SO MUCH...ON SO LITTLE

CIRCUMSTANCES sometimes dictate that the engineer must make an adequate decision on the basis of inadequate data. The inherent risk varies with the confidence one has in the integrity, knowledge and experience of the man or men involved. In the case of the Baruch-Compton-Conant report on the rubber situation, the nation receives its recommendations with the feeling that no group under present conditions could have given us a better appraisal of an exceedingly serious and complicated problem. Engineers and other technical men have special reason to be gratified and encouraged by the committee's recognition of the essential role that science and technology must continue to play in the synthetic rubber program.

In all the terse, clear-cut conclusions of this classic report, one paragraph stands out as a striking tribute to the work of the engineers behind the scenes who have carried so much of the burden and responsibility of the whole effort. "It is fortunate," says the report, "that the program for the needed plants is generally in the hands of as competent engineers as there are in the country. Probably the most interesting and satisfying part of our study is the confidence we have acquired in the men from industry who have the plans in hand and who are satisfied they can lick the problem in the given time. Their competence and experience, their resourcefulness and ingenuity, are the best guarantees we have that they can do so.

"We have been much impressed with the fact that the stupendous undertaking is only possible because of the highly developed skill of our technologists. No one could have examined the facts before us without appreciating the magnitude and scope of the task; no one could have made this study without realizing that because of the shortsightedness and failure to act on technically sound advice we must now proceed with insufficient experience. *We venture the statement that never on the basis of so little has so much been involved.*"

That mistakes of the past should not be repeated in the future is the grave concern of the committee in making its strong recommendation for the establishment of a competent and adequately staffed technical division under the immediate control of the Rubber Administrator. All phases of research, development, construction and operation of the program must be based on sound advice. Never again must we have such "a chaotic situation in which nontechnical men have made decisions without consultation with subordinates nominally in positions of responsibility."

Looking beyond the organization chart and the mere mechanics of administration, the committee recognized the necessity for continuing advance in research and development. It urged free "technological competition" and the "beneficial rivalries of the best brains in industry." It held that, on the one hand, "there should be a complete interchange of information and, on the other, as much competition in research, development and operation as possible. Such, after all, are the conditions applying in the fields of laboratory science where tremendous strides have been made during the last hundred years. Competition and cooperation in this new national effort, we believe, must go hand in hand."

It is our considered opinion that never before have we read a governmental report which so clearly analyzed a highly technical and complicated problem and at the same time laid the only ade-

quate basis for its solution. It is a challenge to every American citizen to do his part in meeting the national crisis. It is addressed particularly to chemical engineers. Never before in our brief industrial history has so much depended on so few.

MORE ALCOHOL PLANTS?

Perhaps there is legitimate ground for questioning one technical recommendation in the Baruch Committee report. Even if one does question that statement, as we do below, the report sets an all-time high for government documents in its technical reliability.

Our question relates to the need for the building of additional alcohol plants in the agricultural states near water transportation. We do not believe that the objective rightly sought in such a recommendation can best be reached by that route. It is clear that without building new plants there is abundant alcohol manufacturing capacity potentially available in beet-sugar plants, sugar refineries, and certain syrup works already in existence. Several large sugar refineries alone could each produce 30 million gallons of alcohol from grain if they were merely given some packed tower stills. They could adapt existing refinery equipment to every other operation than the concentration of the high wines into industrial alcohol. Surely that technique of alcohol making is much the most economic in the use of critical materials and machinery.

The government technical men know this. Unfortunately, however, many of the politicians in Congress refuse to believe it because they still would like to have alcohol plants in their home districts.

It is not yet clear whether we shall need more alcohol late in 1943 than is already assured from going plants and plants nearing completion. But if we do, there are good chemical engineering means for producing at least 200 million gallons of additional industrial alcohol from grain in the manner above described.

CONSERVE TECHNICAL SKILLS

Technological skill of the scientist and the engineer is a great wartime asset. Every public official gives lip service to this fact. Unfortunately, many important officials having to do with man-power questions do not also give administrative support to it. The result is two serious threats of great concern to chemical engineers and to those who need their skilled service.

The first threat is that far too many scarce technical men skilled in chemical engineering, chemistry, and physics, are being allowed to go into non-technical military activities, or are being forced to, with a great national waste of skilled manpower. Fortunately, many, probably most, of the state and local Selective Service boards have recognized the error of such a policy and are doing their best to conserve these skills for their greatest usefulness. But even a few leaks are unfortunate.

Far more dangerous, and far more significant, is the action of Army and Navy officers in recruiting technical manpower for commissioned officers for land, sea, and air services. Apparently, every recruiting unit that goes near a campus makes its first raid on the engineering college. The reason is obvious. The type of young man who makes a most promising engineering student is also a most promising officer candidate. Unfortunately, the recruiting agencies take these men for many jobs for which their engineering or scientific talent is not required. Even though a young engineer may make a splendid deck officer on a ship, a resourceful aircraft pilot or observer, or a very fine infantry officer, there is no excuse for allowing this scarce type of young technical skill to be diverted to those applications. Yet literally thousands of young engineers and scientists have been so taken.

