic articles would be better, and some would be poorer than the same articles made of natural rubber. Further investigations of the processing and compounding will make it possible to meet most of the important requirement with synthetic rubber.

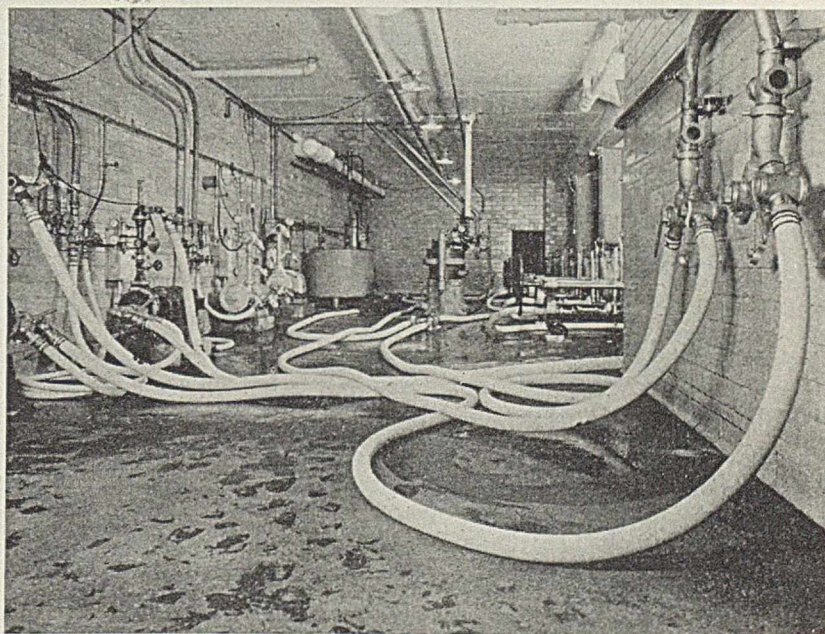


Flax straw pulp is bleached in this rubber-lined sphere in the cigarette paper mill of Ecusta Paper Co. at Pisgah Forest, N. C.



Rubber in this equipment must resist the action of ferric chloride, one of the most corrosive of chemicals

Synthetic rubber hose has been manufactured for several years



In the accompanying table have been listed the principal rubbers as well as natural rubber. From this table it should be possible to choose the synthetic rubber best suited for a given condition. It must be understood, of course, that the tabulation of properties is quite general and specific compounding of any one of the synthetic rubbers might give it a different rating with respect to the specific property listed.

Synthetic rubber hose has been manufactured for several years, and has been used largely for handling gas or oil. This same hose could be made and used for handling water, acids, and alkalis. Neoprene would be preferred for high temperature work or where exceptional water resistance is a factor. Thiokol is suitable for low-temperature work for many services. The Buna types could perhaps be adapted to hose manufacture if necessary.

Suction hose could be fabricated from the synthetic rubbers.

Conveyor belts are widely used in the paper industry for conveying chips, pulp, and not infrequently for transporting logs to and from barking drums. Coal is also moved on conveyor belts in the paper and other industries. Belts for these services are made in various widths and plies and are rubber covered (all around) to prevent water from entering the

carcass and in order to protect from impact, gouging, and tearing, and to provide a surface at all points that will give maximum wear value. Synthetic rubber compounds have been developed out of which good conveyor belts can be made, in fact many have already been made, especially with neoprene.

Transmission belts in the paper industry are used for main line shafts of drive and various general power transmission drives such as found on thrashers, pumps and beaters. Here again synthetic rubber compounds can be used in place of natural rubber; and in cases where oil is present or where high temperatures exist the synthetic can be used to advantage.

The continuous bleaching of pulp has resulted in a very extensive use of rubber in certain paper mills, chlorine and hypochlorite solutions may conveniently be handled in rubber-lined pipe and tanks in this continuous bleaching operation. Vacuum washers are rubber covered, usually with rubber of a hardness from 10-20 plastometer. Compounds of suitable hardness, resiliency, and with sufficient resistance to heat and chemicals can readily be fabricated from the Buna types of rubber. Some difficulties would perhaps arise in applying synthetics here, but this type of equipment could perhaps be adequately protected with synthetics as

more is learned about processing.

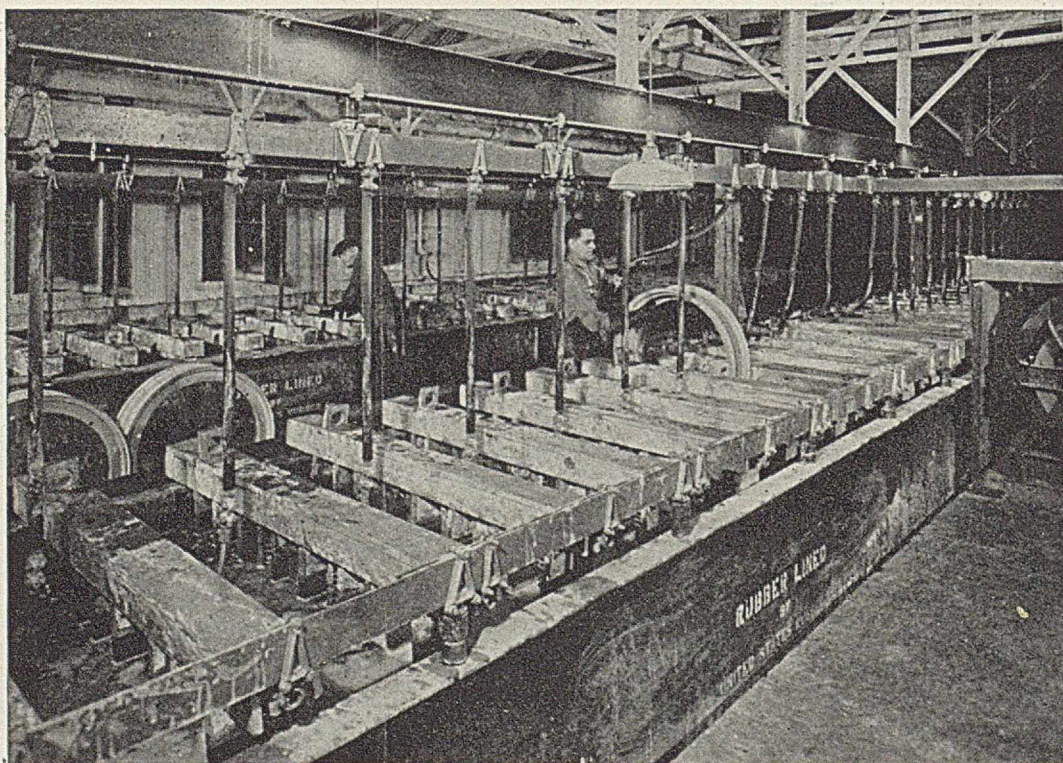
From the foregoing discussion it appears that it would be possible to make many pieces of equipment from one or more of the synthetic rubbers. What difficulties will be encountered in producing all of these articles, and how they will perform as compared with natural rubber, for the most part, remains to be seen.

Styrene can be produced for 30-35c. per lb. and acrylonitrile at 35c. On a large tonnage basis, butadiene could be made for 10-15c. per lb. and the finished Buna type rubbers for 20-25c. per lb. H. I. Cramer, Sharples Chemicals, has prepared an interesting tabulation showing at what prices the various synthetic rubbers will have to sell in order to compete with natural rubber at prices prevailing before our entering the war (*Chem. & Met.*, p. 150, Jan. 1942).

Under present conditions a synthetic rubber would not have to compete in price with natural rubber. If suitable for a vital industrial need a synthetic rubber could sell for several times the price of crude natural rubber and could sell in large volume. It seems likely that in a free market rubber could still sell for a price well below any of the synthetic rubbers.

The author wishes to thank his associates, O. S. True and E. D. Hoff, for assistance in the preparation of this paper.

Neoprene and Buna S have the necessary resistance to water and to plating solutions to be used for the tank lining



Mobilizing Petroleum Hydrocarbons

GEORGE F. FITZGERALD *Chemical Engineer, Olean, N. Y.*

Chem. & Met. INTERPRETATION

The petroleum industry, mobilizing its hydrocarbons for use in high-octane aviation fuel, synthetic rubbers, toluene and other products, will play a vital part in the winning of this war. Just how capable and prepared is the country's largest process industry to meet these new responsibilities? Can the industry supply by 1943 sufficient raw materials for some 600,000 tons of synthetic rubber and 65 million barrels of 100-octane aviation fuel? Herein the author answers this question and gives some interesting aspects of the problem.—*Editors.*

DEMAND FOR petroleum products in 1941 was the greatest in the 80-year history of the industry and exceeded the previous year by ten percent. At the end of last year, daily crude oil production had reached 4,100,000 bbl. Output is expected to reach 4,500,000 bbl. by the middle of this year and five million by July 1943. In the face of an acute rubber shortage, it is interesting to speculate that one day's crude oil production is equivalent on a hydrocarbon basis to our annual crude rubber consumption.

The Far Eastern situation now presents the oil refining industry with a formidable proposition. Will it be possible to guarantee adequate stocks of 100-octane aviation gasoline and, in addition, meet an entirely new demand for synthetic rubber ingredients? It must be remembered that American refineries are supplying fuel to all the Allied nations as well as to our own greatly expanded air forces.

The superiority of 100-octane fuel has won it complete acceptance by all fighting forces. Weight for weight, it yields 20-25 percent more power than 90-octane fuel. This means lighter fuel load and lighter engines per delivered horsepower. These advantages permit higher operating speeds, bigger pay loads and wider radius of operation. In spite of these advantages the suggestion has been made that aviation fuel quality be dropped to 90-octane to release stocks for synthetic rubber.

American 100-plus octane fuel is a blend of light straight-run petroleum

fractions, alkylation products and catalytically cracked gasolines plus tetraethyl lead. Aromatics also might come into use as they have been found satisfactory in England. According to Refining Director W. W. Gary, an acceptable fighting grade fuel for the Army and Navy may be 100 or 100-plus octane rating to be blended approximately as shown in Table I.

FIGHTING GRADE FUEL

Before Pearl Harbor, the Office of Petroleum Coordinator estimated that our defense program would require the expansion of fighting grade fuel capacity to 126,000 bbl. per day before the end of 1942. A month later the figure was raised to 180,000 bbl. per day. By contrast, last year's output reached a peak between 45,000 and 50,000 bbl. per day, which is more than all the rest of the world produces. The OPC has concentrated on making every move count toward increasing output and capacity at the utmost speed. One of its most important efforts was the Petroleum Hydrocarbon Survey which determined the quantities and types of hydrocarbons available from the oil industry. These figures will be of especial value now in locating sources of high-octane fuel, butadiene and styrene.

The call for synthetic rubber bases from petroleum sources momentarily appears to jeopardize the output of 100-octane gasoline. To arrive at an understanding of the situation as it affects the refiners requires an analysis of wartime demand for rub-

ber and fuel and a study of potential and actual sources of raw materials suitable for both. It is the purpose of this article to outline the processes and capacities available for the manufacture of butadiene and fighting grade aviation gasoline.

According to Table I we would need approximately 90,000 bbl. per day of 80-100 octane blending agents to meet the OPC program. Of this amount about half might come from catalytically cracked gasoline and the rest from alkylates and hydrocodimers. The latter two stocks must be made from butane bases and consequently will be in direct competition with raw materials for synthetic rubber.

Principal sources of butane and isobutane are the natural gasoline and gas recycling plants of the Southwest. Vast quantities of petroleum gases from the high pressure fields are passed through absorption towers and fractionating columns to remove "natural" gasoline and the C₃, C₄, and C₅ fractions. Typical analyses are shown in Table II. The lean gas from these recycling plants is returned to the oil-bearing sands to help maintain reservoir pressure. This country's 160-odd natural gasoline plants alone when operating at full capacity can turn out approximately 2,000,000 gal.¹ of butane-propane mixture daily. Refineries also produce large volumes of these gases but usually not enough even for their own blending needs. Texas has 58 plants which produce 43 percent of the country's output of liquefied petroleum gases. In 1939 the total was 223,500,000 gal. which rose to 300,000,000 gal. in 1940 or a gain of 32 percent. The bulk of propanes and butane now go to the bottled gas markets and into industrial fuel. It is in domestic use that they are most apt to be curtailed for government purposes. In 1941 there were over a million retail customers for bottled gas. The potential liquefied

Table I—Typical 100-Octane Gasoline Blend

50% blending agent (88-100 octane)
40% base stocks (75 octane)
10% isopentane
Tetraethyl lead content not to exceed 3 cc. per gal.

petroleum gas supply is in the neighborhood of 33,000,000 gal. per day.

The largest condensate recovery recycling plant in the world² recently completed in Texas handles 225,000,000 cu. ft. of gas daily. The original plan called for recovering 50 percent of the available butane and isobutane content but the expanded armament program made it advisable to increase the design yield to 85 percent. Building more such plants and greatly increasing crude runs are not necessarily the answers to wartime demands. Existing absorption plants could increase their yields by modernization and improved supervision. By so doing they could make available upwards of 30,000 bbl. per day additional butane. The noticeable decline in domestic consumption of motor fuel plus the proposed reduction of its butane content will release almost twice as much more. As in most manufacturing fields, the systematic reduction of waste will result in important savings.

MIXED BUTANES

Such measures could make available 90,000-125,000 bbl.³ per day of mixed butanes in less time and more economically than by building entirely new plants. The technical problems involved are by no means difficult. The chief obstacle is the time element in erecting sufficient rectification and absorption equipment to modernize the existing plants and augment their output. In converting these butanes to alkylates and hydrocodimers for aviation fuel heavy losses are encountered. On the basis of an approximate 60 percent overall yield 75,000 bbl. per day would be sufficient for 45,000 bbl. of high-octane blending agents. By difference, then, there should be from 15,000-45,000 bbl. per day of butane available for rubber production.

Amount of synthetic rubber needed may best be gaged by considering our normal consumption of crude rubber. In 1940 the value of all manufactured rubber goods reached \$940,000,000 while the crude rubber demand exceeded 600,000 long tons.⁴ With conservation measures now in effect, the estimated maximum of

800,000 long tons for 1941 is expected to drop to about 400,000 tons by the end of 1942.

CRUDE RUBBER STOCKS

In a recent statement Jesse Jones, Secretary of Commerce, announced⁵ that our stockpile of crude rubber was over a million tons or about two year's supply for army and navy needs. The United States received about 114,000 tons from the Far East in January and a similar amount in transit was expected to arrive here in February. Naturally no further shipments from Malaya will be made while the Japs are in possession. Reclaimed rubber up to 50 percent is used to extend the crude supply, but our scrap pile will last only 12-18 months with tire rationing in effect.

These figures definitely show that we have approximately a year and a half in which to improve our rubber output. Guayule from the Mexican shrub has been advanced as a possible solution. We now obtain about 4,000 tons of guayule annually but four to six years would elapse before that figure could be substantially increased. South American rubber production likewise calls for long-term development with no immediate increase in tonnage. We are brought abruptly to the realization that synthetic rubber must meet the demand and that *synthetic production must be stepped up to 300,000-400,000 tons for war purposes alone in much less than two years.*

SYNTHETIC RUBBERS

It is outside the scope of this article to discuss synthetic rubber production from the process angle. Our concern is with the types and quantities of raw materials needed with particular emphasis on petroleum derivatives. With several commercial types of synthetic rubber on the market, the government is depending largely on the neoprenes and the butadiene polymers because of their superior wear characteristics. For military purposes in general rubber must meet the requirements of good tire tread material. In this respect thiokol, polysulfide rubbers, polyisobutylenes and others, while very important in specialized fields, are not equal to chlorprenes and butadiene polymers. In its \$400,000,000 building program, the government is putting the greatest emphasis on the butadienes. The "Buna S" type has been adopted as standard for war production. The butadiene is produced from petroleum, natural gas, alcohol or acetylene. The styrene can

be made from benzol derived from coke-oven operations.

Dr. E. R. Weidlein, Consultant, Chemicals Branch of WPB, announced to the oil industry in February that it was necessary to pool all patents, resources and technical experience with the rubber and chemical manufacturers if we are to carry out the rubber program. He stated that raw materials for the first half of that program are in sight and are to come largely from chemical industry. For the second 200,000 tons the petroleum industry is expected to furnish the necessary base stocks.

It is obvious that an abundant supply of acetylene, butadiene and styrene will be needed to expand synthetic rubber production from an estimated 90,000 tons before this year is over to 400,000 tons per year in the next 18 months. The latter quantity is equivalent to a theoretical consumption of 11,000 bbl. of butane per day. This is well within the balance of 15,000-45,000 bbl. left after earmarking sufficient amounts for 100-octane gasoline production. As would be expected, however, theoretical yields are not obtained. High conversion losses and side reactions will probably bring the ultimate demand up to 35,000 bbl. per day³ or very close to our working balance. This demand, of course, will be reduced to the extent that sizable amounts of rubber will be produced from bases other than butadiene. Should unforeseen circumstances require much additional butane it would be necessary to build additional butane recovery plants and further restrict civilian supplies. One possibility which is feasible but probably not strategically sound is the reduction of fighting grade gasoline to 90-95 octane rating. This would release 70,000-80,000 bbl. of butane per day. Such a step would call for a military choice between rubber and 100-octane fuel.

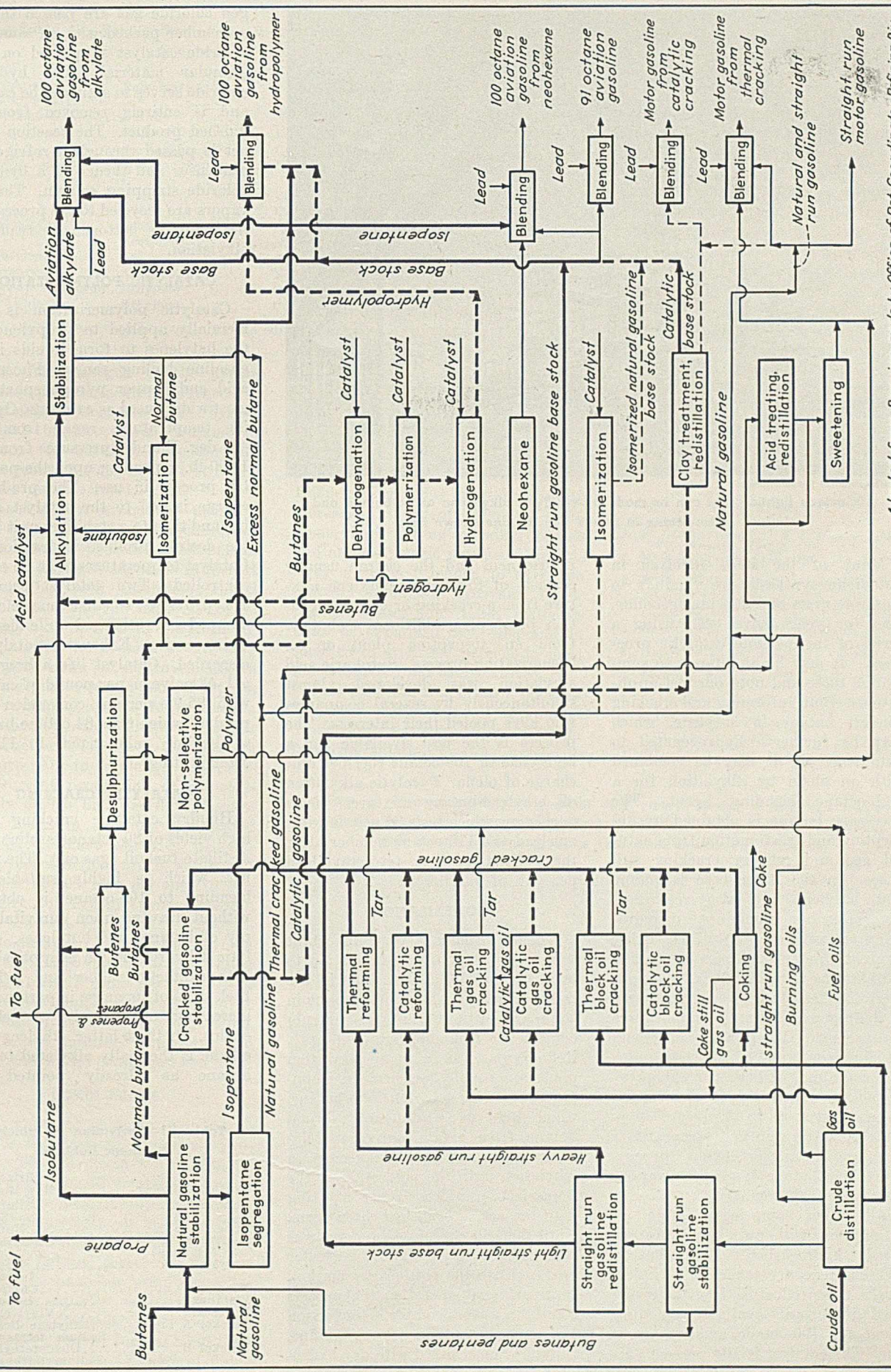
ACETYLENE AND BUTADIENE

Acetylene production from petroleum is under development by research workers at the University of Texas. They report that it has been made experimentally from propane but has not yet reached the commercial stage. Existing facilities for the synthesis of butadiene from petroleum gases are being rapidly augmented. Typical of the new facilities is a 5,000 ton-per-year unit which went into production late in 1941. Several more plants are under construction but details must be considered as military secrets at this time.

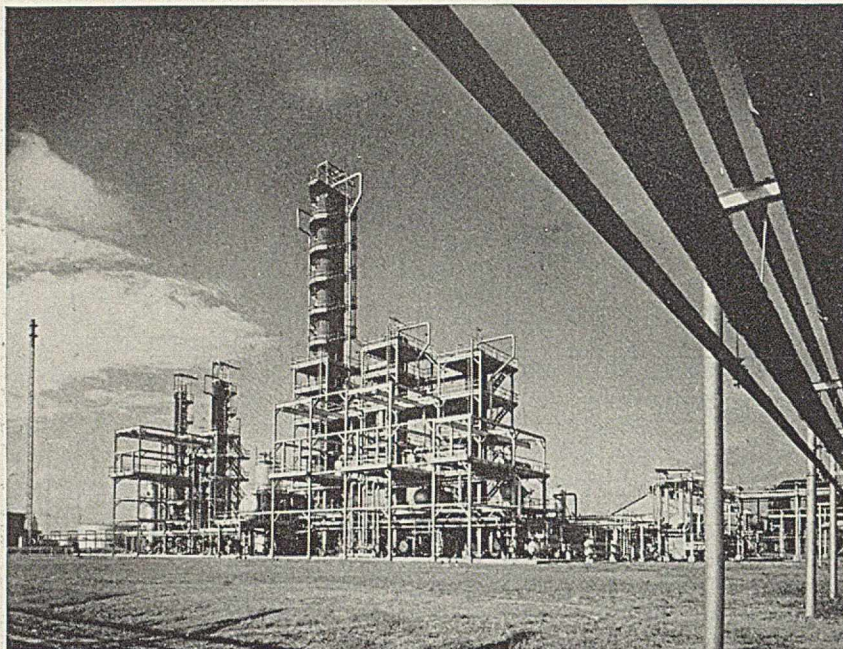
Table II
Raw Midcontinent Petroleum Gas
Typical Percentage Analyses

	A	B
Methane	2.50	2.75
Ethane	7.50	9.25
Propane	21.60	10.70
Isobutane	5.00	8.00
n-Butane	27.00	34.00
Pentane and heavier....	36.40	35.30

RELATIONSHIP OF PROCESSES FOR PRODUCTION OF AVIATION GASOLINE



Adapted from Drawing made by Office of Pet. Coordinator, Refining Div.



Courtesy Robert Yarnall Richie

100-octane fighting fuel can be made by catalytic alkylation of iso-butane and butene to iso-octane in plants like the one shown here

Many of the steps involved in butadiene synthesis are familiar to manufacturers of 100-octane gasoline, who for years have been using a series of thermal and catalytic processes⁷. It may be of interest to summarize these and note parallel applications. Both reforming and cracking convert butane to butylene, which may be further dehydrogenated to butadiene. Or it may be combined with an olefin by alkylation for a high-octane blending agent. The necessary butane is obtained by absorption and fractionation from natural gas and refinery cracking still gases. In the latter case isobutane and butylene are also recovered. Hydroforming combines dehydrogenation with aromatization, using straight run or catalytically cracked naphthas as charging stock. The conversion takes place in an atmosphere of hydrogen at elevated temperatures and pressures. The product represents an 80 percent yield of 80-octane gasoline containing a high percentage of aromatics. Operating conditions can be modified so as to produce 80 percent aromatics rich in toluene. Polymerizing is an analogous process which uses butane or propane vapors instead of hydrogen.