Simultaneously, the technical services of Ordnance, Engineers, Chemical Warfare, and the manufacturing units which provide materiel, are shouting for a greater number of young technical workers in research, development, design, and the engineering aspects of plant operation and supervision. They cannot get nearly enough for the direct military jobs which they must do, both in uniform and in civilian projects.

These facts are recognized by high ranking officials in the War Manpower Commission. They

EDITORIAL VIEWPOINT

are recognized in theory by Selective Service. They are recognized by advisers to the Secretary of War and the Secretary of the Navy. But nothing happens to correct the evil. It seems most unfortunate that top official action does not stop this diversion of skill into jobs for which special skill is not required. If for no other reason than to supply the *technical* uniformed services adequately, these men should be conserved for technical jobs. And if industry is to do its maximum in production, certainly there should be some besides the cripples and morons left for it.

ATTENTION DRAFT BOARDS!

ADDRESSING itself to the "highly competent man" whom the Baruch committee assumed that the Rubber Administrator will immediately place "on a full-time basis in charge of his technical division," the report included this significant suggestion:

9. The Committee suggests the institution of a prompt survey to determine the number of chemical engineers and other technically trained men who will be required to operate the synthetic rubber plants now under construction. And if this survey indicates a serious shortage of such technical talent, the Manpower Commission should be called upon for assistance in devising a policy for meeting the situation.

It is our impression that the Commission, through the National Roster and U. S. Employment Service, had already anticipated this suggestion. So had at least one of the engineering societies. There seems to be a need developing for at least 2,000 recent graduates, which is considerably more than the supply. When you have the chance, bring this serious situation to the attention of the members of your local board.

WASHINGTON HIGHLIGHTS

FATS AND OILS will be abundant; but extensive restrictions on use are imposed. These seeming conflicts of official conclusion represent rational precautions in handling a difficult situation. The total supply of fats and oils potentially available will be adequate despite large Lend-Lease and unusual military uses. But certain types of oils will not be abundant, notably drying oils and certain soap

oils. The one constructive feature of the whole situation is the fact that in revision of Order M-71 the technical men of W.P.B. have recognized the interdependence of all oil-using industries. They have imposed restrictions on each of the major user groups on a coordinated basis. Perhaps no group is going to be entirely happy with its own restrictions; but they can be happy in the thought that an honest effort is made to have everyone share reasonably in the responsibility for curtailment.

BARUCH style reviews are needed for other things than rubber. That fact was clearly indicated in the Baruch report itself. Official Washington understood the meaning of this implication. That there are not other Baruch committees already working on manpower and food problems—to mention but two needs—is partly because there are not enough Baruchs, Conants, and Comptons. Also, this idea tastes about like loose quinine officially.

QUALITY of industrial goods will be critically reviewed by a newly created "Standards Division" of O.P.A. That agency will undertake to prevent the up-grading in name, and in price, of inferior industrial materials or the "skimping of measurements and workmanship." The obvious and important purpose is to prevent price ceilings from bulging upward badly under the strain of quality changes which are not directly covered in a price ticket. Chemical makers will have little to do with this new Division; but chemical engineers making other kinds of goods for which quality standards are a bit vague may need to set up programs of active cooperation. If the leaders in each industry do this promptly, they can prevent the occasional shyster from doing damage to a whole industry.

"NOT TOO FAST" production of a few chemicals is a suggestion from Washington worthy of note. Producers and distributors of industrial chemicals will know sooner than official Washington when they should slow down on output. Self-restraint, for industry inventory controls, will be wise. It is much easier to accomplish self-regulation in these matters than to be subjected to a multitude of official restrictions, quotas, allocations, and priorities. Many chemicals can escape from any need for official regulation if the producers are a bit thoughtful.

An American Source of Natural Resins for the Paint and Varnish Industry

ADRIAAN NAGELVOORT Chemical Engineer, Salt Lake City, Utah

———— Chem. & Met. INTERPRETATION ————

With this country's source of natural resins now cut off by the war and chemicals used in synthetic resins increasing in scarcity, the paint and varnish industry will be particularly interested to learn of the extensive deposits of fossil resins recently discovered in Utah. Development of these deposits, estimated to be sufficient for well over a century, may prove to be of major economic importance to the domestic protective coatings industry.   Herein the author, a prominent chemical engineer, describes the nature of these fossil resins and his processes of separation and purification.—Editors.