Alkylation comprises joining an iso-paraffin with an olefin (unsaturated) hydrocarbon. If iso-butane and butylene are taken as charging stocks the product is iso-octane, the most important available blending agent for 100-octane aviation gasoline. The catalyst is 100 percent sul-

phuric acid and the charge usually consists of the butane-butylene mixture from a cracking or dehydrogenation plant plus additional isobutane from an absorption plant or an isomerization process. Sulphuric acid alkylation was developed almost simultaneously by several companies who have pooled their interests. The process is the best available for a high yield of 100-octane fuel per unit charge of olefin. Pyrolytic alkylation of ethylene-butane mixtures yields neohexane which tests 94 octane without lead and 115 octane number after the addition of 3 cc. tetraethyl lead per gal. of gasoline.¹⁰

ISOMERIZATION

Isomerization is a very important adjunct to alkylation. In relation to our present discussion, this is the factor which puts aviation gasoline in close competition with synthetic rubber for the available butane supply. Refinery gases as fed to an alkylation plant are usually deficient in isobutane and often too rich in n-butane, which acts as a diluent. Normal butane from many sources is relatively abundant but was useless in alkylation until the perfection of the isomerization process for converting it to the active branched-chain form. Until that time a limited amount was blended into gasoline and the greater part went to the bottled gas market. In commercial operation the process results in almost complete conversion of normal butane to isobutane. Butane vapors mixed with dry hydro-

gen chloride gas are passed through a chamber packed with an aluminum chloride catalyst supported on inert granular material. The hydrogen chloride serves to activate the catalyst and is entirely removed from the finished product. The reaction product is passed through a refrigerated condenser and thence to a hydrogen chloride stripping column. The acid vapors are recycled to the process and the acid-free bottoms are ready for alkylation.

CATALYTIC POLYMERIZATION

Catalytic polymerization is commercially applied to propylene and the butylenes to form liquids in the gasoline boiling range. Phosphoric acid and copper pyrophosphate are most widely used as catalysts. Operating temperatures range from 300-400 deg. F under pressures from 700-1,100 lb. depending upon the particular process in use. The pre-heated charge is fed to the catalyst chamber and then to a stabilizer unit where the desired product is fractionated. Catalyst temperatures must be closely controlled. Two catalyst chambers are provided so that one may be dumped and recharged while the other is in service. Exhausted catalyst is discarded. Catalyst life averages 90 gal. of polymer per pound of catalyst with 85-95 percent conversion to a product which tests 84 octane but has a blending value equal to 110-130 octane rating.

CATALYTIC CRACKING

Houdry catalytic cracking gives high yields of 80-octane gasoline from distillate fuel oil (gas oil). The product, which is highly suitable for blending to 100-octane, is obtained without drawing upon our vital supply of butanes and butylenes. Catalytic dehydrogenation is applicable to both synthetic rubber and aviation fuel. It is of immense importance for increasing our supply of selected olefins. Of these latter, ethylene from ethane is thermally alkylated to neohexane as already pointed out.

Table III—Derivation of Principal Synthetic Rubbers

Synthetic Rubber	Principal Raw Materials
Buna S	Butadiene Styrene
Buna N (Hycar) (Chemigum)	Butadiene Acrylonitrile
Butyl	Butadiene Isobutylene
Neoprene	Chloroprene
Vistanex	Isobutylene
Koroseal	Vinyl chloride
Thiokol A	Ethylene dichloride Sodium tetrasulphide
Thiokol B	Dichlorethyl ether Sodium tetrasulphide

Table IV—Relationship of the Petroleum Industry to Synthetic Rubber Intermediates and Raw Materials¹

Synthetic Rubber Intermediate	Raw Material	Source of Raw Material
Butadiene	Butane	Natural or petroleum refinery gases.
	Ethanol	Ethylene, fermentation, etc.
Styrene	—	Cracked petroleum gases.
	Ethylene, benzene	Natural or petroleum refinery gases; coal gases.
	—	Cracked petroleum gases.
Acrylonitrile	—	Carburetted water gas light oils.
	Ethylene	Natural or petroleum refinery gases.
Isobutylene	Acetylene	Natural or petroleum gases; calcium carbide.
	—	Cracked petroleum or natural gases.
Chloroprene	Acetylene	Natural or petroleum gases; calcium carbide.
Ethylene dichloride	Ethylene	Cracked petroleum or natural gases.
Vinyl chloride	Ethylene	Cracked petroleum or natural gases.

¹ Compiled from various sources by the editors.

Isobutylene charged to the hydrocodimer process is first condensed to isooctenes, which are then hydrogenated to isooctanes. Butane to butylene to butadiene are the dehydrogenation steps of interest to the rubber manufacturer.

The national armament program necessarily prohibits publication of much recent process development. These undisclosed advances in the art of refining will doubtless reveal petroleum as the raw material for an entirely new branch of chemical industry. For the present we are content with news of improvements in existing processes and general reports of building projects. More than a score of 100-octane plants are under construction. They are the start in the program to triple or quadruple our current production of approximately 50,000 bbl. per day. Incomplete totals in January^{8,9} indicated over \$150,000,000 worth of projects under construction which would add at least 40,000 bbl. per day to our capacity for fighting grade aviation fuel. Several government construction loans are to be repaid by turning over the entire output to the United States at 12-13 cents per gal. Other plants now building are to produce isobutane, thermally cracked gasoline, polyformed gasoline, isopentane and butadiene but no details are available.

CONCLUSIONS

All industry is being enlisted to further the national armament program. The petroleum world, with its vast production of essential war materials, has consistently shown remarkable foresight. It has kept fully prepared to meet any likely demand from our fighting forces. At any one time in the past few years our aviation fuel capacity was more than ample for our needs. Even today we have more aviation fuel on hand than we had a year ago. Export of fight-

ing grades of fuels was controlled in full cooperation with government agencies.

Demand for synthetic rubber has put an unexpected burden upon the petroleum industry. The production of 100-octane gasoline must be rapidly increased. Sufficient isobutane, butadiene, high octane blending agents and other strategic petroleum derivatives must be provided to carry on the war production program. Existing capacities for these materials must be expanded 300, 400, and in some cases even 500 percent to meet the demand of our armed forces.

This program was given a boost in December when five oil companies owning patents on processes of manufacturing aviation gasoline agreed to

reduce their royalties by 50 percent or to 21 cents per bbl.

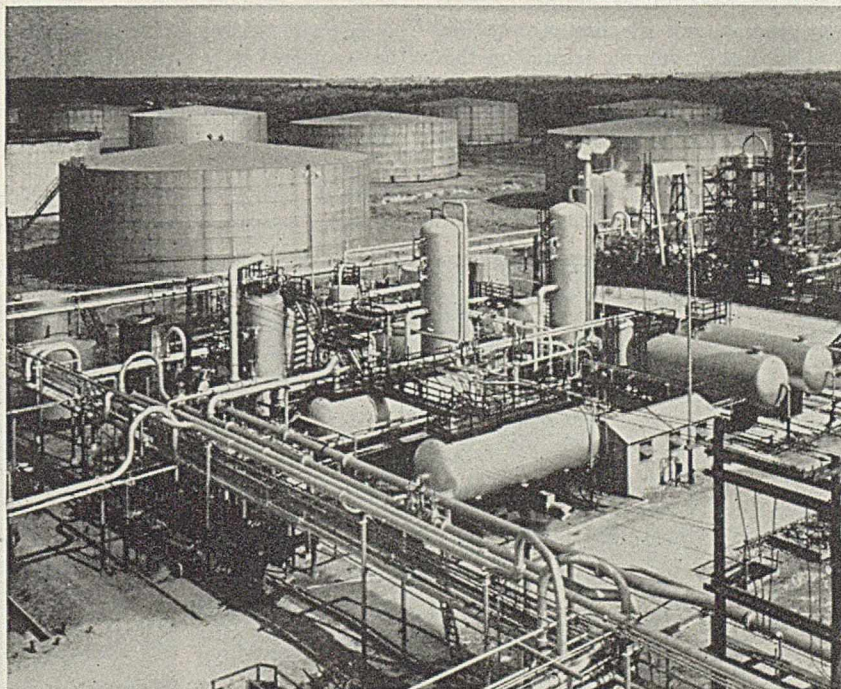
The call of the government for increased supplies of essential petroleum products will be met. The oil industry's unique position as the only branch of American industry prepared for war when hostilities broke out is the guarantee of that statement. Oil refiners have reason to be proud of their development of aviation fuel processes and of their foresight in building capacity which enables this country to have more 100-octane fuel on hand today than was in stock a year ago. Figures and estimates are given to show how vital materials such as butane can be supplied in sufficient amounts for synthetic rubber production without reducing the output of aviation gasoline or seriously reducing civilian supplies.

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Close-up view of an alkylation plant at Baytown, Texas. In this unit waste refinery gases are utilized to produce a blending agent for use in making high octane aviation gasoline (see flow diagram on page 85)

Courtesy Standard Oil Co. (N. J.)



How to Conserve Rubber Equipment

O. S. TRUE, *United States Rubber Co., New York, N. Y.*

Chem. & Met. INTERPRETATION

In view of the present difficulty of securing almost every type of material of construction it behooves the manufacturer to prolong the life of the equipment which he now has by every means at his command. Because of this serious situation the author's suggestions for the protection of rubber linings in tanks, valves and other pieces of equipment are particularly timely.—*Editors.*

IN THE NATIONAL EMERGENCY the United States Rubber Co. has recognized the principle that "every ounce of rubber is a sacred trust." Because of the important part played by this material in the war effort, it becomes the duty of every one to conserve rubber by the proper care of their industrial equipment in which it is used. In the chemical industry there is an unusual opportunity to observe this duty and at the same time to effect production savings through more efficient maintenance of rubber linings.

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 for rubber linings differ appreciably and the life of any installation may depend greatly on the completeness of the original data.

In the erection of large rubber-lined tanks it is important to take

special precautions against damage to the linings. Riggers' slings must be well padded at the point of contact between rope and tank lining. If it is necessary to enter the tank, workmen should wear rubber-soled shoes to avoid abrading and cutting the lining. Care must be taken against the possibility of welding sparks or tools dropping into the tank from construction overhead.

Rubber-lined pipe and fittings should be assembled with care to see that there are no excessive strains on the rubber over the faces of flanges. Only the gaskets that are supplied should be used. There will be soft, pure gum for hard-rubber-lined pipe, and for soft-rubber-lined pipe. Pipe sections should be aligned and bolts brought up evenly with a standard open-end wrench. A bar or hammer should not be used. The pipe should be supported to prevent bending and necessary provision should be made for expansion and contraction in the line. This can be accomplished best

by using flexible expansion joints.

If there is a possibility of mechanical damage to rubber-lined equipment, the lining 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.

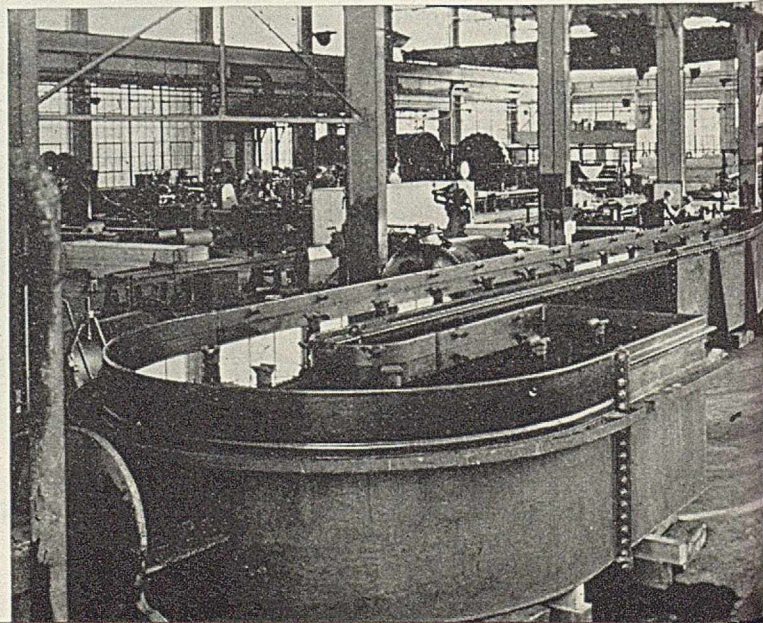
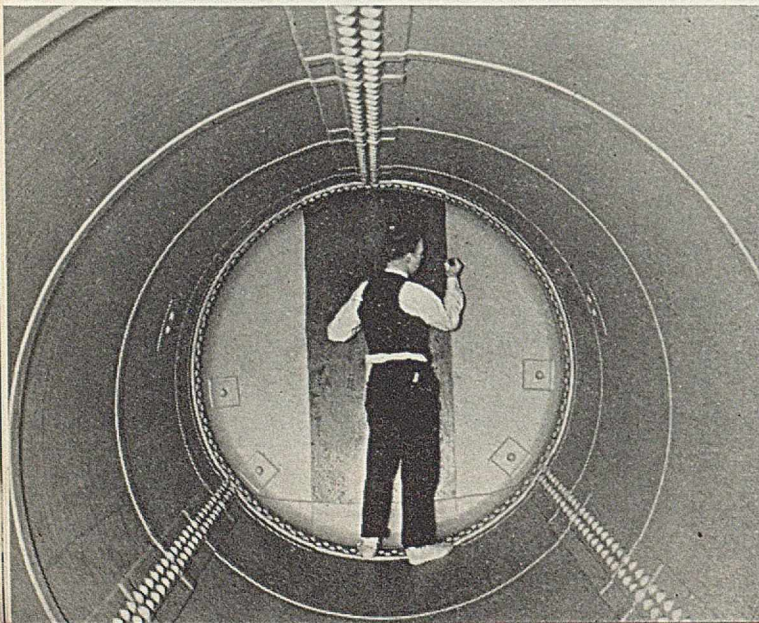
Efforts to increase production frequently result in higher operating temperatures. If production is being pushed, it is advisable to investigate the possible effect of these higher temperatures on any rubber-lined equipment which may be in the flow-sheet. High temperature in general shortens the life of rubber and under certain chemical conditions a small temperature increase may be beyond a safe operating point and result in rapid deterioration of rubber linings.

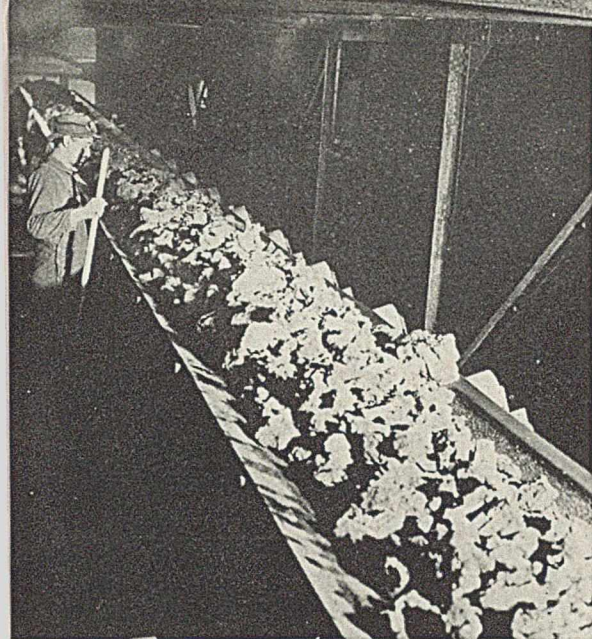
It is a good policy to call in a sales engineer from a rubber company for consultation before making these changes and be guided by his recommendations. He may suggest a supplementary inner lining of brick and acid-proof cement which will create a temperature gradient between solution and rubber lining. This often makes possible the use of rubber under conditions it could not stand without the protection.

In some cases shortages of raw materials are making it necessary to use substitutes or to change processes substantially. Either of these things may result in a radical change of operating conditions for some or all of

An operator should wear rubber-soled shoes when entering a rubber-lined tank to protect the lining from abrasion

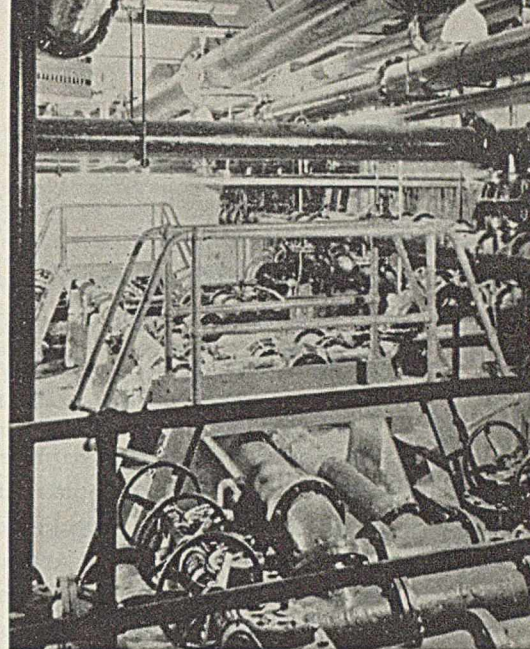
When changing plating solutions remember that linings suitable for nickel can not cope with conditions in a copper bath





It is a good policy to consult a representative of a rubber company before making changes in operating conditions

Rubber-lined pipe and fittings should be assembled with care to see that there are no excessive strains on the rubber over the faces of flanges



the rubber-lined equipment. Since the original specifications of the linings were made to suit a different set of circumstances it will be best to consult with the sales engineer before making the proposed changes. For example, numerous nickel plating operations have been changed over to copper. But a lot of tank linings that are suitable for nickel can not cope with the conditions encountered in a copper bath.

Increases or changes in production procedure which in themselves might not jeopardize rubber lining may possibly result in an increased concentration of impurities or in the production of other impurities detrimental to rubber. If this problem arises, the sales engineer from the rubber company can undoubtedly make helpful recommendations.

Many rubber-lined tanks contain solutions of extremely corrosive materials of high specific gravity but in concentrations low enough not to attack rubber lining. If such tanks are

used for mixing, the operator should be sure that there is sufficient agitation to avoid stratification. If this happens, there is danger to the lower portions of the tank where inspection can not reveal the hazard until it is too late. For example, if 66 deg. Baumé sulphuric acid is added to a solution without agitation it will sink immediately to the bottom of the tank and shortly destroy the lining in that area.

Rubber-lined valves should not be closed under excessive pressure when in service since this tends to crack and destroy the lining.

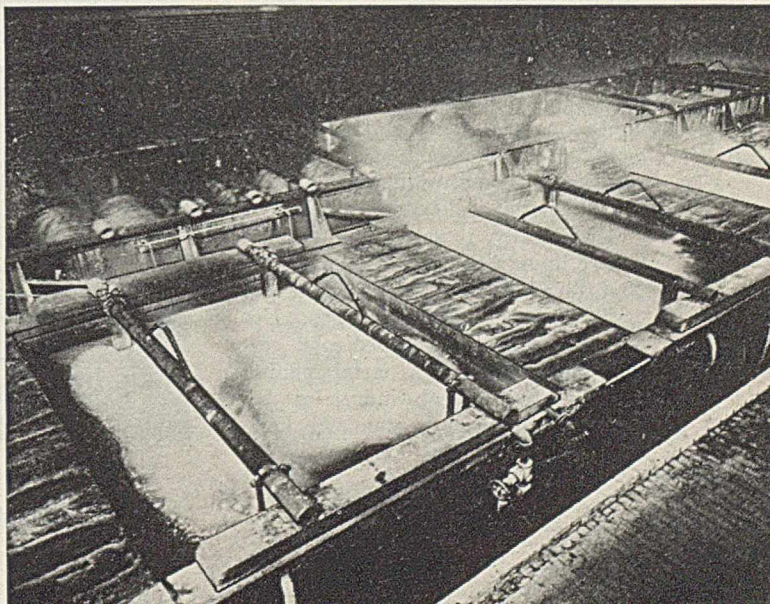
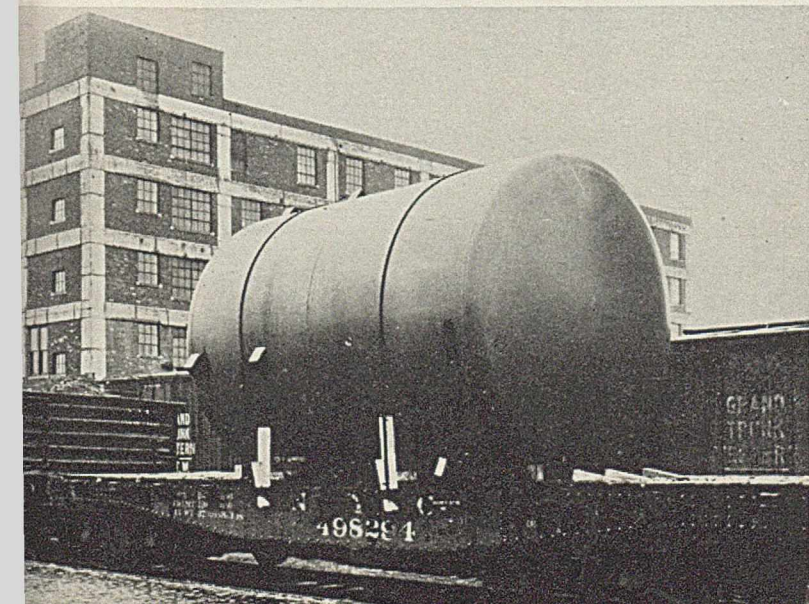
Operators making routine examinations or cleaning rubber-lined tanks should protect the linings from abrasion or cutting by wearing rubber-soled shoes. Points of lubrication on adjoining or overhead equipment should be protected so that lubricants will not drop into the tank or be brought in contact with the rubber lining as natural rubber is damaged by oil. Any damage which may acci-

dentally occur to rubber linings must be repaired at once, and periodic examination should be made so that even the smallest cut will be discovered quickly. This will not only protect the lining against further damage but will also save metal parts of the equipment. Where steel tanks have large surfaces exposed to direct sunlight in warm climates, dark colored paint will cause them to absorb surprisingly large quantities of the heat and the operating temperature of the rubber lining will be unnecessarily high. Such tanks should be covered with light colored paint which will reflect a very large portion of the sun's heat.

If rubber-lined equipment is to be idle for any length of time, the lining should be submerged in a dilute acid solution. Dry air, sunlight, and heat are very detrimental to unprotected rubber linings. Rubber-lined valves which are to be idle should be opened, removed from the line, and carefully cleaned.

Proper care for the rubber linings of tanks such as these will extend their usefulness and thus conserve rubber

Give the rubber manufacturer full and accurate information concerning service conditions when ordering lined equipment



Centrifugal Pumps for Process Use

A. T. NIELSEN *Application Engineer, Worthington Pump & Machinery Corp., Harrison, N. J.*

Chem. & Met. INTERPRETATION

This paper, which was a prize winner in the Hydraulic Institute's recent Second Annual Engineering Contest, presents an exceptionally good picture of the way the centrifugal pump has developed to meet the peculiar requirements of process industries' uses. A number of extremely useful ideas for increasing the life of pumps operating under severe conditions, and for facilitating their inspection and maintenance, are presented. The paper is an important contribution in the series planned by *Chem. & Met.* to deal with the vital problem of making process equipment last longer.—*Editors.*

IN THE TWO DECADES following the first World War, the process industries have undergone tremendous growth. Increasing complexity in the industries' problems has demanded equipment peculiarly fitted to the requirements. Many of the raw, intermediate and finished materials handled are in liquid form so that process industries have placed many and varied demands upon the pump builders. Development of pumping equipment has followed the expected pattern, ranging from the early use or adaptation of existing designs (principally water pumps), to the point where demand arose for pumps especially suited for the work at hand. Handling of liquids of low viscosities of almost any character was found to be possible through refinement of the centrifugal pump.

Today the centrifugal pump is called upon in the handling an almost infinite variety of liquids. The problems incident to pumping of non-corrosive and non-abrasive liquids are generally well understood but where abrasive or corrosive materials are to be pumped, the best methods are not so well understood, and it is to the solution of such problems that the present paper is devoted.

Historically, it may be noted that severe liquid handling problems were first solved with simple containers and with blow cases or acid eggs. Not satisfied with these expedients, certain industries such as metal refining and electrochemical industries attempted to employ standard hori-

zontal double-suction centrifugal pumps. Many difficulties were encountered with impeller corrosion and stuffing box troubles. Designers then decided on the vertical pump with the impeller at the bottom and the shaft within a tube extending above the liquid level. This move eliminated the troublesome stuffing box, but brought other problems in its stead. For example, to offset serious corrosion (generally from sulphuric acid and its salts), lead-lining of these pumps was resorted to. This move eliminated

failure due to galvanic action. However, the double-suction type of impeller was poorly adapted to lead covering so that a single-suction open impeller was used. The unit thus constructed performed quite well and had few drawbacks but was expensive both to build and to operate, and quite inefficient. Still, such units were the best of their time and many sizes and style variations were developed.

Coincident with the development of the vertical pump, efforts were expended to solve the problem presented by the stuffing box in horizontal units when handling corrosive materials. With the advent of such inorganic packings as asbestos, the material so widely used today, it became possible to minimize the maintenance problem. Horizontal units were then constructed which, owing to their short impeller overhang on the shaft, permitted higher speeds, thus reducing power requirements compared with vertical pumps for similar service conditions.

About 15 years ago the metallurgical technique of the then new stainless steel alloys had reached the stage where moderately complicated

Fig. 1—Visual orifice for checking and regulating sealing water flow to centrifugal pump stuffing boxes

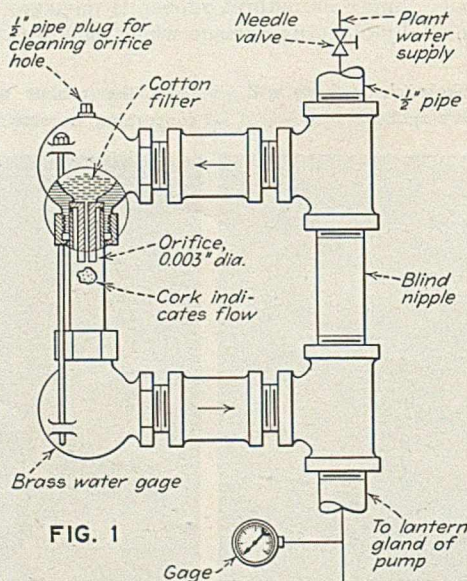
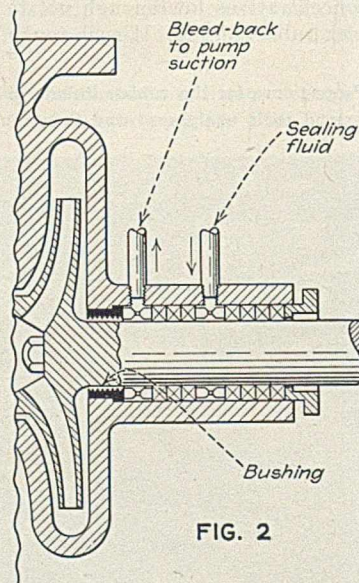


Fig. 2—One means of handling stuffing boxes on high-head, closed-impeller centrifugal pumps



shapes could be cast. Now the so-called "chemical pump" took an entirely new turn. Constructing centrifugal pumps of long-lived materials became commercially possible. In addition, other materials such as the high silicon irons and ceramics also became available, all giving pump builders new and useful construction mediums.

PRESENT-DAY TRENDS

The prime consideration in centrifugal pump design for process industry use is to give the user a unit at as low a first cost as is compatible with the desired life and required

maintenance cost. The horizontal single-suction pump is the logical one to meet these needs. For chemical service the frame of such a pump must be rugged enough to prevent misalignment despite any load or stress imposed. The shaft and its means of support must be constructed so that no measurable deflection in use can take place in that portion upon which the impeller is hung. The reason for this is that the packings normally used in pumps for corrosive materials are of a non-resilient nature and hence have little tendency to "follow" a shaft rotating eccentrically. The logical conclusion is that

the shaft should be supported on ball bearings, since the amount of radial displacement allowed by sleeve bearings—and necessary for their lubrication—is beyond that which can be tolerated by such packings.

To maintain the casing and impeller shapes at a minimum of complication, the single-end-suction pump finds wide favor and also requires but one stuffing box. A heavy shaft can be used as its dimensions do not affect the impeller inlet dimensions as with double-suction impellers. Extremely close fits within the pump proper can be avoided, thus preventing possibility of destructive rubbing contact and galling of high alloy steels.

High efficiency, often considered of prime importance in pump construction, is relatively unimportant in chemical pumps where long life and low maintenance are paramount qualities. Thus impeller vanes can be made heavier and more rugged than in water pumps and casing features such as wearing rings can be eliminated completely. Attainment of long life merely consists in simplifying the unit and increasing the ruggedness of its parts. The designer can, however, impart features very valuable to the ultimate user when the pump is so constructed that its maintenance will be low.

STUFFING BOX POINTERS

Particularly is this true in the case of the stuffing box. The repacking of a chemical pump in service is an unattractive piece of work at best, calling for special packings which are quite costly and sometimes giving so severe a load of maintenance as to amount in a year's time to as much as the original cost of the pump. A great variety of packings are now available, many built for particular services. Without detracting from the advancement made by packing manufacturers, it should be pointed out that the average chemical service can be handled with a good grade of packing which is relatively resistant to the material handled. In general, blue African asbestos is an excellent material for chemical services. The most important thing to keep in mind about a stuffing box is to remember to treat it as though it were a bearing, which means that it must be kept clean, cool and lubricated.

In applying the unit to service, provision must be made to observe these points. The easiest way to do this is to construct the pump with the conventional lantern ring approximately in the center of the box. This ring then can be connected to a source

Fig. 3—Sealing water protects these stuffing boxes against abrasive pigment

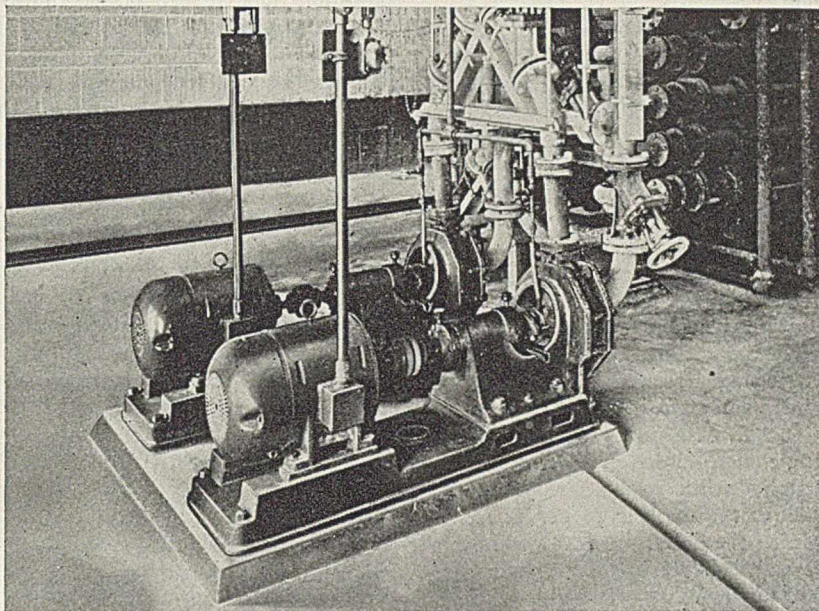
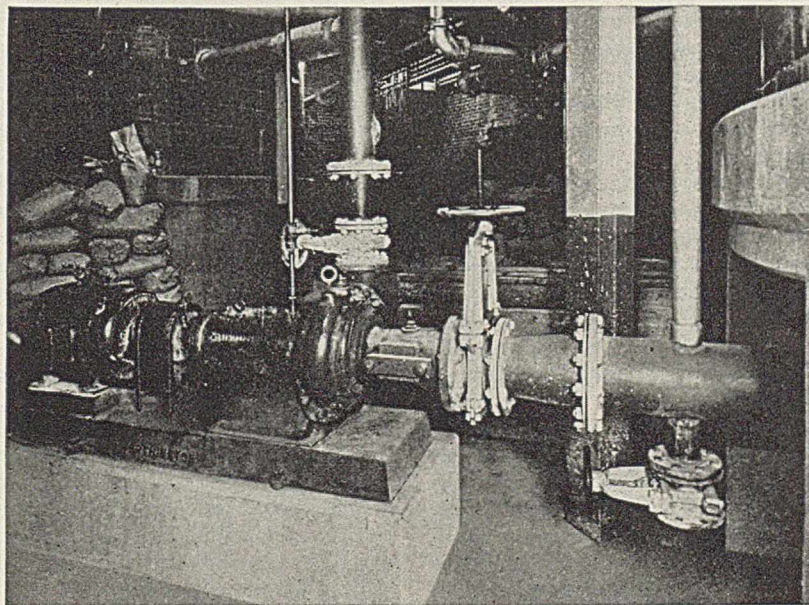


Fig. 4—Mounting pumps on elevated foundations in well-lighted locations facilitates inspection and maintenance in this large paper mill



of clear bland fluid under a pressure at least 5 lb. greater than the pressure existing in the bottom of the stuffing box. Fig. 1 shows a device which has been found useful for constant indication of sealing liquid flow. Similar devices are available, such as described by F. H. McBerty (*Chem. & Met.*, May 1937, p. 257).

With a suitable sealing liquid arrangement, the liquid will enter the lantern ring and flow both toward the pump casing proper and out of the stuffing box at the gland end. Thus a clear film of liquid will be maintained, preventing entrance of the corrosive liquid handled by the pump. Careful measurements made upon a unit where the shaft was running truly concentric within the stuffing box, have shown that the leakage into the pump through the annular orifice between the pump shaft and the packing amounted to no more than 46 parts per million parts of liquid passing through the pump. This is so small a quantity of sealing liquid that it generally can be disregarded as a contaminant of the liquid being pumped, and water is therefore often the best material for stuffing box sealing. If water is prohibited by the nature of the process or other considerations, greases insoluble in the material being handled are available and may be applied to the lantern ring of the stuffing box by a dead-weight loaded grease sealer.

SEALING LIQUID RESULTS

That this method of handling a stuffing box is of extreme value is illustrated by the writer's experience with a pump handling a slurry consisting of 40 percent by volume of paint pigment in water suspension, the water containing about 5 percent sulphuric acid. Upon initial installation, it was found that very frequent repacking was necessary to prevent leakage of the material pumped, with consequent expensive loss of this material at the stuffing box. The pump was installed with about 10 ft. of suction head. The impeller was designed to impose only suction pressure on the bottom on the stuffing box and on the first ring of packing. In spite of the use of many types and styles of packing, a packing schedule of once every eight hours, three times per day, was necessary to prevent loss of the costly pigment.

Since an exact ratio between acid, pigment and water was necessary, the user was reluctant to try a water seal. He was, however, finally prevailed upon to insert a lantern ring in the stuffing box, located midway axially

and connected to an outside source of clear, cool water, at 12-15 lb. pressure. Rather than three times a day, the pump is now being repacked once every six months.

Repeated analyses since the change, comparing the material taken from both the suction and discharge lines, have shown no appreciable dilution nor any change or variation in the subsequent process. Other units in the same plant were checked for shaft concentricity and the stuffing boxes similarly treated, resulting in an annual maintenance saving at this point alone of several thousand dollars. This method of stuffing box maintenance has been widely applied to pumps handling acids, slurries, alkalis and other materials in the chemical industry.

For process units requiring high-head pumps, the method described must be modified somewhat. In high-head, large-capacity chemical pumping operations, the matter of pumping efficiency does become important and each percent of increased efficiency may result in the saving of many dollars per year. For such pumps greater attention must be paid to the impeller design to obtain the most efficient moving element for the particular conditions of service. The single-stage, closed-impeller pump lends itself readily to this refinement.

In the case of water service, the single-stage closed-impeller pump is supplied with wearing rings at the back of the impeller to permit maintaining the liquid pressure within this space at suction pressure, thus simplifying packing of the pump. In a process pump, however, especially where it is constructed of high-alloy materials, such rings are not readily replaceable as they gall at the point of fastening to the impeller. Another means of creating a space back of the impeller and adjacent to the bottom of the stuffing box, which can be maintained at suction pressure, must be resorted to. This can be done by omitting the back impeller ring entirely and inserting in the bottom of the stuffing box a bushing having a close running fit on the shaft. Located directly behind this bushing on the side away from the pump proper, a lantern ring is installed which is connected by means of a tapped hole to the suction of the pump. The cross-sectional area of the connection to the suction is made quite large in comparison with the annular area between the bushing and the shaft, and throttling will consequently occur across this latter opening. The arrangement is indi-

cated in Fig. 2. The pressure on the packing ring adjacent to the lantern ring then becomes suction pressure and the remainder of the stuffing box can be handled as already discussed.

Such a bushing and the sleeve covering this portion of the shaft are inexpensively replaceable parts which can readily be removed and replaced in the event of wear, without damaging other parts of the pump. Single-stage units operating up to 600 ft. head have been built in this manner and have produced enviable service records.

INSTALLATION

Pump installations deserve careful planning, since careless installation, making regular maintenance and inspection difficult, can largely nullify the economical design features built into the pump. Plant designers, in laying out process pumping equipment, too often fail to consider the difficulties to be encountered by the person who has to "live with" this equipment in inappropriate and inaccessible locations. Process pumping equipment is generally of low height and one of the major errors made in its location is to mount the base directly on the floor, making inspection and particularly repacking difficult. Work done in such a position is generally hurried and poorly accomplished to the detriment of the maintenance record. Poorly lighted locations also lead to poor work and high maintenance.

The ideal location is accessible, well lighted and clean—about chest-high on the average workman. Thus normal maintenance jobs such as inspection, greasing of bearings, repacking of stuffing boxes and checking of gaskets can be accomplished in an upright position, using both hands and generally resulting in an excellent job.

A large chemical manufacturer, having constructed a plant, decided after several years to duplicate the installation. However, his engineers decided to locate the pumps quite similarly to the above recommendation. Except for pump placement, the new plant exactly duplicated the old. After several years of operation, a comparison of the maintenance records of the pumps in the new plant with those in the old, indicated that the cost was slightly less than half that of the older installation, fully vindicating the user's judgment regarding placement. The increased construction costs were balanced out by the decreased maintenance cost within 1½ years' operation.

Protection Against War Gases

Chem. & Met. INTERPRETATION

Chemical attack may never come to the civilians of this country, but to be totally unprepared would be dangerous. The information herein, gathered from various sources mentioned in the bibliography gives basic information on protective measures. Original sources should be consulted for further details on gas masks.—Editors.

IN GENERAL, no decontamination measures are necessary following an attack with non-persistent gas. However, if persistent gas is used, liquid contamination of streets and the exterior of buildings may result and unless special measures are adopted, the chemical will remain a source of danger for a considerable time.

The principal decontaminating agent for mustard gas is bleaching powder. Chlorine reacts with mustard gas to destroy it, but the two must be brought into intimate contact. However, dry bleach should not be placed directly upon liquid mustard because of the evolution of heat and flame. This drives off a high concentration of vapor which may be carried some distance by the wind, endangering people who would otherwise be safe. In using bleach on mustard gas, the bleach is either mixed with water to a paste or with sand or earth.

It is a safe rule to use one part of bleach for each part of inert material for each 10 percent available chlorine; thus with one lb. of 70 percent H.T.H., 7 lb. of earth may be used.

Cold water has little effect on mustard gas but hot water is fairly effective. Mustard gas is heavier than water and will lie at the bottom of pools and puddles, remaining effective for a long time, though the water will retard the escape of vapors.

Water quickly destroys Lewisite. However, a solid residue is left which is dangerous to touch, though it gives off no gas. After treatment with water, an area should be covered with a layer of earth, sand or ashes. Objects which are to be handled should be treated with an alkali.

Earth, sand, ashes or sawdust may be spread over a contaminated area to give temporary protection. The covering should be at least 3 in. thick. This does not destroy the chemical agent but merely forms a seal to pre-

vent escape of toxic vapor. If practicable, the covering should be wetted down with water.

Green solution is prepared by dissolving one pound of bicarbonate of soda in one gallon of commercial hypochlorite solution. This mixture

is less efficient for destruction of mustard gas than bleaching powder but it is less corrosive to metals.

Decontamination may be by (1) destroying the agent by the use of other chemicals or by burning; (2) removing the agent by washing it away; (3) covering with a seal, after which it will slowly be destroyed.

Badly contaminated articles which cannot be decontaminated easily should be destroyed by burying in the ground or by burning. Burning should be done in the open or in an incinerator provided with a tall chimney, since the burning process may drive off a high concentration of gas. Land covered with dry grass and underbrush may be decontaminated by being burned over.

Small areas of ground contaminated with mustard gas may be treated by spreading bleaching powder mixed with sand or soil and spading this mixture into the soil. About one lb.

Chemical Properties of Warfare Agents¹

Agent	Action on Metals	Stability on Storage	Action with Water	Hydrolysis Product
Adamsite	Very slight	Stable in steel containers	Insoluble, hydrolyzed with difficulty	HCl; oxide [(C ₂ H ₄) ₂ NHAs ₂ O; toxic if swallowed
Bromacetone	Very corrosive to iron	Unstable in heat or light	None	None
Brombenzylcyanide	Very corrosive to iron; lead or enamel lined shells required	Slowly decomposes	Slowly hydrolyzes	HBr and various compounds
Chloracetophenone	Tarnishes steel slightly	Stable	None	Not readily hydrolyzed
Chlorine	None if dry; vigorous corrosion if wet	Stable in iron cylinders, if dry	Form HCl, HOCl, and ClO ₂	HCl; HOCl; ClO ₂
Chlorpicrin	Produces slight tarnish only	Stable for long periods in steel containers	Very slightly soluble	Hydrolyzes with difficulty
Diphenylcyanarsine	Vigorous corrosion on iron and steel	Very stable	None	None
Diphosgene	None if dry, corrosion if wet	Stable in dry steel containers	Hydrolyzes slowly	ClCO ₂ ; CO ₂ ; HCl
Ethylchlorarsine	None	Stable	Hydrolyzes slowly	Ethylarsenous oxide and HCl (poisonous)
HC Mixture	None if dry	Stable	C ₂ Cl ₄ slowly hydrolyzes; ignites	Smoke in air; (ZnCl ₂) zinc chloride in water
Lewisite	None	Stable in steel containers	Hydrolyzes readily	HCl; oxide; (ClCH) (CHAsO)
Methylchlorarsine	None	Very stable	Slightly soluble	None
Mustard	None	Stable in steel containers	Slowly hydrolyzes	HCl and (HOCH ₂ CH ₂) ₂ S
Phosgene	None if dry; vigorous corrosion if wet	Stable in dry steel containers	Hydrolyzes rapidly	HCl; CO ₂
Titanium tetrachloride	Vigorous corrosion by smoke; none by liquid on steel if dry	Stable in steel containers when dry	Hydrolyzes	Smoke in air; TiCl ₃ SH ₂ O; then HCl and Ti(OH) ₄
White phosphorus	None	Stable out of contact with oxygen	None; stored under water	Smoke in air; phosphoric acid in water

¹Adapted from "Chemicals in War," A. M. Prentiss, McGraw-Hill Book Co. (1937).

Persistency and Toxicity of Chemical Warfare Agents¹

Agent Common Name	CWS Symbol Form	Tactical, ² Physiological Classification	Persistency (Summer)	Persistency (Winter)	Lowest Irritant Concentration ⁴	Intolerable Concentration ⁴	Lethal Concentration ⁴
Bromacetone CH ₃ COCH ₂ Br	BA Liquid	H L	3 hr. in open; 1 to 2 hr. in woods	2 days in open; 7 days in woods	0.0015	0.010	3.20
Brombenzyl cyanide C ₆ H ₅ CHBrCN	CA Gas	H L	3 days in open; 7 days in woods	Several weeks	0.00015	10 min. exposure, 0.0008	50 min. exposure, 0.9; 10 min. exposure, 3.5
Chloracetophenone C ₆ H ₅ COCH ₂ Cl	CN Gas Solid	H L	Solid for days; burning mixture, 10 min.	Several weeks in solid; burning mixture 10 min.	0.0003	10 min. exposure, 0.0045	30 min. exposure, 0.34; 10 min. exposure, 0.55
Chlorpicrin (vomiting gas) Cl ₃ CNO ₂	PS Gas Liquid	C H L	1 hr. in open; 4 hr. in woods	12 hr. in open; 1 week in woods	0.009	10 min. exposure, 0.050	30 min. exposure, 0.80; 10 min. exposure, 2.00
Chlorine Cl ₂	Cl Gas	C LI	5 min. in open; 20 min. in woods	10 min. in open; 1 hr. in woods	0.029	10 min. exposure; 0.10	30 min. exposure, 2.53; 10 min. exposure, 5.60
Phosgene COCl ₂	CG Gas	C LI	10 min. in open; 30 min. in woods	20 min. in open; 2 hr. in woods	0.005	10 min. exposure, 0.020	30 min. exposure, 0.36; 10 min. exposure, 0.50
Diphosgene ClCOCCl ₂	Gas	C LI	15 min. in open; 60 min. in woods	30 min. in open; 3 hr. in woods	0.005	10 min. exposure, 0.40	30 min. exposure, 0.36; 10 min. exposure, 0.50 (U.S.); 0.05 (Germany)
Methyldichlorarsine CH ₃ AsCl ₂	MD Liquid	C LI V	1 hr.	2 to 3 hr.	0.002	1 min. exposure, 0.025	30 min. exposure, 0.125; 10 min. exposure, 0.75
Ethyldichlorarsine C ₂ H ₅ AsCl ₂	ED Liquid Gas	C H LI V	1 to 2 hr. in open; 2 to 6 hr. in woods	2 to 4 hr. in open; 12 hr. in woods	0.001	10 min. exposure, 0.01 (causes sneezing)	30 min. exposure, 0.10; 10 min. exposure, 0.50
Mustard ββ' Dichlorethyl Sulphide (CICH ₂ CH ₂) ₂ S	HS Liquid Vapor	C V	24 hr. in open; 1 week in woods	Several weeks both in open and in woods	0.001	Eye-casualty concentration—1 hr. exposure, 0.001	30 min. exposure, 0.07; 10 min. exposure, 0.15
Lewisite β Chlorvinyl-dichlorarsine ClCH:CHAsCl ₂	M-1 Liquid Vapor	C V	24 hr. in open; 1 week in woods	1 week	0.0008	Minimum irritating concentration, 0.0008	30 min. exposure, 0.048; 10 min. exposure, 0.12
Diphenylchlorarsine (C ₆ H ₅) ₂ AsCl	DA Smoke	H St	5 min. by H.E. detonation; 10 min. by candle dissemination	Same as summer	0.0005	10 min. exposure, 0.0012	30 min. exposure, 0.60; 10 min. exposure, 1.50
Diphenylcyanarsine (C ₆ H ₅) ₂ AsCN	CDA Smoke	H St	Same as DA	Same as DA	0.0001	10 min. exposure, 0.00025	10 min. exposure 1.00
Adamsite Diphenylamine-chlorarsine (C ₆ H ₅) ₂ NHAsCl	DM Gas	H St	10 min. in open from candles	10 min. in open from candles	0.00038	3 min. exposure, 0.005	30 min. exposure, 0.65; 10 min. exposure, 3.00
HC Mixture C ₂ Cl ₄ + Zn + ZnO	HC Smoke	S	Only while burning	Same as summer	Smoke irritation negligible	Smoke irritation negligible	Smoke harmless
Titanium tetrachloride TiCl ₄	FM Smoke	S	10 min in open	Same as summer	Smoke irritation negligible	Smoke irritation negligible	Smoke harmless
Sulphur trioxide solution About 55% SO ₃ + 45% HClSO ₃	FS Smoke	S	While container is operating	Same as summer	Smoke irritation negligible	Smoke irritation negligible	Smoke harmless
White phosphorus P ₄	WP Solid Smoke	S I	Depends upon size of burning particle; usually 10 min. or less in open	Same as summer	Smoke irritation negligible	Smoke irritation negligible	Smoke harmless
Thermit (Al + Fe ₂ O ₃)	Th	I	5 min. when burning	Same as summer	None	None	None
Magnesium Mg	—	I	15-20 min. when burning freely	Same as summer	None	None	Smoke harmless

¹ Adapted from "Chemicals in War," by A. M. Prentiss, McGraw-Hill Book Co.; "Protection Against Gas," issued by Office of Civilian Defense; "Defense Against Chemical Attack," prepared by the Chemical Warfare Service.

² H = Harassant; C = Casualty Agent; S = Screening Agent; I = Incendiary.

³ L = Lacrimator; LI = Lung Irritant; V = Vesicant; St = Sternutator.

⁴ As oz. per 1000 cu. ft., 10 min. exposure for lowest irritant concentration.