AMERICA'S SUPPLY of natural resins has been wholly dependent on foreign sources that are now cut off. The East Indies shipped us damar, pontianak, boea and loba. From the Phillipines we got manila, from New Zealand kauri, from Australia sandarac and accroides, from Africa sandarac, mastic and congo copal. In the trade these resins are usually designated as "gums" but this, of course, is a misnomer. They are true resins and are either of fossil origin or are tappings from standing trees.   They have one characteristic in common: all are used in making protective coatings, in oil varnishes, spirit varnishes or incorporated in paints, lacquers, inks or linoleums. Most highly prized are the fossil resins, since they make the best

Within this dotted area of Utah lie extensive deposits of resin-bearing coals

and most satisfactory surface coatings for most industrial purposes.

There has recently been discovered in certain of our western states a supply of fossil resins great enough to satisfy the entire domestic needs for the next hundred years or more. In origin, these deposits are similar to the imported fossil resins in that both are from prehistoric coniferous trees. Geologically, those of the United States are much older and hence, in some respects, are better for the paint and varnish industries.

UTAH RESIN DEPOSITS

Towards the end of Cretaceous time and before the beginning of the Tertiary period the western plains of the United States were covered with dense forests of conifers, the ancestors of our sequoias and pines. Such trees are prepared for a long life because of their effective means of protection, including waxes that cover their leaves and resins that protect their bark and wood. These waxes and resins probably represent nature's best chemistry in the making of protective coatings.

In Utah, especially, but also in the states of Colorado, New Mexico and Washington certain seams of the Cretaceous and early Tertiary coals contain the fossil remains of the resins and waxes of the conifers of those times. These coals are bituminous, but they are much younger than the bituminous deposits of the eastern seaboard and the middle west, which are of the carboniferous period or

about twice as old. Geologists estimate their age as between 30,000,000 and 80,000,000 years. That these resins have withstood for so long the corrosive action of ground waters that have at times been acid and alkaline as well as salty shows that nature's chemistry has been good. Indeed, it has been so good that the protective coatings have withstood the ravages of time better than the wood fibers they were meant to protect.

In the Utah coal field between Castlegate on the north and Salina canyon on the south, a distance of 70 miles as the crow flies, there are certain seams about 14 feet in thickness in which these resins constitute about five percent of the coal. The resins look like amber and vary in color from water-white through lemon yellow to deep, dark red. They occur in thin lenses from paper thin to one inch or more in thickness.

Two main problems had to be solved in order to prepare these resins for commercial use. The first was the technique of mineral separation: to recover the resin cleanly from the coal. The next was that of processing the recovered resins so that they could be used in the making of light-colored varnishes to meet the varnish makers' most severe tests.

RESIN-COAL SEPARATION

Usual mineral separation processes were tried on the resin-coal mixtures without any noteworthy success. Using water as a medium, jigs and tables did not give a good resin recovery and the product contained too much coal. Froth flotation, using pine oil or other frother, likewise gave a poor recovery and an inferior resin product. Better results were obtained in a flotation cell without the use of a frother but using instead a wetting agent for the coal. Air separation and electrostatic separation did not give satisfactory results. None of these methods allowed a clean separation of the resins from the coal or a separation of the waxes from the resins. This latter step is important to the varnish maker, who cannot tolerate any wax in his varnish.
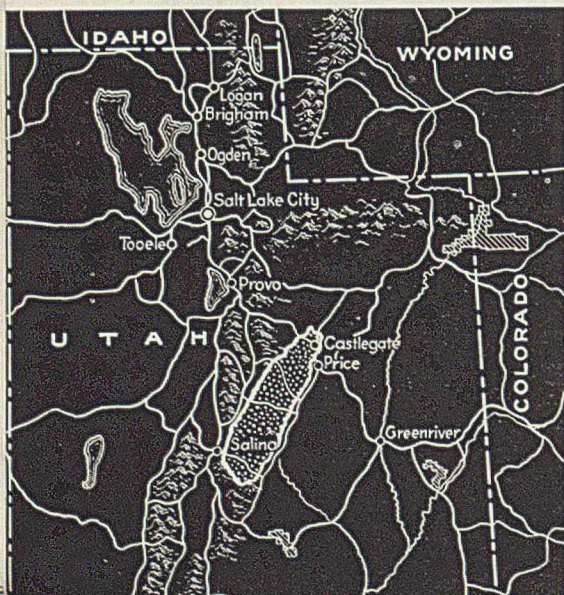
Table I—Certain Characteristics of Utah Natural Resins from Coal

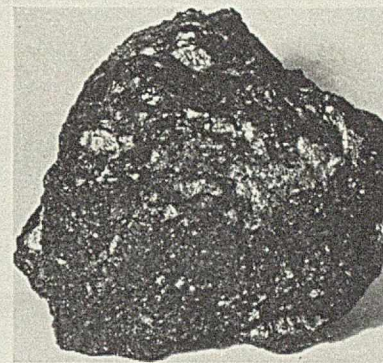| Melting point, crude | 165 deg. C. |
clarified # 1	250 deg. C.
clarified # 2	120 deg. C.
Acid number	6
Hardness	same as Congo
Soluble in:	Benzol, toluol, turpentine, xylol, naphtha, chlorinated hydrocarbons, linseed, soya, tung, castor oils.
Insoluble in:	Alcohol and unaffected by weak acids or alkalis.