Physiological Action and First Aid for Chemical Warfare Agents¹

Agent	Odor In Air	Odor Detectable ²	Physiological Action	Protection Required	Method of Neutralizing	First Aid
Bromacetone	Pungent and stifling	0.0005	Vapor, severe lacrimation; liquid, produces blisters; often toxic	Gas mask; absorbent only	Alkali	Wash eyes with boric acid; wash skin with warm sodium carbonate solution
Brombenzyl cyanide	Like sour fruit	Irritates before odor can be detected	Severe lacrimation and nose irritation; headache	Gas masks; absorbents in canister only	Alcoholic sodium hydroxide spray	Wash eyes with boric acid solution; do not bandage
Chloracetophenone	In low concentrations like apple blossoms	0.0002	Eye and skin irritation; temporary	Gas masks; both absorbent and effective filter	Strong hot sodium carbonate solution	Wash eyes with boric acid; wash skin with warm sodium carbonate solution; do not bandage
Chlorpicrin	Sweetish, like fly-paper, anise	0.0073	Lacrimates; irritates nose and throat; produces nausea and lung irritation	Gas masks with high-grade absorbents in canisters	Sodium sulphite alcohol solution	Wash eyes with boric acid; keep patient warm; protect throat from infection; do not bandage
Chlorine	Pungent	0.0100	Burns upper respiratory tracts	Gas masks; absorbents in canister only	Alkaline solution	Keep patient quiet and warm and treat for bronchial pneumonia; coffee as stimulant
Phosgene	Like ensilage; fresh-cut hay; green corn	0.0044	Burns lower lung surfaces, causing edema; tears in eyes; doped feeling	Gas masks; absorbents in canister only	Steam hydrolyzes; alkalis and amines react with CG	Keep patient quiet; administer heart stimulants; give oxygen in severe cases; treat like pleurisy; no cigarettes
Diphosgene	Disagreeable, suffocating; ensilage; acid	0.0088	Burns lower lung surfaces, causing edema; eyes water; coughing	Gas masks; absorbents in canister only	Steam hydrolyzes; alkalis and amines react with CG	Keep patient quiet; administer heart stimulants; give oxygen in severe cases; treat like pleurisy
Methylchlorarsine		0.0008	Asthma, dyspnea; lung injurant, skin vesicant	Gas masks and best of protective clothing	Sodium hydroxide solution	Wash with soap and water, then with sodium hydroxide (5%); wash eyes with boric acid
Ethylchlorarsine	Biting, irritant; like pepper in nose	0.0010	Vesicant, 1/2 as powerful as HS; powerful sternalator; causes paralysis of fingers	Gas masks and protective clothing	Sodium hydroxide solution; cover with earth, caustic	Wash skin with warm sodium carbonate solution; remove liquid with H ₂ O ₂ or kerosene
Mustard	Like garlic or horse-radish; mustard	0.0013	Dissolves in skin or lung tissue, then produces burns; delayed effect; eye irritation; may lead to pneumonia	Gas masks and protective clothing	Bleaching powder, 3% sodium sulfite in water; steam; gaseous chlorine; or bury under moist earth and unslaked lime	Wash affected parts with kerosene or gasoline, then with strong soap and hot water; rub dry; rinse with hot clean water; agent must be removed within 3 min.
Lewisite	Like geraniums, then biting	0.014	Dissolves in skin, then burns eyes, nasal passages, skin	Gas masks and best of protective clothing	Alcoholic sodium hydroxide spray; wash down with water; cover with earth	Wash with oils, hot water, and soap; dry; first aid must be applied at once; rest
Diphenylchlorarsine	Like shoe polish	0.0003	Sneezing; vomiting; headache	Best type of filter in gas-mask canister	Caustic gaseous chlorine; bleaching powder solution	Chlorine in low concentrations; keep quiet
Diphenylcyanarsine	Like garlic and bitter almonds	0.0003	Sneezing; vomiting; headache	Gas masks, best type of filter	Caustic gaseous chlorine	Chlorine in low concentrations
Adamsite	Odor similar to coal smoke	Almost no odor to average man, up to 0.0025	Headache, nausea, violent sneezing, followed by temporary physical debility	Best type of filter in gas-mask canister	Gaseous chlorine; bleach liquor	Breathe low concentrations of chlorine from bleaching-powder bottle; keep quiet and warm
HC Mixture	Acrid suffocating smoke		None from solid; slightly suffocating action by heavy smoke	None	None needed	None needed
Titanium tetrachloride	Acrid		Liquid burns like strong acid; vapors and smoke irritating to throat	None for ordinary smoke clouds; gas masks needed for heavy concentration only	Alkali; solid or solution	Wash with sodium bicarbonate solution, then with warm water; treat burn with picric acid
Sulphur trioxide solution	Acid or acrid		Liquid burns like strong acid; smoke causes pricking sensation on skin	None for ordinary smoke; gas masks for high concentrations, only rubber gloves for handling liquid	Any alkaline solution	Like an acid burn
White phosphorus	Like matches		Solid particle burns flesh; vapors very poisonous, cause bone decay; smoke relatively harmless	None needed against smoke; fireproof suits against burning particles	None needed; copper sulphate solution stops burning of particles, as does water	Apply copper sulphate solution; pull out solids; treat burn with picric acid; keep burning part under water until medical aid arrives if no CuSO ₄ is available

¹ Adapted from "Chemicals in War," by A. M. Prentiss, McGraw-Hill Book Co.; "Protection Against Gas," issued by Office of Civilian Defense.

² As oz. per 1000 cu. ft.

of bleach is required per square yard of ground. If no bleach is available, the contaminated area should be covered with wet earth.

Lightly contaminated paved streets may be rendered safe by washing down with a heavy stream of water. Bleach paste or sand and bleach mixture should first be used on all heavily contaminated portions.

Walls of buildings should be sprayed or scrubbed with a 50-50 mixture of bleach and water. Wood, concrete and paint absorb mustard and hence a second decontamination may be necessary. After this treatment, the wall should be scrubbed with hot water, soap and washing soda. Floors should be treated with a paste of bleach to a depth of an inch for 6-24 hours. The paste should then be re-

moved and the floor scrubbed.

Metal equipment should be washed with rags saturated with gasoline or kerosene. Bleach solution should then be applied, followed by soap and hot water. Finally, after thorough drying, the surface should be oiled. If the equipment can be seriously damaged by corrosion, the bleach should not be left on the metal for more than a few minutes. In place of these measures, non-corrosive decontamination fluids, if available, may be used.

A person whose clothes have come in contact with mustard vapors should remove them at once and bathe. The clothes should then be aired in the sunlight for at least two days and if they have been contaminated with liquid mustard, they should be steamed for 4-6 hours.

Ordinary dry cleaning will not suffice for treating contaminated clothes. Contaminated shoes should be shuffled in sand and bleach mixture to remove unabsorbed liquids. Once the agent has penetrated the leather, little can be done to make them safe.

Sprayers used in decontamination work may be small hand-operated devices such as garden sprayers or large, power-driven apparatus which can be carried on a truck. For spreading bleach solution on city streets, water sprinklers might be used.

PROTECTIVE MEASURES

Individual protection from chemical warfare agents can be obtained by the use of gas masks and protective clothing. Collective protection, on the other hand, depends upon gas alarms and accessibility of gasproof shelters.

Gasproof shelters are of two general types, non-ventilated and ventilated. The non-ventilated shelter is merely a room, cellar or other inclosure sealed to prevent air from the outside from entering. Such shelters can only be occupied for a limited time. The ventilated shelter is an inclosure rendered reasonably gas-tight and equipped with apparatus to draw in outside air through a canister which removes the harmful gas. Such shelters can be occupied indefinitely.

Details on features and use of gas masks, protective clothing and gasproof shelters are beyond the scope of this article. Authoritative information can be obtained by consulting the references listed in the bibliography.

Since war gases are heavier than air, they tend to hug the ground and accumulate in low-lying places. In open country they will remain effec-

tive in ravines and gullies for a considerable time. Likewise, they persist longer in woods than in open areas.

If used against towns and cities, gas may be expected to accumulate in subways, cellars, sewers and other low-lying places. Hence persons on the upper floors of buildings might be entirely safe, whereas those at ground level would be exposed. Even the upper floors of a 2- or 3-story house are considerably safer than a lower floor or cellar. Gas tends to pass around and over a house if doors and windows are closed. However, unless all cracks and crevices are sealed, the gas will eventually penetrate the house.

Low velocity and steadiness of wind are favorable for the use of gas. If the wind velocity is more than 10-12 miles per hour or if the wind is gusty, the gas cloud is quickly dissipated.

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7. **Air Raid Precautions**, Chemical Publishing Co., Inc., Brooklyn, N. Y. (1941). Contains brief chapters on organization of decontamination service, gas detection and identification, and inspection and repair of respirators. Represents British practice.

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9. **Chemistry in Warfare**, F. A. Hessel, M. S. Hessel, and Wellford Martin, Hastings House, New York, N. Y. (1940). One chapter gives a popular account of chemical warfare gases.

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First Aid Chest For Gas Casualties¹

1. Bleaching powder (high test) . . . 2 lb.
For decontamination of skin from blister agents; for inhalation following irritant smokes.
2. Protective ointment (3 oz. tube) . . . 10
For protection of skin and decontamination following blister agents.
3. Hydrogen peroxide (10 percent avail. 02) 1 qt.
For removing lewisite from skin.
4. Kerosene 6 qt.
For removing mustard from skin.
5. Alcohol (70 percent) 1 qt.
Following No. 4 and No. 8.
6. Soap, cakes 6
To remove No. 3, No. 4, and No. 8.
7. Sodium bicarbonate (baking soda) 5 lb.
(A) For eye irrigation following blister gases, tear gas, or other chemical agents; (B) for washing nose, throat, and stomach following blister agents; (C) for drinking after arsine exposure.
8. Lye 1 lb.
For lewisite if No. 1 and No. 3 not available.
9. Butyn, N.N.R. 3 gr. hypo. tablets, 10 per vial 2
For preparing solution to relieve pain in eyes from mustard and lewisite.
10. Antipruritic ointment 3 oz.
Percent
Benzyl alcohol 50
Stearic acid 30
Glycerine 10
Ethyl alcohol 8
Pontocaine 1
Menthol 1
To relieve itching following mustard burns.
11. Four percent soln. sodium sulfite in 50 percent alcohol . . . 8 oz.
For removing tear gases from skin.
12. Aspirin, 5-grain tablets 100
For headache following irritant smokes.
13. Cupric sulphate (blue vitriol) . . . 1 lb.
For phosphorus burns.
14. Absorbent cotton 1 lb.
15. Enema can and tube for irrigating eyes 1

¹From "Protection Against Gas", Office of Civilian Defense, Washington, D. C.

Load-Center Power Distribution

D. L. BEEMAN and R. H. KAUFMANN

Industrial Engineering Department, General Electric Co.

Chem. & Met. INTERPRETATION

Load-center power distribution as such is not new, having been applied for years in the utility field. However, the development of new equipment has now made it possible to extend its advantages to industrial and commercial buildings where it offers many advantages over former methods. These are savings in time, money and material as well as safer, more reliable service.—Editors.

INTENSIVE manufacturing activity accompanying the present war program has stimulated interest in power distribution systems. A review of these systems has resulted in the development of the "Load-Center Power Distribution Principle" for industrial plants and for other applications where the problems are similar.

There are two outstanding fundamental principles of load-center power distribution: (1) power is distributed at high voltage to the load centers where it is stepped down to utilization voltage and distributed to the load via short secondary feeders; (2) when the total load exceeds about 750 to 1,200 kva., several small unit substations are used rather than a single large substation. Each is located near the center of the load area.

The old method consists of a large substation in which large blocks of power are transformed from high voltage to utilization voltage, the utilization voltage being of the order of 110 to 575 v., and the primary voltage ranging from 2.3 to 15 kv. Power is then distributed throughout the factory through long, heavy low-voltage feeders from one large substation.

One of the most outstanding advantages of load-center distribution under present conditions is that it requires less of the strategic materials so vitally needed for military purposes. Because low-voltage feeder runs are short, there is a large saving in copper. There is also some saving in steel and a slight increase in other materials, principally insulation.

Because the low-voltage feeder runs are short, the investment in secondary cable is materially decreased

for load-center distribution systems. There is also a saving in substation cost because of the lower interrupting capacity breakers of the small unit substation. Instead of an outdoor switching station as conventionally used, a small compact indoor metal-clad structure is all that is required. This offers some reduction in cost.

Because substations of load-center distribution systems are small, they can be added when and where needed without extensive planning and forecasting. This is compared with the old method which, using large substations, involves extensive forecasting of location and magnitude of loads in order to select the most ad-

vantageous location for the large substation.

Furthermore, the small substations lend themselves ideally to being completely built and wired in the factory. It is merely necessary to bolt one or two sections together and connect the cable. This is compared with the older method in which detail drawings must be made for the assembly of the component piecemeal parts. With the factory-assembled equipment, one set of drawings (made by the manufacturer) is required to build standard unit substations. Hence the drafting cost per unit is extremely small.

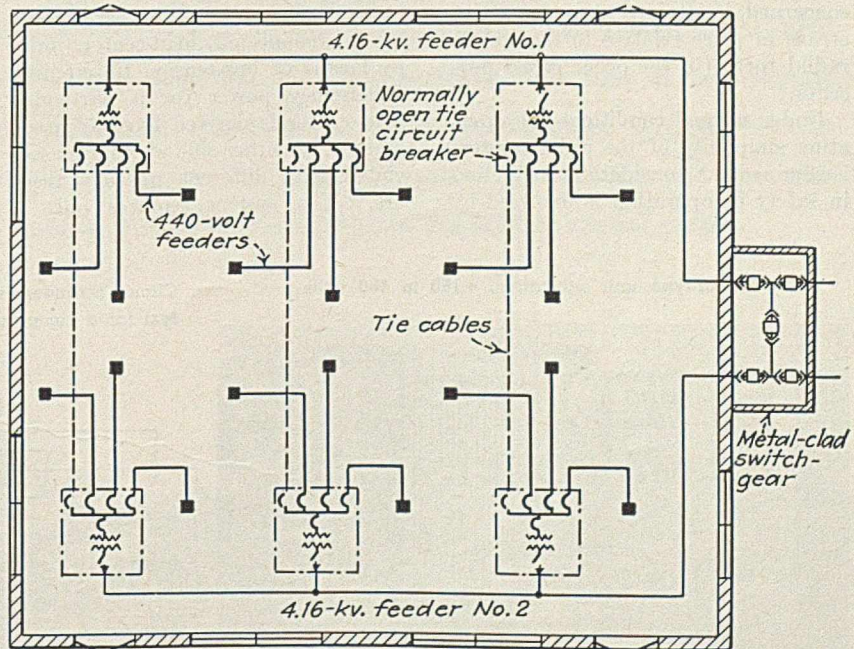
Only a simple functional specification is required for buying unit substations. The older method requires a complete specification for every part. The saving in time and effort in preparing specifications is significant.

Because of the shorter secondary runs accompanying small transformers, voltage drop and flicker are less than with the conventional system.

FORMS OF DISTRIBUTION

Having pointed out the advantages of the load-center distribution center, there remains the need for compar-

Typical load-center distribution system, with power being distributed at high voltage (2.4 to 13.8 kv.) to small unit substations located throughout the plant



ative analysis of system design variations as influenced by considerations of service reliability. In any such analysis, it is important that recognition be given to first cost, safety both to personnel and equipment, operating simplicity, maintenance expense, voltage regulation, power losses, and flexibility.

Simple Radial System—The simple radial system incorporates a single direct electrical channel leading to each load-center low-tension bus. All elements comprising this system are considered to be normally operated at rated capacity. The lowest possible first cost is thus obtained and will be considered as the reference level in cost evaluation of other system forms.

The simplicity of electrical circuit configuration in combination with recognized adequate capacity in all power switching equipment makes for ease of operation and a high order of safety.

The voltage regulation between the primary high-tension bus and the low-tension feeder terminals is in the order of five percent or less, which is not objectionable.

The complete absence of duplication in power-supply channels is the outstanding deficiency.

Primary Selective System—This system is distinguished by the inclusion of load-center primary selector switching in connection with duplicate primary feeders. Means are thus provided for restoring service to all load centers in the absence of voltage on one primary feeder.

An improvement in service reliability, insofar as primary feeders are concerned, is attained at moderate increase in price relative to the simple radial form (in the order of 25 percent).

Under normal conditions the operating simplicity of the radial system is retained. A considerable reduction in safety of operation is incurred by

the use of the primary selector disconnecting switch.

The close physical association of both primary feeder circuits at each load-center primary switching unit is a disconcerting feature. Trouble at this spot as a result of electrical failure, fire, or bomb explosion could easily involve both circuits and result in a complete loss of service.

Secondary Selective System—Distinguished by a low-tension tie breaker between two complementary sections associated with different primary feeders, this system is normally operated in simple radial manner with the tie breaker open. Duplication of service is extended to the load-center low-tension bus.

Reserve transformer capacity has been incorporated to permit the combined load of the two complementary sections to be carried on one transformer on an emergency basis without exceeding 125 percent of rated capacity. On this basis, the first cost becomes about 145 percent compared to the simple radial form.

Electrical faults affecting service on one primary feeder cannot interfere with service on the other feeder. Even closure of the low-tension tie breaker on a solid fault will not disrupt primary feeder power.

All normal switching is performed with full-capacity, low-tension air circuit breakers.

By incorporating electrical operation of the tie breaker, automatic transfer can be obtained, limiting power interruption to a very short duration, thus closely approaching perfect service reliability.

Secondary Network System—This system is characterized by permanently interconnected load-center units by means of low-tension tie circuits. Emergency power for a particular load center is derived from adjacent stations on either side which are associated with different primary feeders. The system requires only a

moderate reserve transformer capacity but involves additional investment in low-tension tie circuits.

The secondary network system allows better transformer utilization when confronted with a shifting load area of higher density although the low-tension tie circuit system must be augmented to accommodate the increased power transformer requirements.

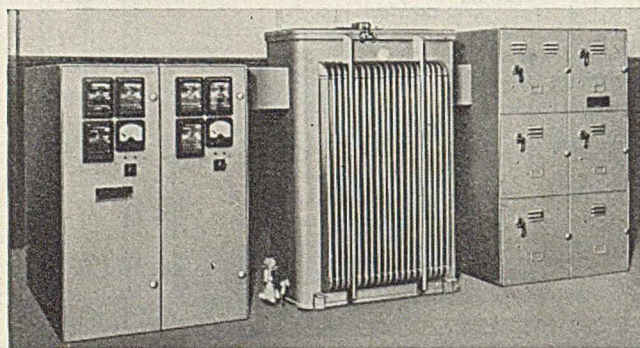
Service reliability is of the highest order, but is associated with a corresponding high order of first cost (approximately 175 percent of the simple radial). The increased cost is largely associated with increased cost of low-tension switching equipment together with the investment in low-tension tie circuits.

Operating simplicity is sacrificed. Any permanently interconnected system presents additional operating problems. The maintenance and adjustment of network protectors and network relays require considerably more skill than do conventional air circuit breakers.

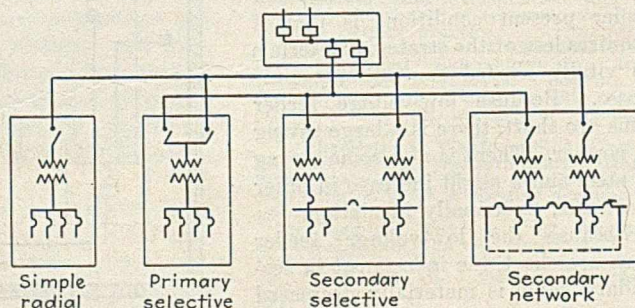
It should be particularly emphasized that one form of system design need not be used exclusively throughout the entire load area if variations in required service reliability seem to favor a combination. On the other hand, it will be advantageous to have a standard system form, to make possible uniformity of operating procedure and a minimum spare parts inventory.

Of these several basic system forms, the secondary selective offers real promise of widespread acceptance in view of: (1) first cost only moderately greater than that of the minimum tolerable system; (2) a high order of safety; (3) simplicity of operation; (4) service duplication extended to the low-tension bus; (5) reduction in degree of service reliability may be exchanged for reduced first cost; (6) increased cost largely invested in active material.

Indoor-type unit substation, 4,160 to 480 volts



Circuit arrangements of load-center power distribution. See text for a comparative analysis of these four basic systems



CHEM & MET REPORT ON

Electronic Devices For Process Control—I

TO CHEMICAL ENGINEERS, SUPERINTENDENTS
AND PRODUCTION EXECUTIVES

Now that manpower shortages are definitely making themselves felt, process industries have urgent need for new and better tools with which to increase labor and production efficiency. Many possibilities for such improvement exist in the application of electronic devices to the control of processes. Although not yet well known to the majority of chemical engineers except in a few common industrial applications, electronic tubes and photocells have developed with amazing rapidity, and the scope of their accomplishments is legion. To make clear what some of these accomplishments are, the editors have enlisted the assistance of an authority well known in the field of industrial electronic tube applications. This first of two reports will discuss the types and principles of electronic devices used in control. The second will deal with control applications, and also with a number of important uses outside the field of control proper.

CHEMICAL AND METALLURGICAL ENGINEERING • MARCH, 1942

Electronic Devices For Process Control—I

THEODORE A. COHEN *Vice-President, Research and Development
Wheelco Instruments Co., Chicago, Ill.*

Chem. & Met. INTERPRETATION

This is the first of two *Chem. & Met.* Reports on a subject which has received all too little attention from chemical engineers. In the recent past, electronic devices, both electronic tubes and photocells, have been developed to a high state of perfection. As improvement has come about, applications have grown apace, and today these extremely versatile tools have expanded their fields of use far beyond the communications industry, and into a tremendous variety of industrial applications. Although the main aim of this and the report to follow next month will be to deal with electronic devices in relation to their use in process control, other aspects are also of great importance, for example, in the rectification and inversion of electric currents. A part of the second report, therefore, will take up some of these uses. After an introductory part which will discuss the types and principles of electronic devices met in industrial control, the remaining portion of these articles will be devoted to a resume of applications which in scope and variety should prove decidedly suggestive to engineers on the look-out for better and easily adapted methods—*Editors.*

ELECTRONIC DEVICES, in the space of a few years, have taken a place of tremendous importance in industry, although as yet their vast possibilities have barely been assayed. They are the basis of a large part of the communications field and yet their applications are by no means limited to communications. Indeed, it may eventually be true that industrial usage will overshadow that in radio, television, telephony and sound reproduction. For electronic devices are able to do many things better, faster, more accurately, cheaper, and with less wear and tear than their mechanical counterparts. They can control all manner of mechanisms from a beam of light, or from a minute movement or a change in a physical or chemical property of material. They measure numerous variables with high accuracy and can convert electric currents of one type to another with ease and facility.

Although it is often remarked that nobody knows what an electron is, still, this has offered little hindrance to extension of applications for electronic devices which now are numbered well in the thousands. Many of these uses

are directly in the field of the process industries and chemical engineers to an ever increasing extent are coming in contact with controls and other equipment employing these versatile devices. Rapid as has been the expansion of the field, still the growth of its literature has all but kept pace. Excellent books have been written on industrial applications alone, so it is obvious that the present writer, in the space at his disposal, cannot hope to do more than scratch the surface, set down a few principles and describe a few applications particularly pertinent to the process industry group.

In attempting a general theoretical discussion of electronics the starting point is necessarily a brief review of the atomic theory. This theory states that the ultimate particles of matter are atoms each of which consists of a central nucleus or mass of positively charged particles termed a proton, around which negatively charged particles called electrons move in intricate orbits. The positive charge of the proton nucleus exactly equals the combined negative charges of the electrons which revolve about it so that

the atom in its normal state is neutral, that is, without an electrical charge.

It is possible, however, for an atom to lose one or more of its electrons and thus to carry a reduced negative charge. The effect is to leave the atom positively charged, in which condition it is termed an ion.

An electric current is produced by any condition which results in the flow of electrons from one point in a circuit to another. In the usual sense, electrical flow takes place through a material termed a conductor. In the science of electronics (applied to devices using electron tubes), the flow of electrons takes place through a more or less completely evacuated space, and is a primary function of the apparatus.

The term, electronics, is generally used to denote the study of activity and control of electrons. In view of the limitations placed upon the present article, the term is here used more specifically to apply to the study and application of devices in which electron tubes, such as photoelectric cells and amplifiers, are used.

A few more definitions are also in order. An electron tube, also known as a thermionic valve, radio tube and by various other names, is a mechanism for the control or translation of energy (usually electrical), which consists of an evacuated or partly evacuated inclosure, with two or more electrodes.

A photoelectric cell, also referred to as a photocell, phototube or light valve, is one class of electron tube in which a flow of electrons between two or more electrodes in an inclosure is brought about by the action of light or other radiation on one of the electrodes. The flow of electrons in the external circuit of the photoelectric cell is capable of controlling some other mechanism such as another electron tube, or a sensitive electro-magnetic relay.

The science of electronics has come to cover a great many electronic devices. In general, however, these devices fall into two classes which are frequently interdependent on each other for the solution of a given problem. Thermionic tubes proper form the first class while photoelectric mechanisms which control the flow of electrons by means of illumination form the second class.

Historically, the photoelectric cell considerably antedates the thermionic tube. It was the latter, however, which developed first and without which the photoelectric cell would certainly never have reached its present useful state. On that account the first part of this discussion will deal with the thermionic tube, the second part with the photoelectric cell. A continuation of this paper (to appear in our April number—*Editor*) will deal briefly with a few of the more specialized types of electronic devices used for process industry applications other than in control, and also with the applications of both thermionic tubes and photoelectric cells in process control.

ELECTRON TUBES

Although properly the term electron tube should also include the photoelectric cell, present day usage restricts this designation largely to electron tubes of non-light-sensitive types. For the remainder of this discussion, therefore, this distinction will be accepted.

An electron tube is a device consisting of an envelope or inclosure, generally of glass or metal, evacuated to any desired extent and containing a gas or vapor at a pre-chosen pressure. In the envelope are two or more electrodes. Between these electrodes a flow of electrons can be induced under suitable circumstances.

Electron tubes are divided into two main classes, the first or high-vacuum type, including all tubes in which the electron current flow takes place in a highly evacuated space, while the second or gas-filled type includes those in which the current flow occurs in an inclosure containing a gas or vapor at a pressure considerably higher than in tubes of the first class. Both types are fundamentally similar in that each has an element which serves as a source of electrons and a second element which acts as the receiver of the electrons. A tube of either class may have one or more additional elements serving as control electrodes to regulate the flow of the electron current. It is clear, then, that the principal difference between these two types of tube is the pressure of gas or vapor in the space between the electrodes. In the high-vacuum tube the pressure is reduced to about 10^{-3} microns while in the so-called gas-filled tube, the tube is first evacuated and then the desired gas or vapor is admitted to a pressure ranging from 1 to 500 microns, depending on the requirements for the particular tube.

In the standard terminology of electronics, the tube element which serves as the source of electrons is called the cathode, while the element to which the electrons flow is called the anode (or plate). Other electrodes which may be used in the tube are referred to as control electrodes (or sometimes as grids).

The present day electron tube is a direct result of the discovery during the latter part of the last century that it was possible to produce a flow of electric current through an evacuated inclosure between an incandescent filament and a positively charged plate. Since Thomas A. Edison was one of the first to notice this effect, it has since been called the Edison effect. In 1883, during his experiments with the incandescent lamp, Edison found that when he mounted a small metal plate in the lamp and connected the plate through a meter to the positive terminal of a direct current source, the meter would indicate a small flow of current (Fig. 1). Conversely, with the negative terminal connected to the plate, no current would flow. Edison himself was primarily interested in the

production of light by means of electricity and apparently made no attempt to explain this effect. It was not until six years later that Ambrose Fleming in England appreciated the significance of the phenomenon and recognized that such a device could be employed as a rectifier. Eventually he used a tube of this character as a wireless signal detector.

While a two-electrode tube of this sort did have important possibilities as a rectifier (which possibilities were not at that time fully recognized) the step which was to make the electron tube the versatile servant it now is, was still to be taken. It was not until 1906-7 that the simple idea of applying a third intermediate electrode for control purposes was applied by Lee De Forest (Fig. 2). This third element, which he termed a grid, immediately opened up the entire field of electronics to the extremely diverse stage of development which it has reached today. Electronic tubes now operate in many capacities which may be roughly classified as:

1. Amplifiers and de-amplifiers
2. Oscillators or generators
3. Rectifiers for both high and low frequency
4. Relay tubes
5. Inverters, for changing direct to alternating current
6. A variety of tubes for measuring physical units such as voltage, current and numerous other miscellaneous applications

It has already been mentioned that present-day electronic tubes, particularly when they are used for control purposes, may be classified as high-vacuum and gas-filled types. In these two types, the main applications are as follows:

High-Vacuum tubes

1. Rectifiers
2. Amplifiers
3. Oscillators or generators
4. Measuring devices
5. Relays

Gas-Filled Tubes

1. Rectifiers
2. Inverters
3. Relays

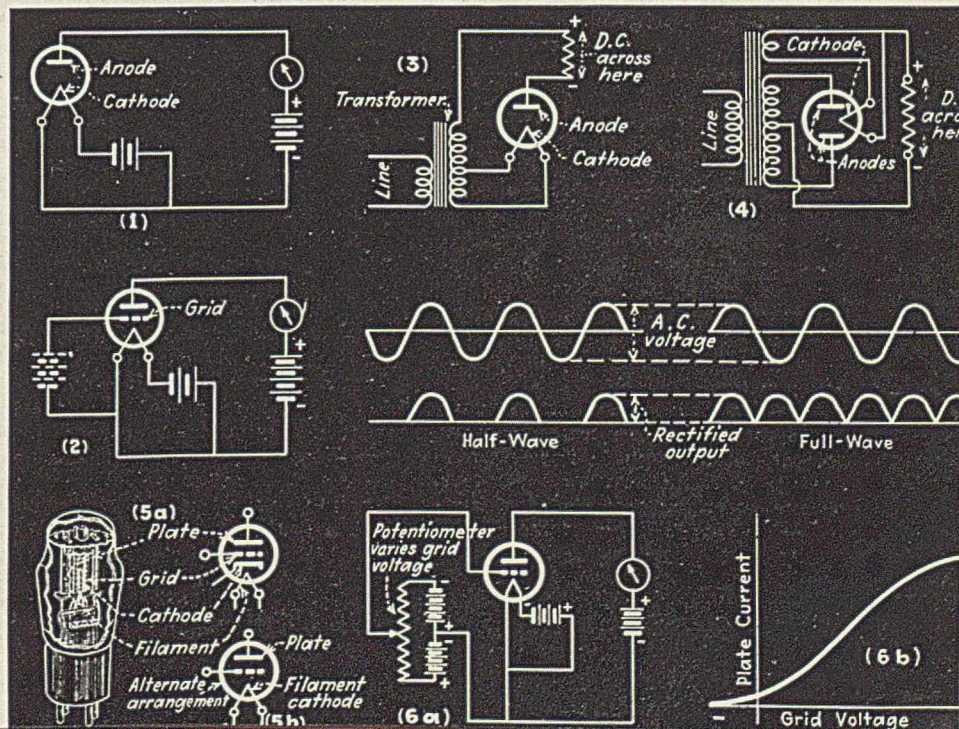
Electronic tubes of these two classes are sometimes used in combination and in some cases may be applied interchangeably. The present article is concerned primarily with the high-vacuum type, which is the one chiefly used for industrial control, and with the gas-filled type employed as a relay tube. The second article will touch briefly on other applications of the gas-filled tube of interest to chemical engineers.

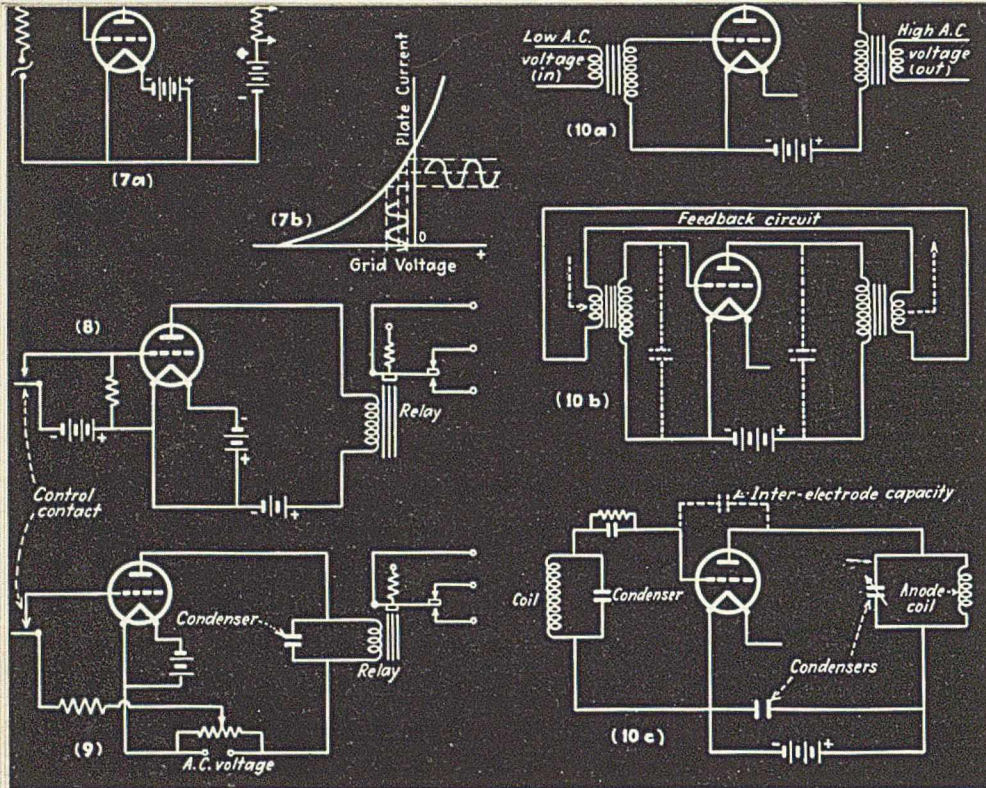
HIGH-VACUUM TUBES

Rectifiers—The rectifier consists of two electrodes in an evacuated inclosure and is the simplest form of high-vacuum electronic tube. Its operation, as has already been noted, is based upon the Edison effect. In common with all other electronic tubes, one of its electrodes which is designated as the cathode serves as a source of electrons, while the other, known as the anode, functions as an electrode collector. The cathode usually consists of a heated wire filament which is sometimes coated with a rare-earth oxide capable of giving up electrons at a lower temperature than the heated wire itself. The second electrode, or anode, is a metal plate situated close to the cathode. As in Fig. 3, when an alternating voltage is impressed upon the anode and cathode in series with a load, current flows between them and through the load only

- (1) Edison-effect circuit; (2) DeForest's apparatus, adding control grid; (3) Half-wave rectifier circuit; (4) Full-wave rectifier; (5a) Modern triode tube; (5b) Alternate form with filament cathode; (6a) Circuit for determining tube characteristics; (6b)

Typical electronic tube characteristic curve





(7a) Typical amplifier circuit; (7b) Effect on plate current of varying grid voltage; (8) High-vacuum electronic tube relay; (9) Gaseous electronic tube relay; (10) Steps in evolution of vacuum tube generator; (a) A.c. amplifier; (b) Back-coupled amplifier; (c) High-frequency oscillator circuit

during those portions of the cycle when the anode is positive.

The mechanism of this action is clear when one considers the nature of the electron and the electron-emitting cathode. The release of electrons from the surface of the heated filament (which in an electron tube is heated electrically, although it might be heated by any other means), may be likened to the escape of atoms from the surface of a liquid as its temperature is raised. According to the kinetic theory, as the temperature of the filament is raised, the activity of the atoms increases and more and more electrons leave their orbits, flying into the space surrounding the filament. The normal course of events an equilibrium is quickly reached with as many electrons returning to the atoms as leave in a given time.

However, when it is recalled that electrons are negative charges and hence capable of attraction by a positive charge, it will be evident that the equilibrium can be upset by introducing a positively charged object in the vicinity of the electron-emitting filament. In Edison's experiment, when he maintained his anode plate at a positive potential, a small current of electrons flowed continuously from the heated filament to the anode and thence through the meter in his external circuit. In the rectifier, however, with an alternating potential applied to the anode as shown in Fig. 3, only during the portion of the alternating current cycle when the anode is positive can electrons flow from the cathode to the anode. During portions of the cycle when the anode is negative, the electron

flow is suppressed and the electron equilibrium at the cathode is restored.

Thus with a rectifier tube interposed in the load circuit, one-half of the alternating current wave is stopped in the load circuit, with the result that a pulsating direct current flows. Rectification of this type is called half-wave rectification and can be used in cases where a pulsating direct current is not a disadvantage. Where full-wave rectification is desired, two half-wave rectifiers may be employed, so connected as to allow each rectifier to work alternately and thus deliver a rectified output in which both halves of the alternating current wave are turned in the same direction to deliver a smoother direct current output to the load. As shown in Fig. 4, it is usual to construct the two half-wave rectifiers in a single evacuated envelope, employing a common cathode. Half of the transformer secondary is used to apply potential to one anode plate, the other half to the other anode. A separate secondary winding is used to provide the heating current for the cathode filament.

Amplifiers—Although it was several years before De Forest's three-element tube became a full fledged amplifier, the amplifying type of electronic tube definitely stems from his idea. In the construction of the three-electrode tube (Fig. 5), the control electrode or grid is placed closer to the cathode than is the anode. The effect of this is that a smaller voltage is required on the grid to influence the electron stream between the cathode and the anode than would be required at the anode. Thus the grid acts as a valve which, with the application of relatively little energy, can con-

trol the flow of a comparatively large amount of energy (Fig. 6). A small positive voltage impressed on the grid will greatly increase the flow of electrons to the anode, while a small negative voltage will greatly decrease the flow. The ratio of voltage change in the control grid circuit, to the corresponding voltage change produced in the anode circuit, due to the change of anode current through the load, is called the amplification coefficient of the tube. These relations may be seen more clearly by reference to the circuit and diagram of Fig. 7.

Amplifier tubes may be designed to operate for the amplification of (1) direct current; (2) low-frequency alternating current; (3) high-frequency alternating current. The same basic electron tube is used for each type of service. If greater overall amplification is desired than is obtainable with a single amplifier tube, it is possible to couple amplifiers in cascade fashion, so that the output of the first amplifier is fed to the second as input, and so on. Depending on how the amplifier is to be used, a variety of methods of feeding one amplifier from the output of the preceding amplifier may be used.

Amplifier tubes, so far as they are used for industrial control purposes, are generally applied as relays in cases where it is desired to operate a rugged electro-magnetic relay by an extremely weak control current. A common example is in cases where the primary detection means is a photoelectric cell, the current output of which is necessarily small. Although sufficiently sensitive electro-magnetic relays can be employed on certain photoelectric applications, such relays are generally impractical owing to their extreme delicacy. Use of an electronic amplifier permits a rugged relay to be used and so results in a much more reliable installation. Examples of the use of amplifier tubes for the operation of electro-magnetic relays appear in Figs. 8 and 9.

This combination of amplifier tube and electromagnetic relay is an extremely common one in industrial control, for a very small change in the grid voltage of the amplifier tube can be made to control a large amount of current at the magnetic relay. A common arrangement is to apply a fixed negative bias (potential) to the grid of the tube so that when the grid circuit is closed through the control contact, no grid current will flow and hence the control contacts will not be required to carry current. Without such a negative bias, the grid, when it is made positive with respect to the cathode, acts as an anode, thus permitting a grid current to flow. Fig. 8 shows a circuit of this type in which the anode current through a magnetic relay is suppressed when the grid is negatively biased by closing of the control contact. This type of relay mechanism is the sort commonly used as an amplifier relay for photoelectric cells.

GAS-FILLED TUBES

In discussing the high vacuum electronic tube it was brought out that as the grid voltage is changed, the anode current varies. This variation is gradual and the rate of change is dependent upon the rate of change of the grid voltage. However, when the three electrode tube contains a gas, the operation is quite different.

A gas-filled tube is first evacuated and then filled to some predetermined pressure such as 100 microns with a gas such as argon, or with a vapor such as mercury. When an electron current flows between the cathode and anode, in a tube in which gas molecules are present, the effect of these molecules is to increase the electron current by a process known as gas amplification. This process takes place substantially as follows: When electrons are liberated from the cathode and move toward the anode, they will, if they collide with gas molecules and have previously acquired sufficient kinetic energy in their travel, ionize these molecules by knocking off one or more electrons from the molecules. The new electrons thus produced join the stream of electrons from the cathode and flow to the anode, thus increasing the external current. The ionized molecules of gas are drawn toward the cathode where they pick up their missing electrons and become neutralized, ready to pass back into the space between cathode and anode, to await further collisions.

This action within the tube can best be understood by ignoring the control electrode for the moment. As the anode voltage is raised, an increasing number of electrons is drawn to the anode. The greater number of electrons flowing to the anode increases the possibilities for collisions between electrons and gas molecules and as the anode voltage is increased, a point is reached when the current through the gas space between the cathode and anode will increase rapidly to some ultimate value without any further increase in the anode voltage. Under these conditions, as long as the anode remains positive, the current flow will maintain the ionization of the gas indefinitely and will produce a visible glow discharge.

The point where the sudden increase in the electron current takes place is called the break-down point of the tube. After break-down, the current is limited only by the resistance of the external circuit and the situation is similar to that in a mercury vapor or fluorescent lamp. However, when the tube is provided with a control grid, the grid can prevent ionization entirely if it is made completely negative with respect to the cathode. Under these conditions no electrons can pass from the cathode to the anode. If the control electrode is then slowly made more positive in potential, a point will be reached at which ionization of the gas will occur, but at a considerably lower voltage than if applied to the anode.

The grid potential at which ionization occurs is termed the striking potential, and application of the striking potential upon the grid acts as a control trigger, giving a sudden large surge of anode current. Once the striking potential has been reached, making the grid potential negative again will not stop the anode current flow, since it is now maintained by ionization of the gas. The glow discharge may be stopped and the anode current reduced to zero only by opening the anode circuit.

The action of opening the anode circuit can be taken care of automatically in commercial devices by energizing the tube with alternating current. In a tube so energized the anode current can flow only during the positive portions of the anode alternating current cycle, and the discharge will be extinguished every half cycle. A gas-filled three-electrode tube has the advantage of permitting considerably higher anode current than a similar high vacuum tube and this current can be abruptly released by the trigger action of the tube to operate a rugged electro-magnetic relay. A typical circuit for such a tube is shown in Fig. 9.

OSCILLATOR TUBES

The electronic oscillator tube, or alternating current generating tube, is essentially an amplifier in which the output energy is fed back into the input side of the amplifier. This is accomplished so that the feed-back is in proper phase to augment the momentary grid voltage changes. The oscillator circuit can be considered as an electrical analog of the balance wheel and hair spring assembly in a watch. Consider for a moment how this assembly stores energy. The balance wheel is first given an impulse in one direction and moves in that direction until the impulse energy has been stored by the spring. The wheel then reverses its direction of rotation until the spring is wound up in the opposite direction. The balance wheel can be made to continue oscillating with a fixed period if sufficient energy to offset the losses dissipated in work is imparted to the wheel at every oscillation.

An electronic tube oscillator also provides means for storing energy and the characteristics of the energy-storing circuit determine the frequency of oscillation of the current in the circuit. The circuit provides a means for storing energy in either the grid or anode circuit, or both. The storing means usually consists of a coil and a condenser in parallel. When a current is induced in the coil, the potential across the coil will charge the condenser in one direction. The condenser will then discharge through the coil and recharge itself in the opposite direction. In this way an oscillating current is set up in the coil and condenser combination, which dies out gradually as the energy of the system is dissipated. Such a system as this is known as a resonant circuit. Like the balance

wheel it can be kept in operation provided a timed impulse of energy is given to the system. Such a system, compared with an amplifier circuit from which it evolved, is shown in Figs. 10a and b.

With a tube oscillator circuit, the oscillation frequency depends on the capacity of the condenser and the inductance of the coil. The tube has the function of applying the needed impulse to the resonant circuit at the proper time to maintain oscillation, just as the mechanical impulse maintained oscillation of the balance wheel. Fig. 10b shows a back-coupled amplifier circuit. Consider that an electrical impulse causing a change in the grid voltage takes place. The tube amplifies this change and causes a large change in anode current. The effect of this change is to charge the anode condenser in one direction, whereupon the condenser attempts to discharge through the anode inductance. However, owing to the connection through the feed-back circuit, the condenser discharge causes a new voltage to appear in the grid circuit in proper phase relationship to the original grid voltage change. The direction of grid voltage change is such as to cause a second anode current change and the recharging of the anode condenser. Therefore the entire operating cycle is repeated, the tube acting as an alternating current generator with a frequency of alternation depending on the values of inductance and capacity.

A part of the energy produced in the oscillator circuit may be removed and utilized for other purposes in a variety of ways. A common method is to let the oscillating current flow through a resistor in the anode circuit, across which an alternating voltage may be taken off. Oscillators may be designed for either high or low frequency.

An interesting feature of an oscillating circuit is that, as the energy of oscillation increases, the anode current decreases. A properly designed oscillator draws a minimum amount of anode energy from the anode battery. Generally the strength of oscillation may be increased by increasing the coupling between the anode and grid circuits. But this decreases the anode current. Hence, by controlling the energy of oscillation (i.e., by controlling the feed-back energy), the anode current can be controlled sufficiently to operate an electromagnetic relay in the anode circuit. This method is being employed in industrial control.

The circuit of Fig. 10c shows the arrangement of a typical high frequency oscillator. In this the coupling or feed-back circuit is completed through the inter-electrode capacity of the tube. A resistor is employed in the grid circuit to prevent the grid from becoming too highly positive. The grid becomes more positive for some portion of the oscillating cycle when the strength of oscillation increases. As this occurs the grid attracts electrons from the cathode and a small grid current flows. However, as this grid current flows through the

grid resistor, it decreases the positive bias (increases the negative bias) of the grid, owing to the voltage drop across the resistor. Hence, with the grid biased more negatively, the anode current is reduced.

On the other hand, if the strength of oscillation diminishes, either as a result of drawing energy from the oscillator or because the ability of the feed-back circuit to transfer energy from the anode circuit to the grid circuit is changed, the grid current is reduced. This in turn causes the grid to become less negative (more positive), thus increasing the anode current. From this it is clear that by varying the feed-back energy in the oscillator, the anode current which the tube draws from the anode battery can be varied. A variety of important uses is made of this phenomenon in industrial apparatus.

PHOTOELECTRIC CELLS

As has already been noted, the photoelectric cell was invented long before the thermionic tube but the discovery received little attention and was put to almost no practical use prior to the development of the three-electrode relay type electronic tube. Four general classes of photoelectric cells are known today. While each group contains a number of variations, these variations all depend on the same general operating principles. Photoelectric cells may be classified as follows:

1. Photo Voltaic Cells
 - Becquerel cell (semi-conductor, electrolytic)
 - Photolytic cell (electrolytic CuO)
 - Electrolytic cell (solid electrolyte)
 - Crystal cell (cuprous oxide)
2. Photo-Conductive Cells
 - Selenium bar
 - Selenium bridge
3. Semi-Conductor (barrier layer) Cells
 - Adams and Day cell (1876)
 - Fritts cell (1884)
 - Grondahl and Geiger cell (1927)
 - Present-day cells (Lange, 1930)
 - Cuprous oxide and copper (Westinghouse Photex)
 - Selenium and iron (G.E., and Weston Photronic)

4. Photo-Emissive Cells
 - High-vacuum cells
 - Gaseous cells
5. Special Types
 - Grid-controlled emissive cells
 - Electron multipliers
 - Knowles Photoglow tube

PHOTO VOLTAIC CELLS

As a rough approximation, it may be stated that photoelectric cells either generate an electric current under the influence of illumination, or change their resistance so as to vary a flow of current from an external source when subjected to the influence of light. The earliest cell to be developed was of the former type. Photo voltaic cells generate electrical energy upon being illuminated and generally consist of two electrodes immersed in a solution.

In 1839 Becquerel discovered that two metal electrodes immersed in an electrolyte of their salts would show a difference of potential upon illumination of one of the electrodes. Although the process was not understood at that time, 1839 may still be considered as the date marking the first electrolytic photo element. The Becquerel cell is illustrated in Fig. 11.

It was many years before electrolytic cells of this type found considerable commercial use. Two such cells have been developed in recent years. One type consists of an oxidized copper plate suspended in an electrolyte of lead nitrate. The anode is of lead. A somewhat different and better cell, developed in America, is called the photolytic cell (Fig. 12) and differs from the type just described in that the lead anode is replaced by a second cuprous oxide electrode. The effect is to keep the potential of the cell when it is not illuminated (dark potential) at a low level.

This type of cell suffered from a number of drawbacks, one of the most serious of which was the tendency of the electrolyte to become cloudy owing to the precipitation of salts. An improvement resulted from the use of a solid electrolyte gel made with gelatin or agar agar. Another type of cell using a solid electrolyte employs for this purpose a rock salt crystal which

is moistened before sealing (Fig. 13).

All of the aforementioned electrolytic cells operate similarly. When two metal electrodes are immersed in a solution of the salts of the electrode material, an equal and opposite potential is set up between the electrodes and the solution. When one of the electrodes is illuminated, electrons are released from this electrode into the electrolyte so that a potential difference between the electrodes results.

The mechanism whereby illumination liberates electrons from a material under the influence of light is not dissimilar to the liberation discussed in an earlier part of this article in the case of a heated filament. As the number of electrons released depends upon the amount of heat energy imparted to the filament, so the number released in a photoelectric cell also depends on the amount of energy in the form of light falling on the electrode.

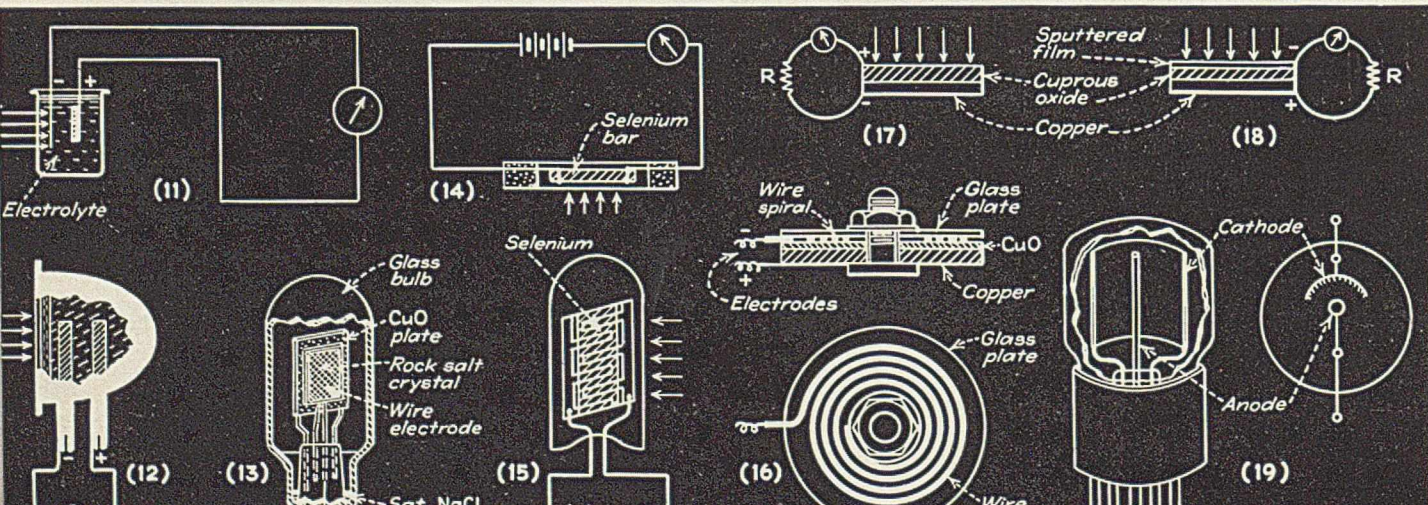
Photo voltaic cells have occasional industrial uses because, with sufficiently intense illumination, they can be made to operate fairly rugged relays. On the other hand, their use is becoming less important owing to their sluggishness.