A study of the physical characteristics of the coal, resin and wax showed the specific gravity of the coal to be 1.280, that of the resin to be 1.02-1.06, while that of the wax was less than 1.0.

Coal is not readily wetted by water nor by an aqueous salt solution, but it is wetted by water or a salt solution containing one part of tannic acid per million parts of water. Furthermore, neither the resins nor the waxes are wetted by solutions of such dilution. However, at a strength of one part of tannic acid per 100,-000 parts of water or salt solution the resins but not the waxes are wetted. Wax is the most difficult of all to wet. Utilizing these facts, a very simple sink-and-float process was devised by which these coal constituents could be separated.

To break apart mechanically the resins and wax from the coal, it is first necessary to crush the coal to pass a 10 mesh screen. Finer crushing is neither desirable nor advisable. Indeed, crushing the coal to pass a one inch screen is sufficient to release most of the resins and wax. This is due to the fact that on breaking, the coal parts along the resin seams which therefore, since it is more friable than the coal, is easily released. Coal so crushed is easy to market as a stoker product while pulverized coal is difficult to market. Besides, the resins are not too much pulverized for easy handling in the sink-and-float apparatus. By crushing only to one inch, about 85 percent of the resins are found to be in the sizes below 10 mesh.

Crushed coal is first screened over a 10-mesh screen. The oversize goes to market as such while the undersize is sent to the wetter, a device like a log washer or screw conveyor where it is wetted with a salt solution having a specific gravity of 1.10 and which contains one part of tannic acid per million parts of water. Only the minimum quantity of water is used, just enough to make a thin paste, since it has been found that coal is more readily wetted in this condition.

From the wetter, the coal paste flows with more of the salt solution to the sink-and-float tank, which is a V-shaped vessel or an invert-cone like a "callow" cone provided with means for drawing off the sunken coal and for overflowing the floating resins. The floated resins go to a mechanical filter while the barren coal is then sent to a filter bed of the type used in treating city water. Here the salt solution is recovered for reuse and the coal is washed to recover any adhering salt. The washed coal then goes to a dryer to be later used in making smokeless fuel or coke or for use as a pulverized fuel.
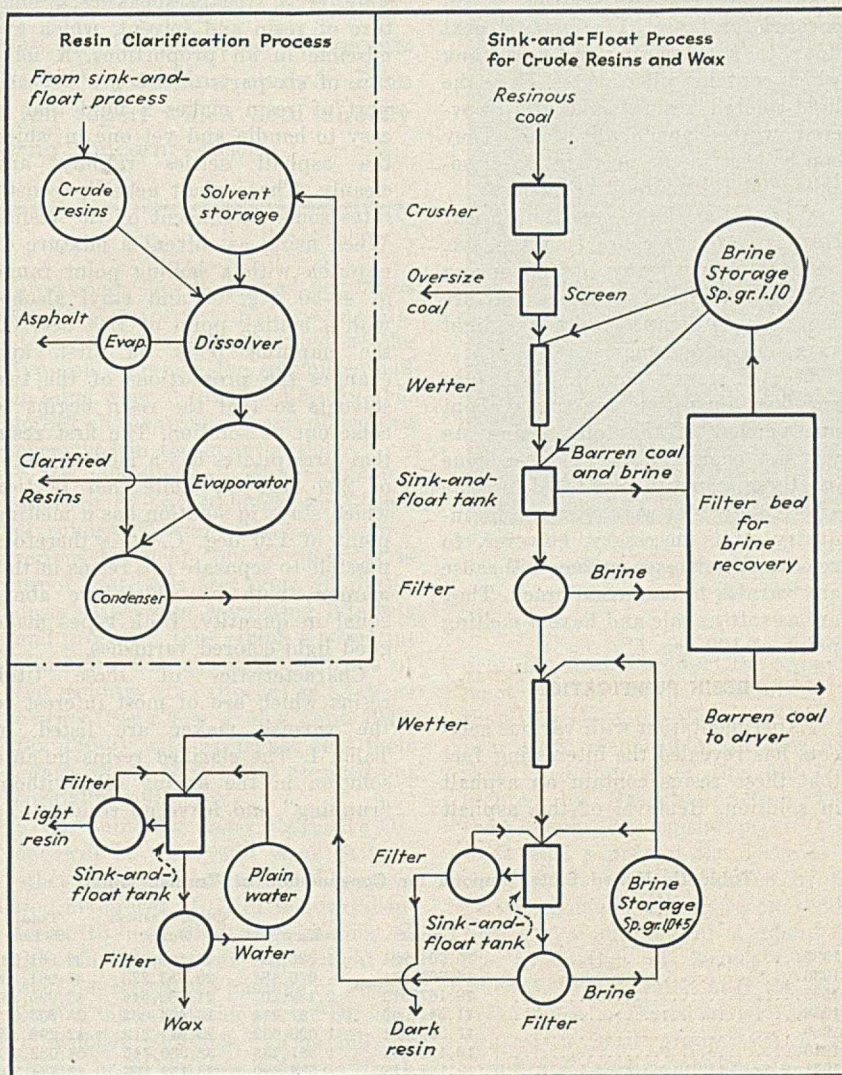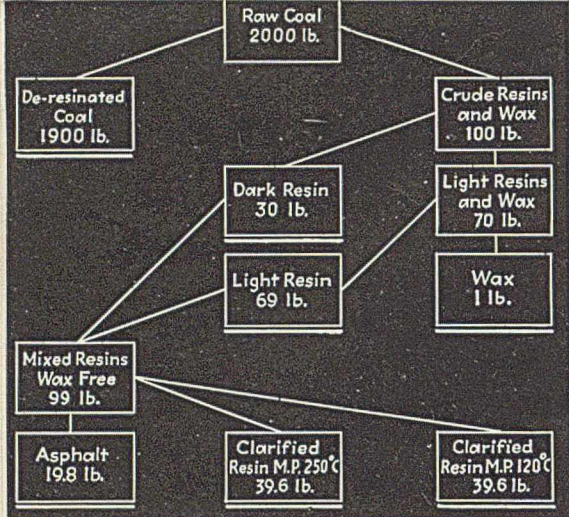
RESIN-WAX SEPARATION

The surface area of a sink-and-float tank determines its productive capacity. Such a vessel with a surface of 10 square feet has a capacity of 100 tons of coal per day or five tons of resin per day.

Floated resins, after filtering but still wet, go to a second wetter where they are treated with a salt solution having a specific gravity of 1.045 and which contains one part of tannic acid per 100,000 parts of solution. This will wet the resins but not the waxes. These then flow to a second sink-and-float tank where the heavier

Light areas in this piece of coal represent seams of friable fossil resins

Flow sheet of processes for obtaining varnish-grade resins from Utah coals

Raw Coal 2000 lb.

De-resinated Coal 1900 lb.

Crude Resins and Wax 100 lb.

Dark Resin 30 lb.

Light Resins and Wax 70 lb.

Light Resin 69 lb.

Wax 1 lb.

Mixed Resins Wax Free 99 lb.

Asphalt 19.8 lb.

Clarified Resin M.P. 250°C 39.6 lb.

Clarified Resin M.P. 120°C 39.6 lb.

Yields and products from Utah resinous coals, with marketable items underlined

resins sink and the lighter resins and waxes float. These heavier products are deep, dark red in color and constitute some 30 percent of the total resins. They are recovered, washed and dried and used where color is of no consequence to the final product.

The floated resin-and-wax mixture then goes to a second mechanical filter where the salt solution is recovered for reuse. The mixture next flows to a third sink-and-float tank which contains plain water. Here the light-colored resins sink, are recovered, washed and finally dried. They can be used in the preparation of so-called "dark colored" varnishes.

While the light resins appear clear and lemon-colored to the eye, on cooking with any of the drying oils they result in varnishes that are too dark to compete with the light varnishes of commerce.

Floated waxes from this last sink-and-float operation constitute about one percent of the total resins. As yet, not enough work has been done on these constituents to determine where they best can be used in industry. It is necessary, however, to remove these waxes as they will cause any varnish to craze and crack. They are as soft as talc and have a melting point of 100 deg. C.

RESIN PURIFICATION

Experimentation with various solvents has revealed the interesting fact that these resins contain an asphalt in solution. Removal of this asphalt

was the second part of the problem that had to be solved in order to make a product that could compete on even terms with the foreign resins. The Utah resins are soluble in benzol, toluol, xylol, naphtha, carbon bisulphide, the chlorinated hydrocarbons and the drying oils. However, they are not soluble in alcohol, acetone, the hydrocarbons of the paraffin series nor most of the other organic solvents. Asphalt is also soluble in these. Ether alone dissolves most of the resins without dissolving much asphalt.

A combination of solvents actually proved to be an effective means for separating the asphalt from the resins. A mixture of 60 percent naphtha and 40 percent alcohol dissolves the resins completely and precipitates the asphalt as a black, sticky mass that settles rapidly out of the solution. Recovery of the resins is then a matter of decanting off the clear resin solution and evaporating the solvent and recovering.