PHOTO-CONDUCTIVE CELLS

Where the photo voltaic cell is actually a generator of electric current, the photo-conductive cell is a partial conductor which, upon illumination, changes its resistance. The first intelligent observation of the phenomenon of change in electrical resistance of a body with intensity of illumination was made by Willoughby Smith in 1873. Smith was employing tiny rods of selenium metal as a high resistance element in an experimental cable station. He found that these rods became much better conductors of electricity when they were exposed to daylight or to any artificial illumination. Selenium, discovered by Berzelius in 1817, under dark conditions is a very poor conductor but its conductivity improves considerably when it is illuminated. An early experimental cell employing selenium, developed by Adams and Day in 1876, is shown in Fig. 14.

(11) Becquerel photo-sensitive cell of 1839; (12) Electrolytic cuprous oxide cell; (13) Electrolytic cell with solid electrolyte; (14) Adams and Day selenium cell; (15) Selenium photo-con-

ductive cell; (16) Grondahl and Geiger cuprous oxide rectifier disk; (17) Back-effect barrier layer cell; (18) Front-effect barrier layer cell; (19) Modern photo-emissive cell



Just how light affects the resistance of selenium is not definitely known but the probable mechanism may be explained as follows. The light is assumed to liberate electrons within the selenium which, as they travel through the substance, may strike positive ions and reunite with them to produce neutral atoms. Since, for any level of illumination, an equilibrium must shortly be reached between the rate of release of the electrons and the rate of recombination, then a maximum value of conductivity for that level of illumination will be reached. When the light is removed, recombination of the electrons and ions will first take place rapidly, thus reducing the number of free electrons and raising resistance, but as the number decreases, so does the probability of recombination and a second equilibrium will be attained at lower conductivity.

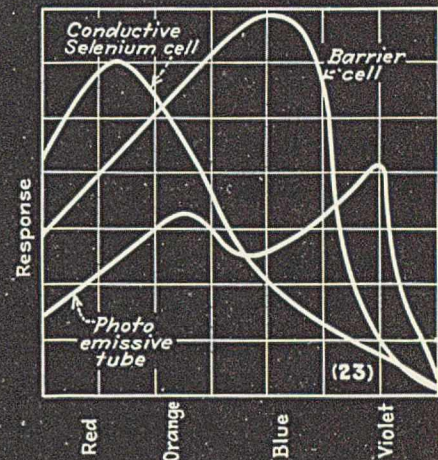
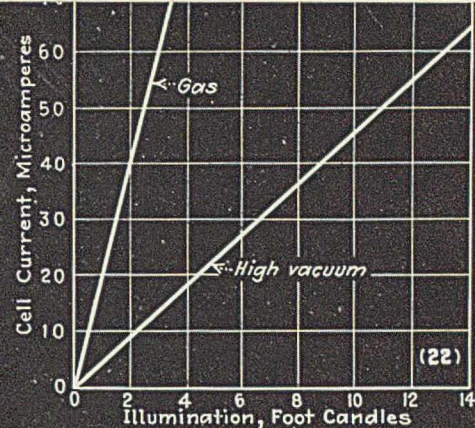
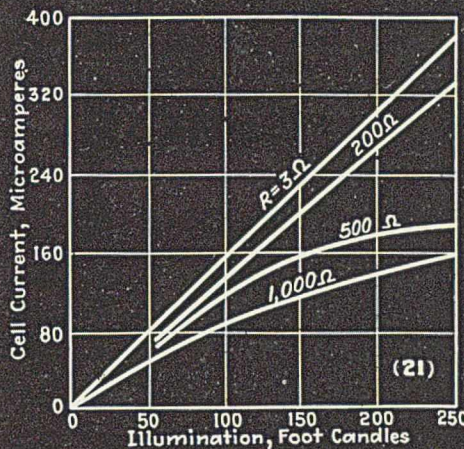
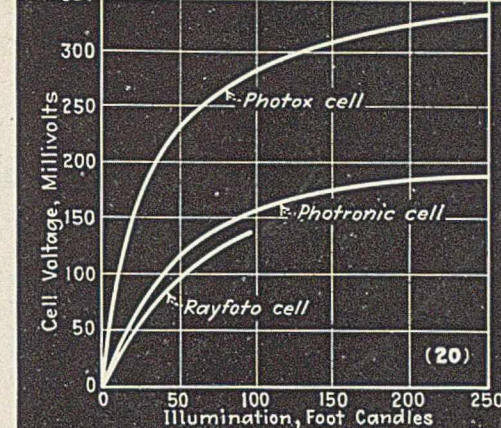
As would be expected from the description of the supposed mechanism of conductivity variation in selenium, the release and recombination of free electrons in the material is quite sluggish and the change in conductivity is incapable of following rapid changes in the incident light.

Since the early work with selenium, many investigators have attempted to improve this type of cell, but the limitations of the method have prevented any great success. Perhaps the best of these cells is the Thirring type which decreases the sluggishness to a considerable extent and has a rather high ratio of light to dark resistance. This cell consists of a sputtered film of selenium between two electrodes in an evacuated bulb. It appears in Fig. 15. This cell is rarely used today.

SEMI-CONDUCTOR CELLS

Like the photo voltaic type, the semiconductor or barrier layer cell also generates electrical energy upon being illuminated and may be considered as a form of Becquerel cell having a solid, dry electrolyte. Interestingly enough, the development of these cells hinges on work which was carried out on selenium cells by Adams and Day. In 1876 these investigators found that the illumination of a selenium rod produced a spontaneous potential, independent of the resistance change in the material. They found that on exposing the rod to light a reversal in the galvanometer throw indicated a reversal of the current. This they explained as an additional potential produced within the rod by the incident light.

In 1884 an improved selenium cell was designed which was remarkably like cells manufactured today. Charles Fritts, in New York, built a type consisting of a metallic supporting plate, covered with a thin layer of selenium, upon which light fell through a thin sheet of gold leaf. This cell also produced a spontaneous potential upon illumination. Fritts' cell offered an improved arrangement in construction, making possible longitudinal illumination, but it suffered from the disad-



(20) Voltage produced by barrier layer cells; (21) Current output of Photronic cell; (22) Current output of photo-emissive cells; (23) Response of photocells of various types to light of various colors (wave lengths)

vantage of high contact resistance and reduced photoelectric current owing to the loosely attached gold electrode.

These objections probably account for the fact that commercial use of cells of this type was not attained until 1927. In that year Grondahl and Geiger were searching for a satisfactory dry-disk rectifier material. In working with their cuprous oxide rectifier they discovered a change in resistance when the edge portion was illuminated. This cell, shown in Fig. 16, still did not have the sheet-like translucent front electrode upon which modern cells depend for their higher efficiency. However, with the publication of their findings, many investigators took up the work, among them Lange, Everett, Bergmann, Falkenthal, Rothe, Bohucke and others. The result of this increased interest in the solid-electrode dry-type photo voltaic cell was the modern barrier layer cell now used to such a large extent in colorimetric equipment and illumination and exposure meters.

MODERN BARRIER CELLS

The modern barrier layer cell is made in two distinct types, one known as the back-wall or back-effect cell (Fig. 17), the second known as the front-wall or front-effect cell (Fig. 18). The first type employs a thin layer of cuprous oxide formed upon a copper surface. A ring of gold or platinum is sputtered or deposited upon the outer edge of the

cuprous oxide to serve as a contacting means. Impingement of light upon the cuprous oxide film causes electrons to flow across the boundary between the oxide and the copper. Owing to the fact that the action of the light takes place at the boundary surface between the oxide and the metal, the light must pass through the layer of oxide. In this cell the boundary is the seat of the barrier effect. Since the electrons flow from the oxide to the copper, the copper becomes negative with respect to the oxide. When an external circuit is completed between the copper and the oxide, an external current flow is produced, the electrons flowing in that direction.

As has been noted, this cell is referred to as the back-effect cell because the emission of electrons takes place at the back of the oxide film, requiring the light to pass through the film. A better type of cell, the front-effect type of Fig. 18, is made by sputtering a thin translucent film of silver, gold or platinum on the exposed surface of the cuprous oxide layer which has previously been formed on copper as in the back-effect film. Light entering the cell passes through the sputtered film, with the emission of electrons taking place at both surfaces of the oxide. This emission is, however, greater at the front surface, causing the sputtered film to become negatively charged with respect to the copper and producing a current flow through an external circuit from

the sputtered film, through the circuit, to the copper backing. In this cell, as distinguished from the back-effect type, the light is only very slightly absorbed in passing through the sputtered film.

Other materials than copper and cuprous oxide may be used in the manufacture of barrier layer cells. One commercial form, for example, employs iron selenide and iron.

Cells of the photo voltaic and barrier layer types have the important advantage that they require no external voltage supply and are themselves generators of electricity. One reason for the interest they have attracted lies in the fact that they offer a means for the direct conversion of solar energy into electrical energy. Such cells have actually been used to drive tiny electric motors direct from sunlight. With them it is possible to obtain an output of about 1 watt per square yard of sensitive surface, but at the present stage of development such cells would be a decidedly inefficient method of converting solar energy which as an average reaches the earth at the rate of about 2,000 watts per square meter. The output is, however, sufficient to operate sensitive relays when enough illumination is available. Current and voltage characteristics of a number of different makes of barrier layer cells are shown in Figs. 20 and 21.

PHOTO-EMISSIVE CELLS

From the industrial standpoint today, by far the largest number of applications fall in the field of the photo-emissive cell, an electronic tube which like the earlier conductive cell of the selenium type varies its conductivity with variations in the intensity of incident illumination. In cells of this type an electrode coated with a material capable of emitting electrons under the impingement of light serves as a cathode, while a nearby wire electrode serves as an anode. When light falls upon the cathode, electrons are liberated. These electrons are attracted to the positively charged anode and an electron flow from cathode to anode takes place. The number of electrons available is dependent upon the illumination and the potential difference between the electrodes.

The discovery of photo-emission goes back to observations made by Hertz in 1885-7, when he was experimenting with what was to become the groundwork of wireless. He noted that the maximum intensity of spark at the receiving gap was obtained when the gap was irradiated with ultra-violet light. In 1888 Hallwachs tested the effect of ultra-violet on a charged gold-leaf electroscope and found that such radiation quickly dissipated a negative charge but had no effect on a positive charge. The following year Stoletow interposed a mesh screen between an arc light and a highly polished metal plate, connecting the plate and screen in series with a battery and galvanometer, an arrangement quite similar to a modern photo-

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emissive cell. When the plate was irradiated, he found that a small current flowed from the plate to the screen.

In 1890, two experimenters, Elster and Geitel, studied the photo-sensitivity of various metals, and found that the more electro-positive metals gave the best results. To use the alkali metals, sodium and potassium, they made mercury amalgams which gave excellent results with visible light, as well as ultra-violet, especially when the cell was inclosed in a highly evacuated glass tube. Thus they showed that both the Hallwachs and Hertzian effects were caused by the liberation of negative electrons from a photoelectrically sensitive substance, by the impingement of light on the substance.

In its modern development, the photo-emissive cell has appeared in two different forms, the high-vacuum and the gas-filled types, just as the electronic tube has developed in both directions. The high-vacuum photo-emissive cell, like the high-vacuum electronic tube, is simpler in its general function. This cell consists essentially of a half cylinder of metal upon which an alkali metal is deposited. This cathode is mounted within an evacuated glass bulb. Placed parallel to and along the center axis of the half cylinder, and insulated from it, is a wire electrode which serves as the anode. When light impinges upon the cathode, electrons are given off from the surface of the alkali metal and flow toward the positively charged anode. Since there would be no flow without a potential difference between anode and cathode, a battery must be provided in the external circuit to keep the anode positive with respect to the cathode.

Cells of this type are the most useful of all photoelectric devices. They may be designed for an output directly proportional to the illumination. In addition, they are decidedly free of fatigue effects. Having high internal impedance, they operate satisfactorily with a variety of amplification methods. Their sole disadvantage is that their output is quite small, although this disadvantage is not serious in view of the excellent electronic amplifiers now available. A tube of this type is illustrated in Fig. 19.

GAS-FILLED PHOTO CELLS

In some ways, the gas-filled photo-emissive cell resembles the gas-filled electronic tube already discussed. In both cases the presence of gas molecules in the tube results in ionization of the molecules, with the production of additional electrons and a considerable increase in the available electron current from cathode to anode. This cell is similar in construction to the high-vacuum photo-emissive cell except for

the traces of gas present in the inclosure. In one commonly employed type, the cell is evacuated and then filled with argon to a pressure of 100 microns.

The number of ionizing collisions which may take place within such a cell obviously depends upon the number of electrons issuing from the cathode and hence upon the amount of light impinging on the cathode. Since the possibilities for collision depend also on the number of electrons actually leaving the vicinity of the cathode, the difference in potential between anode and cathode is also a determining factor. Once these factors are fixed, the number of collisions determines the number of additional electrons produced. The result of this process of gas amplification is the loss of linear relation between the light and the current output. This disadvantage is not especially serious in the case of control equipment, but may be important in certain other applications.

Another more serious disadvantage is the possibility of initiating a glow discharge, similar to that resulting from triggering a gas-filled electronic tube into the self-ionizing state. The ionization potential of the gas is generally in the neighborhood of 90 to 100 volts, and as the anode voltage approaches this potential, a glow discharge is produced, similar to the discharge in a neon tube. Hence an anode current will flow, even when the cathode is not illuminated. This current may increase to such a degree that the tube will be injured if external resistance is not placed in the anode circuit. On that account it is customary to use a resistance of 100,000 ohms or more in series with gas-filled photo-emissive tubes. However, this is not disadvantageous since a resistor is required for coupling such a tube to the types of amplifier customarily used with it.

Another disadvantage of the gas-filled tube is that, unlike the high-vacuum photo tube, which responds instantly to changes in light density, the gas-filled type shows a definite time lag. This is caused by the relatively large mass of the positive ions which require appreciable time to move from the vicinity of the anode, to the cathode, where they liberate additional electrons. At first the anode current rapidly increases with illumination, but gradually reaches an equilibrium value. A similar though reverse effect is obtained when the illumination is removed. The tube again exhibits inertia and the current does not fall instantly.

For most control purposes the lag of a gas-filled photo-emissive cell is unimportant. The cell is obviously inferior to the high vacuum photo tube in respect to its responsiveness, but its gas amplification gives it a place in industrial apparatus. Comparative performances of various photocell types are plotted in Figs. 22 and 23.

(*Editor's Note:* As explained in the earlier part of this paper, a second article will follow in our April issue.)

Machinery, Materials and Products

CHEM
& MET

PROCESS
EQUIPMENT NEWS

Asbestos-Cement Building

IN ANTICIPATION of shortages of metals used in building construction, Keasbey & Mattison Co., Ambler, Pa., has experimented with and finally announced an all-asbestos-cement building, employing asbestos-cement tubular sections as the structural members, sheet asbestos for the side walls and corrugated asbestos sheathing for the roof. Such buildings are based on units 16 ft. long and 12 ft. wide, with 15 ft. of clear height. Thus a building of any size can be constructed by simply combining the required number of 12x16-ft. units. It is pointed out by the manufacturer that installation can be handled by unskilled workmen, thus keeping erection costs at a minimum. Such buildings are said to be fire-resisting, weather-resisting and free from maintenance.

Sand-Bag Filler

A SIMPLE, light-weight device, available at low cost for the easy filling of sand bags has been announced by Spinks Scale Co., 656 Mayland Ave., S. W., Atlanta, Ga. This filler, a development of this company's previously manufactured coal-bag filler, is said to enable one man to fill more sand bags per day than two men can fill when one holds the bag, and the other shovels. The filler allows the bag to rest on the ground while being filled so that it can readily be removed

from the filled bag without lifting the bag, thus allowing row after row of bags to be filled around a pile of sand. Bags are tied where filled and not handled until ready to be used, thus lessening fatigue and resulting in increased production. The manufacturer states that the most economical way of filling sand bags is to dump the sand near the location where the bags are to be used, filling the bags there. Thus these heavy, unwieldy packages need be handled only once in placing them in the desired position, as compared with the extra handling and trucking required when bags are filled at a point other than that where they are to be used.

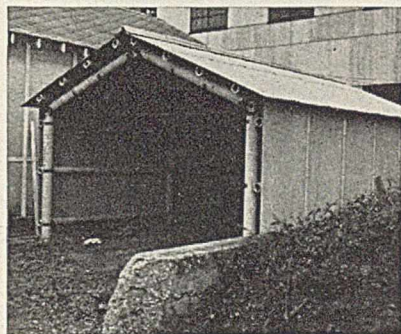
Heat Transfer Device

CONTINUOUS OPERATION under pressure in a closed system, and extremely rapid heat transfer rates, are features of the Votator, manufactured by the Votator Division of The Girdler Corp., Louisville, Ky. Developed for rapid cooling in the vegetable shortening, margarine, lard and ice cream industries, the company is now offering this heat transfer mechanism for use in numerous other industries where liquids and viscous materials are to be heated or cooled with extreme speed. The device employs a very high ratio of transfer surface to volume of material undergoing treatment, and maintains its high heat transfer rate continuously by the use of rotating scrapers which remove the film of material from the heat transfer surface. As shown in the accompanying illustration, the

machine consists of a jacketed vessel of small diameter in relation to its length, the jacket being heavily insulated and adapted to the handling of either high or low temperature heat transfer media. Within the vessel is a rotating element carrying scraper blades. This element, known as the Mutator shaft, serves not only to carry the scraper blades but, equally important, acts as a filler so as to reduce the working volume to the small annular space between the vessel wall and the Mutator shaft.

Owing to these features, the manufacturer claims that extremely high K values may be secured, together with uniform temperatures throughout the product, and accurate temperature control. Ordinarily a wide range of temperature change may be obtained in the product in the matter of a few seconds. So rapid is the heat transfer that many products can be super-cooled well below the crystallization point and discharged in a liquid state. Furthermore this can be done out of contact with the atmosphere and, if desired, predetermined quantities of gas may be incorporated into the product or the Votator can be used to make a uniform mixture or emulsion during the heat transfer process. The mechanism is adapted to various piping hook-ups and can, if desired, be employed in multiple assemblies for both heating and cooling. Standard sizes and designs are available, as well as individually engineered units.

Asbestos-cement building



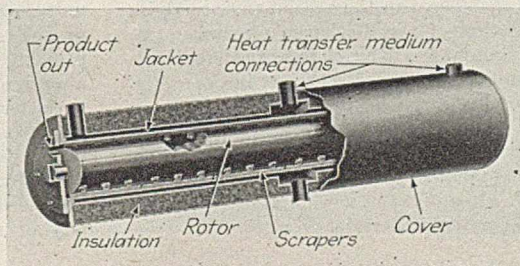
One-man sand-bag filler



Heavy-drum carrier



Cutaway view of Votator

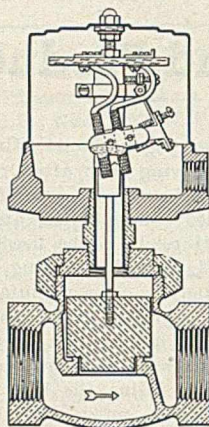


Drum Carrier

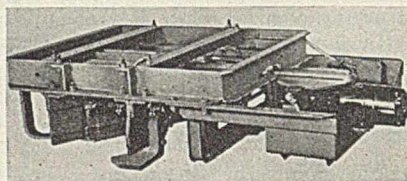
A NEW DRUM CARRIER with a capacity up to 600 lb., designed especially for the handling of heavy drums and known as the Little Giant, has been announced by Ernst Magic Carrier Sales Co., 1456 Jefferson Ave., Buffalo, N. Y. One man using one hand to operate one of these carriers is claimed to take the place of several men formerly required to break-over, balance and move the drum. The simple lifting device and self-balancing three-wheel construction are said to eliminate possibility of accidents. Special non-sparking wheels are available where precautions against explosions are necessary.

Flow Alarm

A NEW ITEM recently added to the Magnetrol liquid-level-control line of Fred H. Schaub Engineering Co., 325 West Huron St., Chicago, Ill., is a flow alarm designed to signal starting, stopping or insufficient flow of water, oil, gas or air. Built in pipe sizes from $\frac{3}{4}$ to 4 in., the device is designed for maximum operating pressure of 400 lb. W.O.G. It consists of a globe valve body to which is attached a head containing one of this company's Magnetrol magnetic switching devices. A plunger within the valve is raised off its seat by the flowing fluid, its motion being transmitted magnetically through a non-magnetic tube closed at its upper end to a mercury switch which completes the circuit when the flow drops to approximately 10 percent of the maximum flow for which the unit is designed. Special units can be built to give an alarm for any predetermined rate of flow less than maximum. It will be noted that through use of the magnetic transmission the valve requires no stuffing box.



Magnetic flow alarm



Electrically operated track switch

Electric Track Switch

FOR USE on cab-operated, gravity and automatic dispatch overhead material handling systems, the Cleveland Tram-rail Division of the Cleveland Crane & Engineering Co., Wickliffe, Ohio, has developed a new electrically operated track switch designated as motor driven Type H. This development enables the operator to pre-set the switch at some distance ahead while traveling, thus saving time lost in hand-switching. If desired, indexes on gravity or automatic dispatch carriers may be set to actuate trippers which will cause one or several switches to take the positions desired. Ruggedly built of welded steel, the switch consists of an outer supporting frame and an inner sliding frame. The former element may be bolted rigidly to the superstructure, while the latter, riding on multiple easy-operating rollers, carries a straight and a curved rail and is set in position by a motor-driven cam through a lever arrangement.

Continuous Pressure Filter

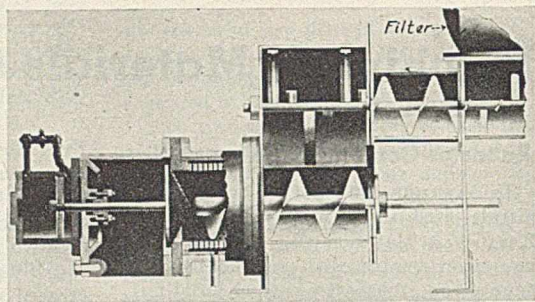
WHAT IS DESCRIBED by the manufacturer as the first continuous pressure filter, is the McCaskell automatic rotary leaf pressure filter developed by Goslin-Birmingham Mfg. Co., Birmingham, Ala. This machine makes possible continuous cake building, washing, drying, and discharge under higher differential pressures than are available with vacuum filters. It is claimed to be able to handle volatile solvents, corrosive liquids and viscous and high temperature slurries in a totally enclosed continuous pressure cycle. Economies in space, labor and maintenance, higher rates of flow, and the ability to dry the cake by air or steam pressure

are characteristics claimed for the new filter press.

The McCaskell design follows that of this company's Vallez rotary pressure-leaf filter in general construction, employing a number of round filter leaves spaced at regular intervals along a shaft, each leaf made up of pie-shaped sectors from which the filtrate drains into an individual port through a hollow filter shaft and an automatic disk-type filter valve. Contrary to usual rotary pressure-leaf filter operation, however, the new filter operates with partial rather than complete submergence, with pressure applied to the liquid and the submerged elements by air or gas pressure in the upper filter body. A low initial pressure with regulated increase to full differential pressure over the cake-building cycle is provided for by bleeder valve control of the leaf segments, which is said to result in exceptional clarity of filtrate. A continuous spray applied to the rotating leaves above the liquor level provides for washing. Cake discharge proceeds continuously as the leaf elements rotate past a hopper, discharge being accomplished by a pulsating reverse flow. Cake falls from the hoppers into a scroll conveyor, while a hydraulically loaded floating cake discharge valve unloads the cake continuously from the scroll compression cylinder without loss of pressure.

As shown in the accompanying cross-section of the discharge mechanism, a vacuum de-airing chamber can be provided in the discharge in case of products which must be de-aired or de-gassed.

These filters are available in a range of standard sizes from 20 to 600 sq. ft. of filter area, in a wide variety of construction materials.



Discharge mechanism of McCaskell continuous filter



Saboteurs are blinded by new anti-sabotage luminaire

Anti-Sabotage Light

GLARE, ordinarily anathema to lighting engineers, is made use of by Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., in a new anti-sabotage luminaire lighting fixture to blind would-be intruders, while permitting guards of defense plants to remain inconspicuous in the shadows. The new fixture employs a Fresnel lens which throws a flat, fan-shaped beam of light. When a row of these luminaires is set on posts several feet away from the buildings to be protected, their light is projected slightly downward and away from the buildings, leaving the space between the luminaires and the buildings virtually in darkness. Intruders are clearly visible but guards behind the lights cannot be seen.

Automatic Molding Press

TO PROVIDE faster molding of plastic products than has hitherto been possible with a machine of this capacity, Watson-Stillman Co., Roselle, N. J., has developed an improved 75-ton fully automatic compression molding machine capable of handling an 18x18-in. die. Powered by a 5-hp. motor, the unit has a 10-in. stroke with an approach speed of 210 in. per min., a pressing speed of 3.3 in. per min., and a return of 140 in. per min. All settings for time periods, materials, quantities and pressures can be made independently and easily from a single control panel. The hydraulically operated feeder puts a predetermined quantity of material in each mold cavity,

after which the molds are closed under pressure, and high pressure applied automatically at a predetermined time. Molds can be de-gassed if necessary. Pieces are then stripped and blown down a chute to an automatic piece-weighting scale. Work which fails to strip off automatically rings an alarm.