Since the resins are colloids, the solution is strictly speaking a mixture of resin and solvent, which are miscible in all proportions. A mixture of six parts of solvent for each part of resin makes a fluid that is easy to handle and yet one in which the asphalt settles rapidly and cleanly. The asphalt actually constitutes some 20 percent of the resins. When using as solvent a mixture of naphtha with a boiling point range of 40-60 deg. C. and ethyl alcohol with a boiling point of 78.4 deg. C., the naphtha boils off first and changes the proportions of the two solvents so that the resin begins to come out of solution. The first resin that precipitates has a melting point of 250 deg. C., while that portion which stays in solution has a melting point of 120 deg. C. It is therefore possible to separate two resins in this manner, both of which are about equal in quantity. Both types make good light-colored varnishes.

Characteristics of these Utah resins which are of most interest to the varnish maker are listed in Table I. The clarified resins go into solution in the drying oils without "running" and leave no residue.

A typical 25 gallon varnish made with dehydrated castor oil cooked for an hour and twenty minutes at 560 deg. F., thinned with mineral spirits, driers added in the proportion of 0.5 percent Pb and 0.01 percent Co dried to give a tough, high-gloss flexible film dust-free in two hours and tack-free in four hours.

POTENTIAL SUPPLY

Utah mines now produce about 90,000 tons of coal per week. The miners avoid the resin-bearing coals as much as possible as the consumers object to its speckled appearance and the excess soot it produces. However, about 14,000 tons or some 15 percent of the total coal actually mined is resin-bearing. With an average of five percent resin content, this represents about 100 tons of resin per day that goes up in smoke and soot to dirty our cities.

Experiments have shown that removal of the resin improves the coking quality of the coal. This opens a large field for the industrial use of these resinous coals. Salt Lake City consumes about 1,000 tons of fuel per day. If this were all of a smokeless grade it would represent about 2,000 tons of coal or 100 tons of resin per day that could be recovered from this tonnage. Other users of smokeless fuel or coke could easily bring the daily resin production up to several hundred tons, easily enough to take care of the entire requirements of the domestic paint and varnish industry. Table II shows United States imports for consumption of natural varnish-type resins during the past several years.

The State of Utah has been giving serious consideration to making an appropriation to provide for an initial plant for producing about five tons of resins per day. This plant will demonstrate the process and quality of the product, after which it is hoped that an appropriation from the Government will provide for a plant sufficient to take care of the present industrial needs of the country.

World War I exploded the idea that only Germany could make dyes and fine chemicals. This present war should free the United States of dependence on foreign sources for its supply of natural resins. Furthermore, the utilization of our own natural resins at this critical time would also release for more important war uses some of the glycerin, alcohol, phenol and other chemicals that are now being used in large quantities in making synthetic resins.

Table II—United States Imports for Consumption of Varnish Gums[1]

	Damar	Kauri	Other Varnish Gums	Total in Lb.
1935	15,004,904	1,386,821	20,569,307	36,961,032
1936	15,707,671	970,484	20,383,225	37,061,380
1937	18,167,512	2,139,207	24,788,544	45,095,263
1938	11,541,965	767,014	16,494,033	28,803,012
1939	17,334,581	1,020,632	23,941,313	42,296,526
1940	19,110,593	1,561,135	33,360,745	54,032,473
1941 (9 mos.)	19,138,415	533,690	23,152,196	42,824,301

[1]Division of Foreign Trade Statistics, U. S. Dept. of Commerce.

Baruch-Compton-Conant Report Challenges Us All

JOSEPH A. CONRY

Former Member of Congress and U. S. Minister to Russia, Washington, D. C.

─────── *Chem. & Met.* INTERPRETATION ───────

President Roosevelt and others have correctly appraised the report of the Rubber Committee as one of the most outstanding public documents of this war—a great service to the Nation in time of dire emergency. By clarifying in the public mind a maze of conflicting and complicated impressions, it clears the decks for national action— gasoline and rubber rationing, salvage and reclamation as a means of necessary conservation and, most important to chemical engineers the prompt acceleration of the synthetic program as the only hope for keeping the war rolling on rubber! Broader considerations of the report in relation to the public interest are reviewed here by a former member of the National Legislative and Diplomatic Services of this country whose long experience and disinterested viewpoints lend proper perspective to such a history-making study. Then follows selected excerpts from the full report which deal directly with problems of chemical engineering concern.—*Editors.*

O.E.M. photos by Palmer

Removing sheets of synthetic rubber from a vacuum dryer

IT is doubtful if any government report ever received such eager scrutiny as the Baruch-Compton-Conant report on the rubber situation. It was a prize essay in style, the joint composition of two scientists helped by a skilled executive, a trio eminent for knowledge and sage philosophy, capable of lifting criticism to a higher standard than any hitherto reached in public reports.

The daily papers gave it front-page space with heavy headlines in deepest black, marking the deadline of delays, incompetence and conflicting authority in certain branches of the service where imperfection thrived like weeds in an unkept garden.

The success of the report was manifest in the universal satisfaction shown on its publication. President Roosevelt set the style by applauding it as "Excellent" and declared his intention of adopting all of its recommendations so that it might be made operative without delay. He appointed a well-seasoned executive. Mr. William M. Jeffers, president of the Union Pacific Railroad System, to systematize rubber conservation and production, just as he had developed his great transportation system. Mr. Jeffers is generally accepted as the type of American the committee had in mind when it suggested a man able to lick all the problems and difficulties unearthed in the investigation.

Mr. Jeffers at once admitted he was innocent of any technical knowledge of rubber. To some this may mean a serious handicap, but to others it is proof that he is free from all prejudices as between competing interests and processes, thus giving a warm invitation to the chemical engineers of the country to appear as *Amicus Curiae* (See *Chem. & Met.* Sept. 1942, pp. 186-9) with assurance that their advice would be not only received but cordially welcomed.

His authority under Executive Order will be so crystal clear that no other agency will be tempted to question his power. It is of incidental interest to note that the creation of this office was what was sought by the Congress in the passage of Senate 2600, a bill to provide for a "Director of Rubber Su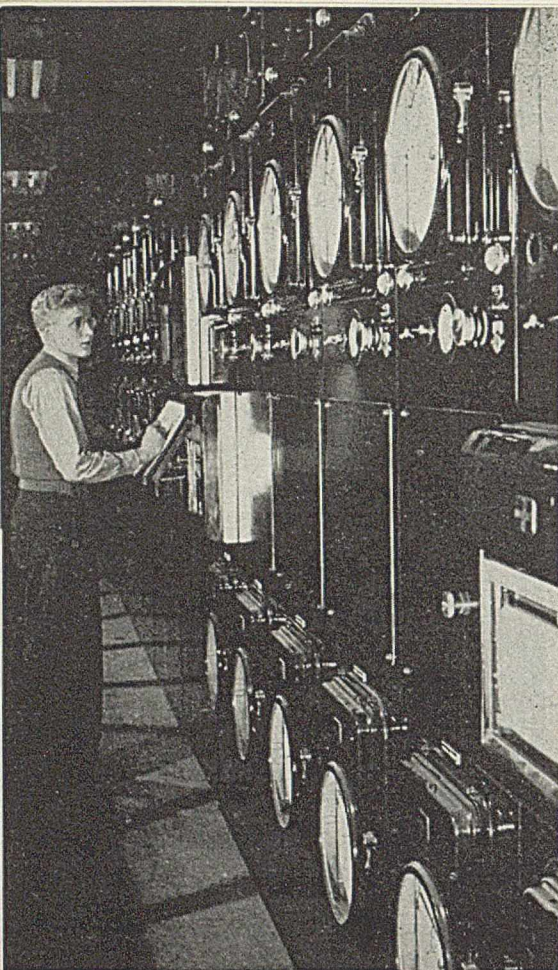pplies." This bill, of course, brought a veto from the President, but it also brought the appointment of the Baruch-Committee so that, in a sense, the Western Senators who were responsible for the passage by Congress of this bill have secured by Executive action what they sought by legislation.

At least a part of the demands of the farmers were recognized by the Baruch Committee in its recommendation for a building of a plant for the production of 30,000 tons of Buna-S, to be located near the grain area, to be "operated under the control of a local group." Also the significant recommendation was made

Control instruments in polymerization tanks maintain proper temperature

the financial strength and it is significant that the report recommended that the funds required for the entire rubber program be put directly at the disposal of the Rubber Administrator instead of indirectly through the Reconstruction Finance Corporation.

Analyzing this now famous report, one is impressed with the fact that while criticism ran free, fierce and furious, at no place in the report does evidence appear of an approach to personalities.

Failure to take advantage of the alleged Russian offer to provide reports of Soviet efforts and success in producing synthetic rubber has not yet been explained. If Mr. Baruch were unable to get the reason, there is only one man in Washington able to ferret out the true story. He is the President. To him alone is responsible the Secretary of State who controls all the secrets of our foreign relations. Perhaps the offer might have been a bi-lateral one intimating certain considerations not at all feasible at this time.

Mr. Jeffers is urged to go ahead without delay on the present program for the production of synthetic rubber under those processes known to be sound. He is to have "an adequate technical staff under his immediate supervision" and he must not wait for perfection.

He has been told a weapon on the battlefield is better than on a blueprint, as he well knows that a locomotive on the rails is worth a dozen in the repair shop. So with the blessings of the Committee, he is told to produce during the year 1943, 400,000 lb. of Buna S, 30,000 tons of neoprene, 62,000 tons of butyl rubber, and 24,000 tons of Thiokol. If he carries out this program, he will lift a great burden of worry from the American people.

The Synthetic Rubber Program

Excerpts from the Baruch-Compton-Conant Report as transmitted to Congress by the President of the United States September 10, 1942.

that facilities for production of 100,-000,000 gal. of alcohol be erected on sites near the grain-producing area and accessible to water transportation.