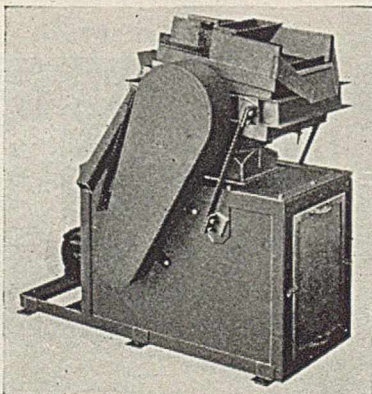
Specific Gravity Separator

AIR FLOTATION for the separation of high-gravity materials, such as stone, glass, and metals, from seeds and grains such as soybeans, corn and other cereals, is accomplished by the new Air-Float Stoner developed by Sutton, Steele & Steele, Inc., Dallas, Tex. Extremely high separating efficiency with very large capacity per unit of power expended is claimed for the new machine. Separation is effected by difference between the bulk density of the stock and its contaminations. The stock flows downward over a rapidly oscillating sloping screen deck, on a cushion of air supplied by a blower beneath the deck. Materials of higher specific gravity work uphill and leave through a throat at the high side of the deck. Power required is low since the machine does not have to lift the entire mass of material simply to remove a small percentage of heavy contamination. In-

75-ton automatic molding press



Air-Float Stoner



stead, the material flows downhill in a fluid condition, while higher gravity substances sink through the mass and work uphill, against the flow of stock. Up to 16 tons per hour capacity is claimed for a single standard size separator, with a power consumption of about 0.6 hp. per ton per hour capacity.

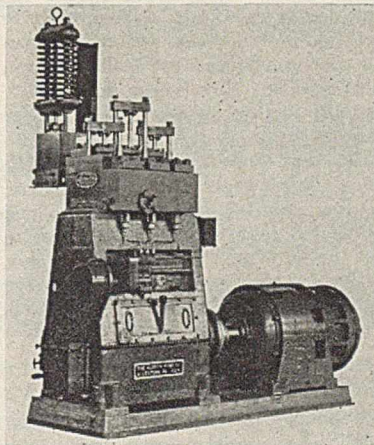
Compact Fork Truck

ALTHOUGH LIGHT in weight to permit it to operate over weak floor constructions, the new Clipper type gas-powered fork truck built by Clark Truetraactor Division of Clark Equipment Co., Battle Creek, Mich., is available in capacities of 1,000, 1,500 and 2,000 lb. The truck is built in six models with standard finger lifting heights of 60 to 108 in., with other heights optional. It is compact in design and able, according to the manufacturer, to operate on a continuous 24-hour basis in congested areas. It features front-wheel drive, rear-wheel steer, hydraulic lift, tilt and braking, and a self-starter. Safe operation at speeds from 1 to 7 m.p.h., forward or reverse, is claimed.

Power Pump

A NEW LINE of high-pressure, vertical, triplex constant-stroke pumps has been announced by Aldrich Pump Co., Allentown, Pa. Available in sizes from 10 to 150 hp., these pumps are designed for pressures up to 9,800 lb. per sq. in., in

Vertical, triplex high-pressure pump



Compact fork-type truck



capacities to 220 g.p.m. Drive is by gear-head motor or speed reducer, with provision in the larger sizes for the use of built-in gearing, or belt drive direct to the crankshaft. When desired, as for use in connection with a central hydraulic accumulator system serving several presses in constant operation, these pumps can be fitted with this company's synchronized suction valve control. For special process work at high pressure, as in oil refining and certain chemical industries, the outboard plungers are sealed dust- and weather-tight, with a removable cover.

Equipment Briefs

MANY NEW FEATURES are said to be incorporated in the latest centralized lubrication system announced by Lincoln Engineering Co., 5701 Natural Bridge Ave., St. Louis, Mo. The system, the Centro-Matic, consists of a number of injectors, one for each bearing to be lubricated, each connected to the bearing by tubing or flexible high-pressure hose, and each individually adjusted to discharge the required amount of lubricant. The injectors can be mounted singly or in manifold and are supplied with lubricant from a central pumping unit. A single lubricant supply line between the pumping unit and the injectors is an important feature, another being the wide range of pumping unit types available.

A NEW high-powered communicator for contacting selectively up to 20 substations, or paging all substations simultaneously, has been announced by Executone, Inc., 415 Lexington Ave., New York, N. Y. With this new model, natural two-way conversations are instantly possible. The station is enclosed in a 10x12x9-in. cabinet, with built-in microphone and speaker, and buttons for calling the 20 substations. The latter can be private, i.e., equipped with earphones, or remote, to permit conversation with a man many feet from his station.

A SIMPLE DEVICE to permit rapid soldering of electric wiring is the Jigger, a self-contained soldering unit recently introduced by Jiggers, Inc., 215 West Illinois St., Chicago, Ill. Each Jigger, which is slipped over the ends of the wires to be soldered, consists of solder and flux hermetically sealed in a waterproof, heat-generating outer shell. When the Jigger is touched with a lighted match, it ignites and produces the proper temperature to flow the solder into the splice. The burnt shell is then dropped off and the correctly soldered splice revealed.

AN IMPROVED and simplified design of its system for controlling arc welding machines, which eliminates the need for meters showing volts and amperes, has been announced by Lincoln Electric Co., Cleveland, Ohio. The

new system employs a job selector dial and a current control dial, calibrated and equipped with a handle and pointer. It is claimed that the welding operator can quickly select the proper combination for highest quality welds and highest possible welding speed, because he can vary both the slope of the volt-ampere curve and the amount of welding current, independently and positively, to suit every job encountered. Both voltage control (job selector) and current control are continuous in operation, making possible thousands of possible combinations of voltage and current.

UNIVERSAL HOSE TOOL is the name of a new hose-clamp-applying device for use on both rubber and fabric hose, recently announced by American Machine & Metals, Inc., East Moline, Ill. The tool bends the hose band around the hose, then by turning a small wheel and pushing it down, the band is clinched firmly, leaving a permanent sturdy connection. In three simple operations, hose couplings can be made in a few minutes on liquid, gas or air hose. Two sizes are available, the larger for 1-3 in. hose and the smaller $\frac{1}{4}$ - $\frac{3}{4}$ in. hose. In addition to saving time, the new tool is said to decrease the necessary clamp stock materially.

FURTHER IMPROVEMENT in fluorescent lighting is said now to be available for the production of essential military and civilian materials through the use of the new RF lighting equipment introduced by Benjamin Electric Mfg. Co., Des Plaines, Ill. The new equipment is said to provide even more light for the power consumed, to provide a new solution to the flicker problem, to assure quicker starting and to reduce installation and maintenance costs. It is said to be suitable for high mountings and wide spacings. Employing twin-lamp units, 35-40 footcandles of general illumination can be provided with a power consumption of about 200 watts when installed on 10x10 ft. spacings. Employing a full-wave rectifier-type circuit, the units are said to reduce flicker to such an extent that even single-lamp units can be employed satisfactorily in many cases without special balancing devices. Lamps of 85-watt size are employed in both single- and twin-lamp types.

Turbine Pumps

A NEW LINE of small-capacity, high-pressure centrifugal pumps of the so-called turbine type, made in a variety of designs for various operating conditions, has been introduced by the Dayton-Dowd Co., Quincy, Ill. Type T, the general-purpose pump of this line, is made in sizes from 1 to 150 g.p.m., for heads up to 300 lb. and speeds to 3,600 r.p.m., while other types are available for the same capacity range and for pressures to 500 lb. and temperatures to 850 deg. F. The lower pressure pumps

of the series, such as the general-purpose pump and the 250-lb. high temperature pump, employ an overhung rotor with a single stuffing box, while the 500-lb. low and high temperature pumps carry the rotors on bearings at either end, thus requiring two stuffing boxes.

These pumps are of the type operating on the regenerative principle, in which a single multi-vaned impeller operates at normal speeds to develop extremely high pressure in a single-stage casing. The head characteristics are especially flexible and motor overloading is said to be impossible, if the pump is selected for the maximum head conditions, as power decreases as the head decreases. The pumps develop a high suction lift, up to 28 ft., while the type of construction employed facilitates the use of special alloys and permits easy repairs. An extra set of side plates and an impeller can be stocked for ready replacement.

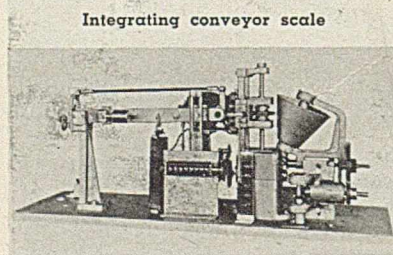
Another feature of the design is that the stuffing box is located in the area of lowest pressure within the pump. The pumps are inherently self-priming and capable of handling volatile liquids without becoming vapor-bound. All models employ anti-friction bearings and make provision for micrometer adjustment of the impeller clearance. For the higher pressure pumps, a built-in bypass and relief valve may be provided if required. In the case of the higher temperature pumps, both bearings and stuffing boxes are water-cooled.

Corrosion-Resisting Valves

MATERIAL INCREASE in its productive capacity for corrosion-resisting valves has been announced by Jenkins Bros., 80 White St., New York, N. Y. The company is thus in a position to offer faster delivery on such valves for orders having high priority ratings. In addition to globe, angle Y and check valves, the line now includes solid-wedge and double-disk-taper-seat gate valves in sizes up to 6 in. The company is now certifying its valve castings, employing both X-ray and pressure tests on each casting.

Conveyor Scale

A NEW SYSTEM for the integration of weight of material passing over a conveyor scale has been developed by Fairbanks, Morse & Co., 600 South Michigan Ave., Chicago, Ill. The integrator is of a simple design, which takes simultaneous account of the instantaneous



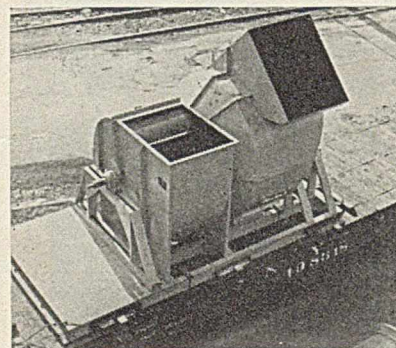
Integrating conveyor scale

weight on a scale-balanced section of the conveyor belt, and of the belt speed, converting these two functions into velocities which are applied to a differential gear, the output of which drives the integrator. The scale beam operates between close-spaced electric contacts on a movable contact table powered by a fractional-horsepower reversible motor. The function of this mechanism is to position a roller on a vertical shaft in the same vertical position as that at which the scale beam balances. The roller is driven by contact with a cone pulley driven from the conveyor belt. The conveyor belt drives one side of the differential at a speed proportional to the belt speed. The roller drives the other side at a speed proportional to the instantaneous weight on the belt. Therefore, the differential output is proportional to the weight passing per unit of time and is so recorded. Through the use of a Selsyn motor, operated by the integrator, a remote integrator can be employed, as well as a remote recorder, if desired. The scale is fully automatic in operation and requires no attendance.

Blackout Fan

ALTHOUGH it was developed primarily for the collection of fly-ash from cupolas and similar equipment, the new Filtrite Fan announced by Claude B. Schneible Co., Chicago, Ill., has been found to be extremely effective, according to the manufacturer, in reducing all glow from fired equipment which would otherwise be visible from the air. As is shown in the accompanying illustration, the unit is a dry-type collector, comprising a centrifugal collection chamber in series with a fan. The reverse in direction of gases passing through the apparatus prevents direct visibility of the fire, while the provision which is made for diluting the gases with air not only lowers their temperature to a point where they can be handled safely by the fan, but prevents any possibility of luminous gas passing through the equipment. The device, which is available in a variety of capacities, is of unit construction, mounted on a bed plate providing space for the belted motor. To maintain low bearing temperatures, the through shaft is water-cooled.

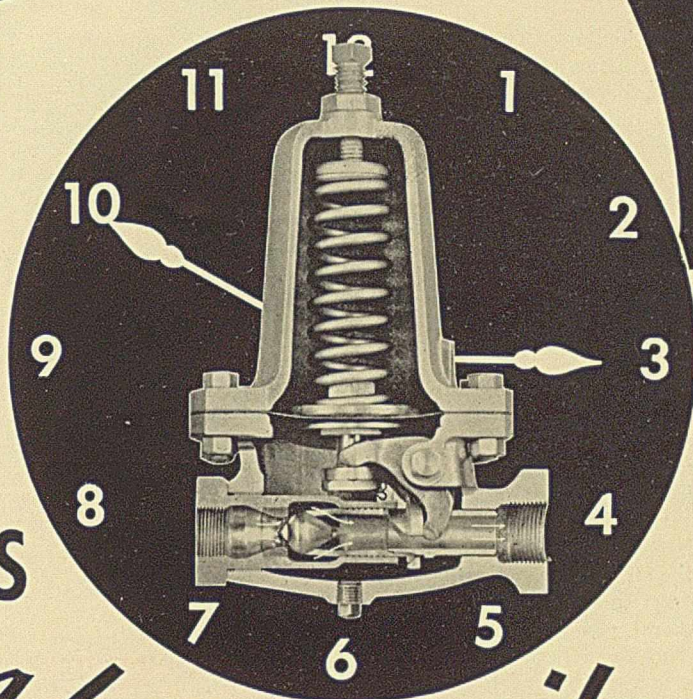
Blackout fly-ash collector



IN THESE DAYS OF
24-Hour Operation

Get
THESE
DOZEN
VALVE
BENEFITS

24 hours daily

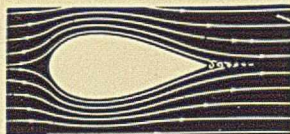


1. MAXIMUM CAPACITY WHEN NEEDED MOST
2. ACCURATE PRESSURE CONTROL UNDER TOUGHEST WORKING CONDITIONS
3. TROUBLE-FREE SERVICE
4. SMOOTH OPERATION
5. TIGHT CLOSURE
6. ACCURATE REGULATION
7. SPEEDIER PRODUCTION RESULTS
8. ELIMINATION OF FAILURES
9. CONSTANT DELIVERY PRESSURE
10. COST SAVING OPERATION
11. NO SPOILAGE
12. PRACTICALLY ZERO IN MAINTENANCE COSTS

CASH STANDARD
Streamlined
REDUCING VALVE

TYPE 1000
PRESSURE

Whether you are operating one, two, or three shifts a day, the "1000" valve, through "Streamlined" performance, is a valuable factor in aiding in smooth operation, high production, and better quality results. Check the twelve points and you will see that you get every advantage in pressure reduction for steam, air, oil—most anything that flows. The "1000" valve stays on the job for years rendering remarkable service—all without giving trouble. The Streamlined flow around the inner valve eliminates turbulence, thereby giving you best control under varying loads. You get better pressure control and greater capacity because there's a straight path for the fluid through the flow tube.



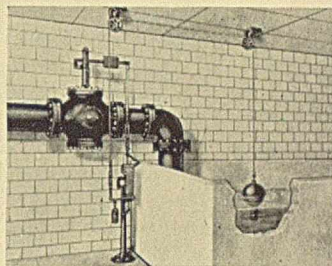
HERE'S THE "1000" FLOW PATTERN
The Streamlined form of the inner valve eliminates turbulence. It produces the flow pattern shown at left which makes for maximum capacity when it is needed most and permits accurate pressure control under toughest working conditions.

A
CASH STANDARD
"GET ACQUAINTED"
COLUMN

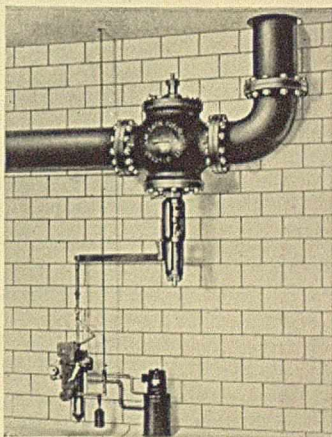


Question: "Don't you people make anything besides that Streamlined Valve you talk about so much?"

Answer: "Yes Sir; we do! And we propose to picture one or two of them here each time."



In automatic liquid level control, two things are often of prime importance: (1) to hold the level within the closest kind of limits; (2) to do it dependably, day by day. How Cash Standard controls do both is shown above. A Type 100-L Controller operates a 12" Balanced Valve regulating liquid supply to a large tank. It is pilot actuated for sensitivity. It has operating power to spare—for any size Valve, however large.



Here, a Type 100-L Controller operates a 10" Cash Standard Balanced Valve. It regulates flow through a make-up line to a "dirty water" heater on the floor above. The lever of the "100-L" responds to slightest movement of a float in the heater—causing immediate movement of the power piston which operates the Valve. But there is no "hunting" because the Controller is fully compensated. It has a "range" adjustment too. It gets accurate results with any size valve—no matter how small or how large the valve may be. It is simply a matter of using the right size power cylinder.



You can find out full details on all of these 12 points by reading Bulletin "1000"—send for it.

A. W. CASH COMPANY
DECATUR, ILLINOIS

CASH STANDARD
CONTROLS..
VALVES

Get Free Bulletins on
Above . . . Write to
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DECATUR, ILL.

Naval Stores and Terpene Chemicals

ONE OF THE PIONEERS in the recovery of naval stores (turpentine and rosin) from cutover Southern pine forests, was the Newport Industries, Inc., the first commercial operation starting in 1913. The Pensacola, Fla., plant can process 500 tons of wood daily and is the largest of the company's three properties.

Stumps are delivered by rail and truck. After grinding, the wood is carried on belt conveyors either directly to extractors or via storage bins. Preheated, close-cut petroleum naphtha (dry point about 115 deg. C.) extracts all the valuable products. The spent chips are steamed in order to remove solvent and then conveyed to boilers where they are used as fuel, or delivered to a plant adjoining the Newport operation for fabricating into building and insulating board.

FF wood rosin is the still residue after distillation of the extract to separate solvent and all the natural oils recovered from the wood. Most of the FF rosin is redissolved in petroleum naphtha and the solution filtered cold through adsorbent earth. Any desired degree of decolorization of the rosin is obtained.

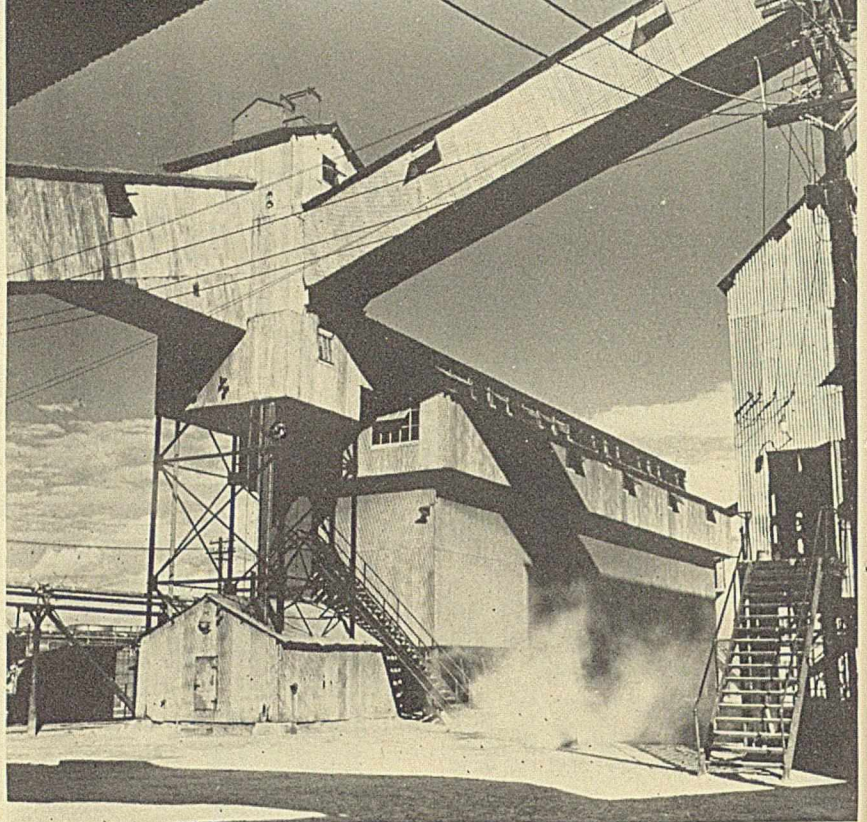
The pale rosins are pumped as hot liquid to various departments for processing into specialty products. The treatments include Dowtherm controlled, high-temperature, partial vacuum distillation, chemical reaction with lime and/or zinc oxide and combinations of these. Catalytic partial polymerization is an important recent rosin development.

Turpentine, dipentene and pine oil are separated from each other and from the petroleum solvent by vacuum fractionation in packed columns. Turpentine is refractionated to recover pinene used for the production of synthetic camphor by others. Pine Oil is chemically processed at the Pensacola plant to produce alpha and beta terpineol, anethol (N.F.), camphor (U.S.P.), fenchone and technical terpin hydrate. Dipentene will be processed in a plant under construction to make paracymene, para-menthane, methyl tolyl carbinol, methyl acetophenone, para-methyl alpha-methyl styrene and isopropyl benzoic (cumic) acid—many of them new terpene industrial chemicals. Terpene hydrocarbons in pine stumpwood are the raw material for isoprene by a new process also to be in operation next year.

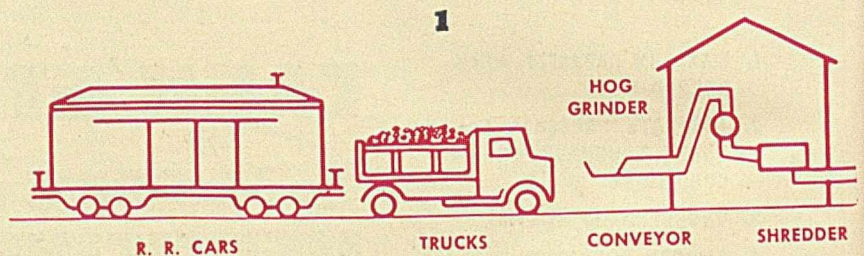
CHEMICAL & METALLURGICAL
ENGINEERING

March, 1942

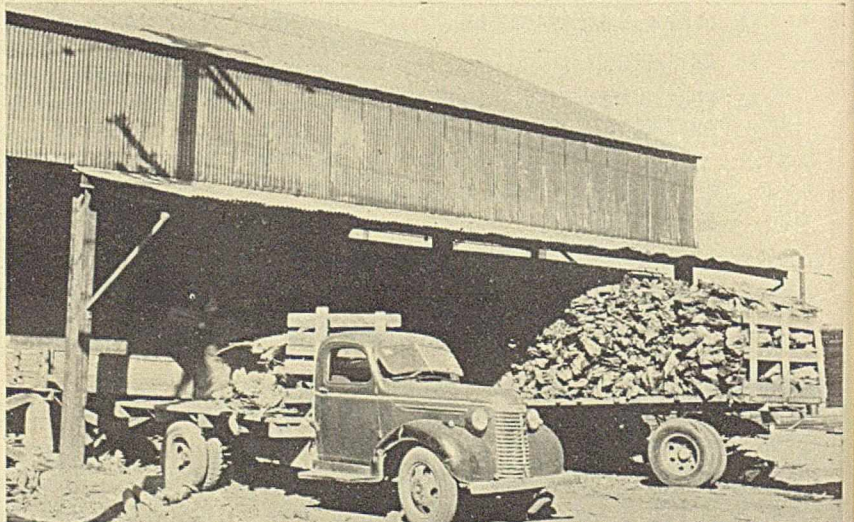
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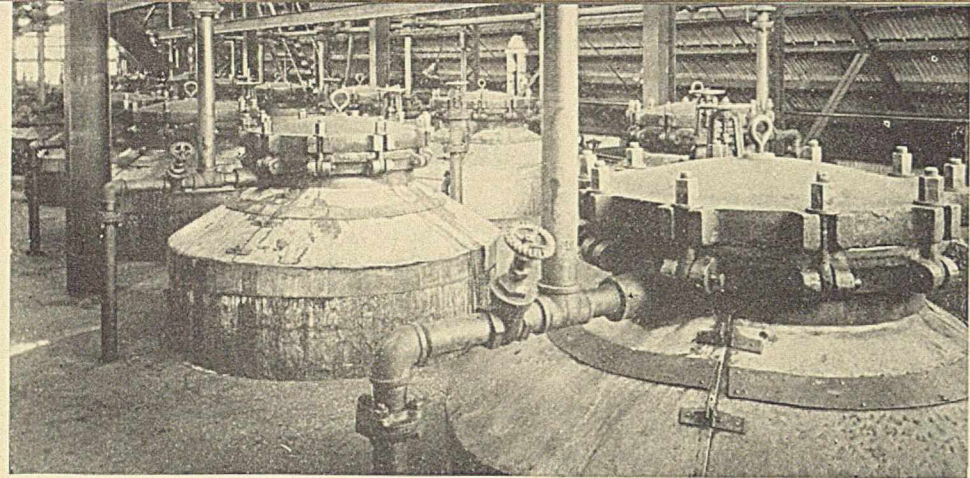


1 An elaborate conveying system is used for delivering the stump wood from the storage piles to the hog grinders and shredders

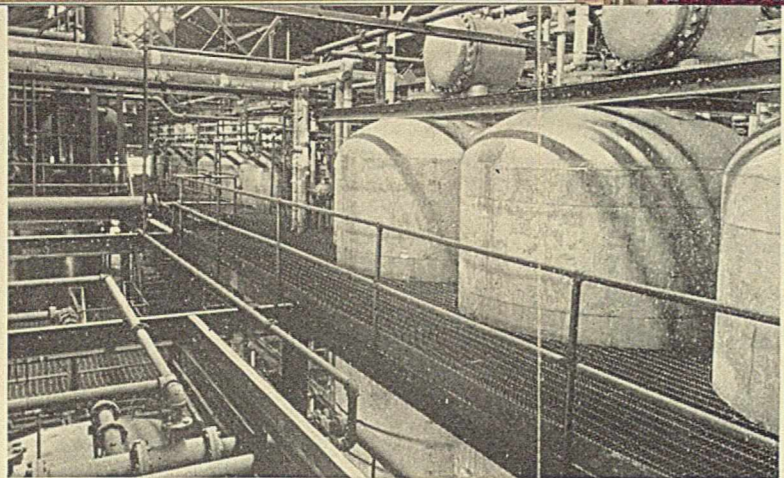


2 Production of naval stores at the Pensacola, Fla., plant of Newport Industries, Inc., starts with the delivery of stump wood in trucks and railroad cars

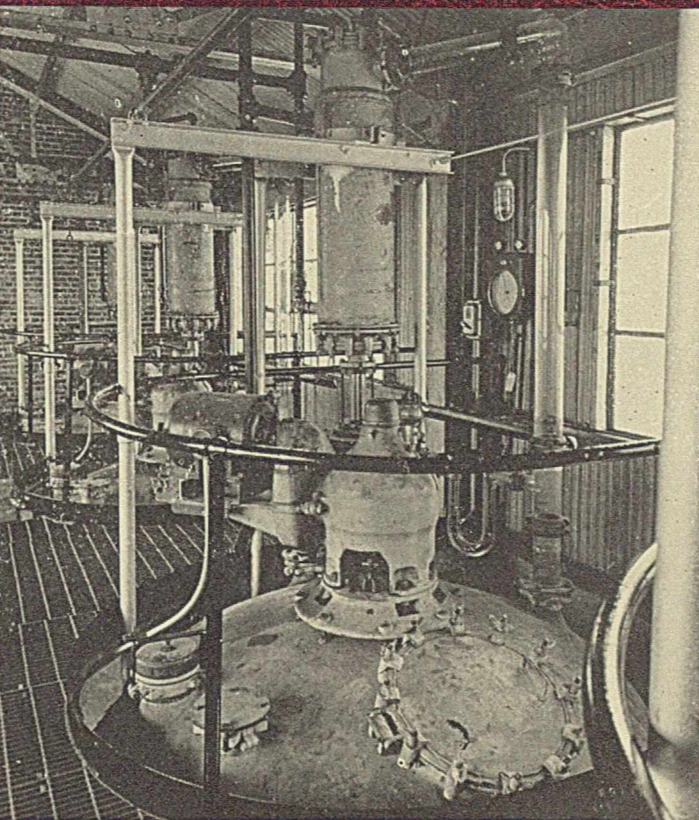




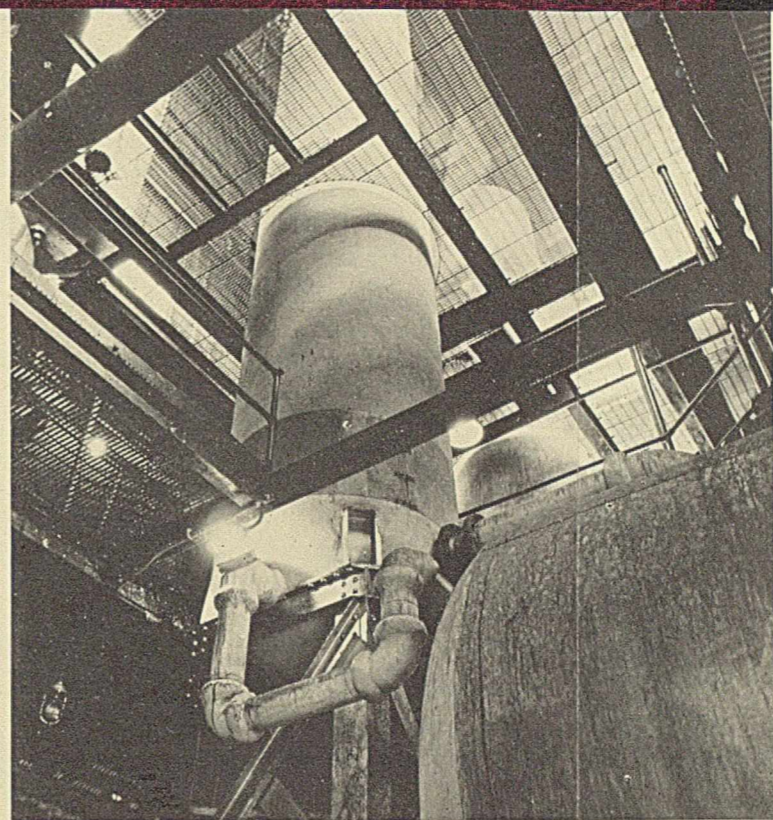
4 Lorrys are used to convey the wood from the storage bins to the extractors. A lorry may be seen in the upper left hand corner of the charging floor above tops of extractors



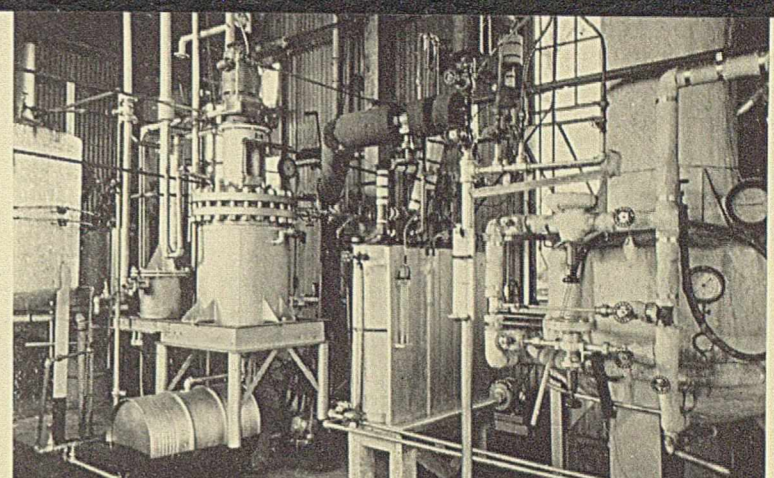
6 FF rosin is redissolved in petroleum naphtha and the solution filtered cold through adsorbant earth in this battery of towers



8 Pale rosins are converted by catalytic partial polymerization in these reactors into specialty products

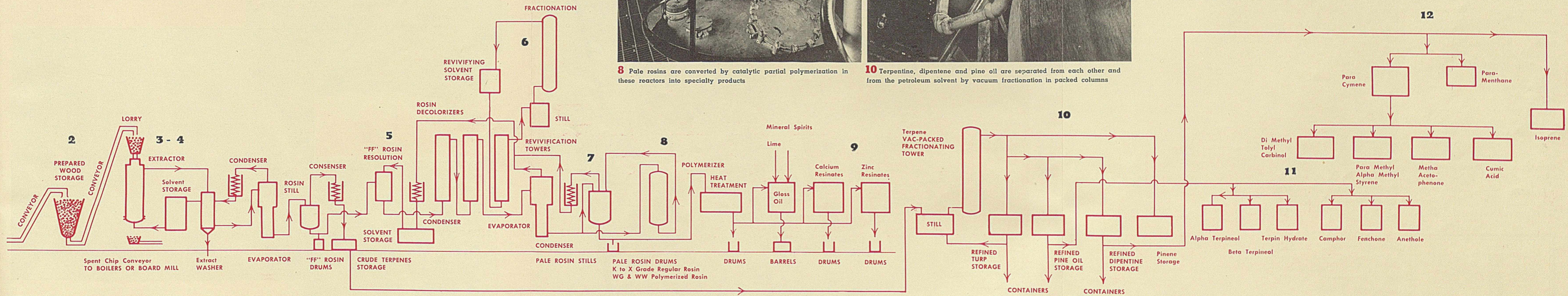


10 Terpentine, dipentene and pine oil are separated from each other and from the petroleum solvent by vacuum fractionation in packed columns



12 Pilot plant used for developing processes to produce new terpene chemicals and isoprene shortly to be in commercial production

A
Chem & Met
FLOW
SHEET



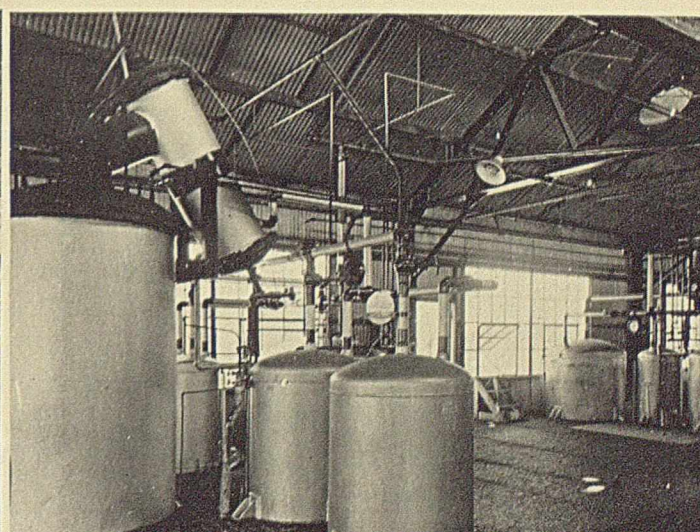
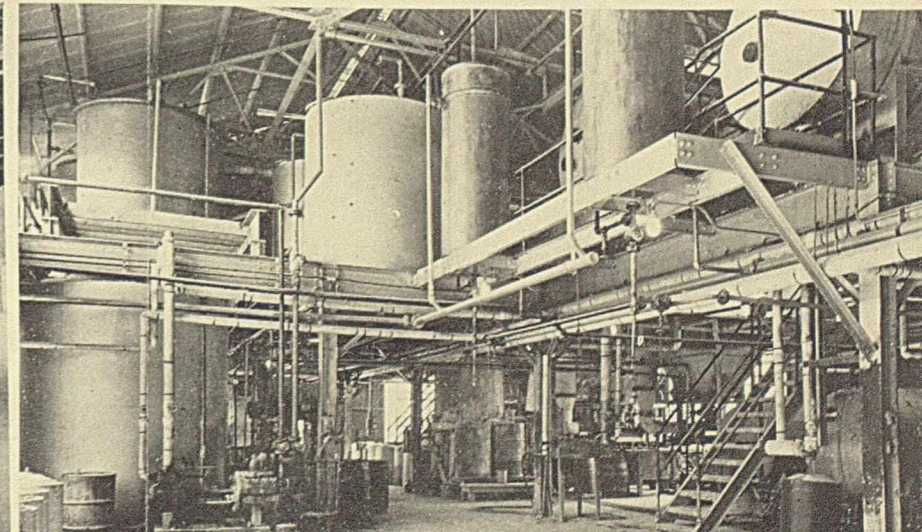
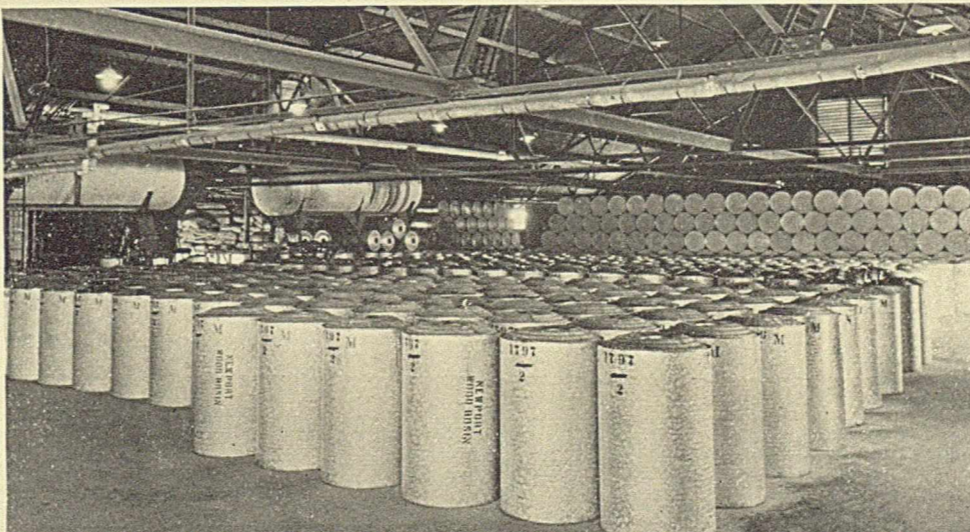
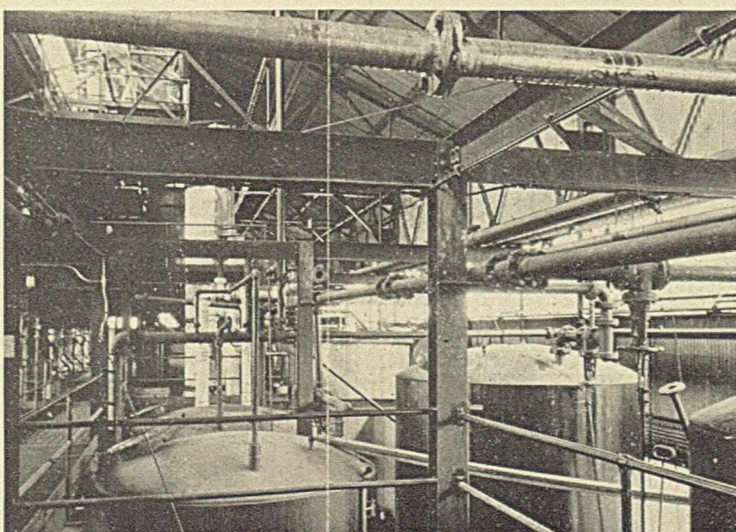
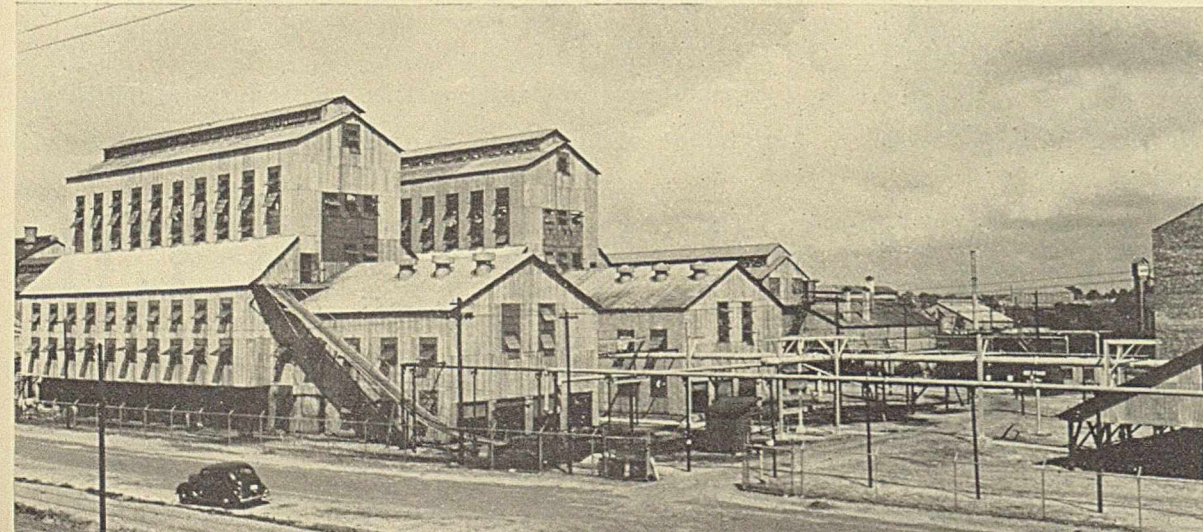
3 Shredded wood is conveyed by belt directly to extractors or via storage bins. This conveyor and the extractor building are shown in the left foreground of this portion of the plant

5 Extract is evaporated and spent chips are steamed to remove solvent. Evaporators and FF rosin re-solution equipment are shown

7 Liquid rosin from the finishing stills is pumped to elevated horizontal tanks shown in the background, from which it is run into 500-lb. galvanized drums cooling in the foreground

9 Pale rosins are also converted into specialties by high temperature treatment, partial vacuum distillation, reaction with lime and/or zinc oxide and combinations of these

11 Operating floor, showing high vacuum stills and receivers in the plant producing camphor, anethole and terpineol



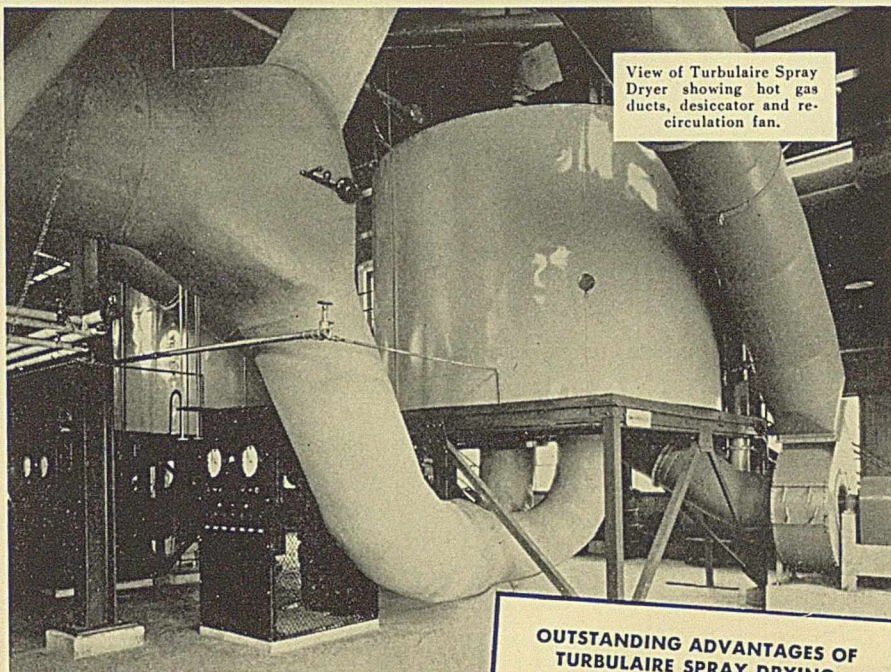
TURBULAIRE

instantaneous drying

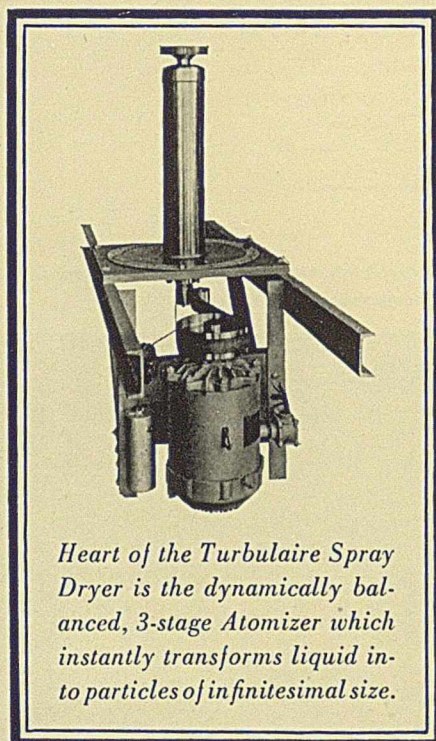
SPEEDS STRATEGIC MATERIAL RECLAMATION

• Reclamation of strategic materials is vital to war production because every ton of loss prevented means tons less of raw materials required. Turbulaire Spray Dryers are reclaiming Magnesium Chloride from a plant's waste liquors, high-vitamin stock food from Molasses residue, Yeast from brewery waste. They are used in the processing of Magnesium Chloride, resins, in the ceramic field for the cleaning of clay, and for many other uses in the food and chemical fields. Back of every Turbulaire Dryer stands the technical skill and experience that assures extremely efficient operation of each unit of its rated capacity.

• Turbulaire Dryers available in sizes to conform to the character of the product to be dried and volume handled.



View of Turbulaire Spray Dryer showing hot gas ducts, desiccator and re-circulation fan.



Heart of the Turbulaire Spray Dryer is the dynamically balanced, 3-stage Atomizer which instantly transforms liquid into particles of infinitesimal size.

• Complete laboratory facilities are available to make sample test runs. A one pint sample of your product is sufficient for a preliminary examination to determine the advisability of spray drying it. Dispatch of a sample for testing incurs no obligation.

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PRECIPITATION COMPANY OF CANADA, LTD.
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OUTSTANDING ADVANTAGES OF TURBULAIRE SPRAY DRYING

Processes solids from solutions, suspensions or slurries.

Dried product is finely divided powder with uniform physical and chemical characteristics.

Makes use of waste gases from boilers or furnaces.

Temperature differential control maintained within close limits.

Stainless steel, corrosion-resisting construction available for special material processing.

Full automatic control from central switchboard.

Processed product ready for storage or packaging.

TURBULAIRE*

*TUR-BU-LAIRE

SPRAY DRYERS



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 TODAY!

Complete description of
 Turbulaire Spray Drying
 is available upon request.

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- 1 **HELP YOU Train Piping Crews**
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Today's situation calls for *round-the-clock* production. That means your plant must get better service from valves and fittings, and have better-trained men to keep piping on the job. Crane Shop Bulletins for maintenance workers are aimed to help you get both. Their wealth of practical pointers aids in guiding new men, as well as assists veteran crews in stepping up efficiency of piping equipment.

If your plant is not enjoying the benefits of this timely service, as are countless others, you will certainly want to get in touch with your local Crane Representative today. There is no charge or obligation.



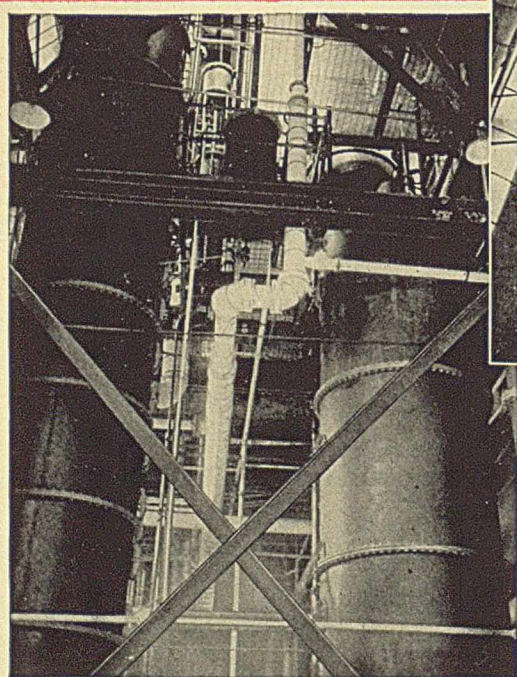
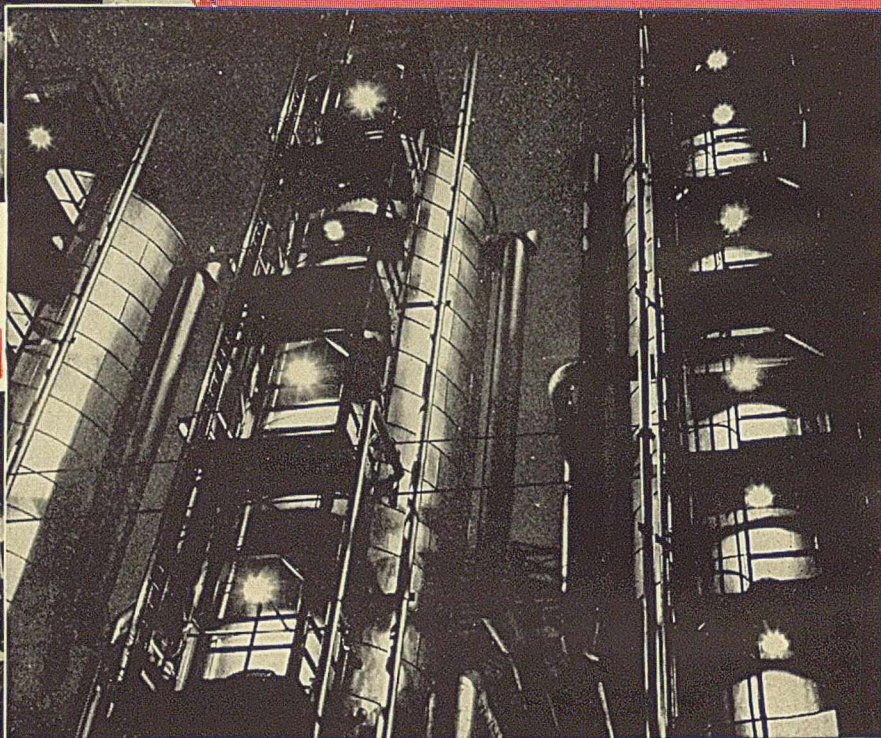
CRANE

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VALVES • FITTINGS • PIPE
PLUMBING • HEATING • PUMPS

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