No delay is to be permitted for the immediate operation of the plants for synthetic rubber from petroleum. Thus both of the great interests involved are assured of sympathetic advice in working out their problems. The committee suggested and it is certain that chemical engineers and other competent technical men will be at hand for the assistance of the director with only one thought animating their action, to produce rubber.

Mr. Jeffers has before him the formula of re-creating our industrial system with full knowledge of the value of a free and unbiased professional body of advisors. He is to be the catalytic power of the Baruch report. Competent men will supplant "good fellows." Should some smaller person vain of his political pull impinge on the work of the boss his vanity will be sadly bruised or even destroyed. There is only one way to run a ship, the captain must be in command.

Having the authority, he must have

SUMMARY: To safeguard the military situation in the critical year of 1943 against the possible delays in synthetic rubber production, or failure to secure crude rubber imports or further expansion of requirements dictated by enemy actions or new strategy; also to provide the additional rubber needed to maintain the civilian automobile use considered absolutely essential; the Committee recommends (1) that there be no further substitution in the plans for the synthetic program now laid down; (2) immediate authorization of an additional 140,000 tons of Buna-S capacity per year; (3) the immediate institution of a refinery conversion program to yield a total of 100,000 tons of butadiene in addition to that now planned; (4) the immediate adjustment in the rates of construction of present styrene and polymerization plants in order to obtain the maximum production of Buna S in 1943; (5) the construction of an additional plant for the production of 20,000 tons of neoprene per year; (6) the erection of a 27,000-ton butadiene plant from grain and an associated polymerization plant to production 30,-000 tons of Buna S, both to be located near the center of grain production; the construction to be started six months hence unless the Rubber Administrator determines otherwise; the process to be employed to be determined in the light of the information then available; (7) the immediate erection of alcohol plants to produce 100,000 gal. per year, using recently developed apparatus; the plants to be erected on sites near the grain-producing states and located on water transportation.

PRESENT STATUS

The present plans for the production of synthetic rubber as outlined to us by the governmental agencies concerned called for the erection of the following types of plants in the United States; (a) for the production of neoprene, eventual capacity 40,000 tons per year (in addition to a 9,000-ton plant now in operation by a private company); (b) for the production of butyl rubber to yield 132,000 tons per year; (c) for an over-all production of 705,000 tons of Buna S. This production of Buna S involves construction in terms of plants for producing styrene and butadiene and for the co-polymerization of butadiene and styrene with the formation of Buna S.

For the manufacture of butadiene the following processes are scheduled: (all figures expressed in the long-ton equivalent of Buna S).

1. from alcohol by the Carbide and Carbon Chemical process, rated capacity ....242,000 tons
2. from butane (in natural gas) by a process developed by the Phillips Petroleum Co.......... 50,000 tons
3. from butane by the Houdry process .... 16,500 tons

4. from butylene (obtained by the cracking of petroleum) by a process developed by Standard Oil Co. of New Jersey............283,000 tons
5. by the cracking at high temperatures of gas and heavy oils (the so-called thermal or refinery conversion process) .... 20,000 tons
6. by combination of (4) and (5) in one locality............ 93,500 tons

The Committee has examined the present status of the Government's schedules and estimates that *if the construction program can be met on the dates specified* there will be produced during 1943: 400,000 tons of Buna S; 30,000 tons of neoprene (in part from private sources). We believe that these processes will ultimately work on a large scale and yield satisfactory products.

Furthermore, our experts estimate that the time required to get the various plants running smoothly under actual operating conditions will not be so lengthy as to cause serious delay. On the other hand it must be remembered that we are dealing here with a new industry and that in the production of Buna S three separate manufacturing operations are concerned, no one of which has been carried out as yet on anything approaching the present contemplated scale.

Therefore, until more experience has been gained by the operation of one of the large-scale units at each step, we must consider that a considerable element of risk is present in the picture. The importance of completing rapidly one full-scale plant using each process and the erection of pilot plants is considered in the technical section of this report.

The Committee wishes to emphasize once again at this point that the whole question of obtaining synthetic rubbers in adequate amounts in 1943 hinges on the rate of construction of the manufacturing plants. Unless the present situation involving the assigning of priorities and allocating of materials is improved, there is grave danger that there will be serious delays in the completion of the plants and consequent reduction in the amount of synthetic materials produced. Furthermore, unless the administrative changes recommended in a later section of this report are put in to effect, conflicting governmental plans with respect to the oil industry may seriously jeopardize the production of butadiene.

OTHER PROCESSES

We have also examined with the aid of our experts many other processes for the production of butadiene and synthetic rubber. We find that quite apart from their merits or demerits, no one of them could now be substituted in the present program with hope of accelerating the production of Buna S in the critical year 1943.

We would be blind if we did not see the efforts now in progress on the part of many companies to have a part in the development of a large new industry with vast post-war possibilities. This has been accentuated in the minds of the petroleum producers, by gasoline rationing with its attendant loss of sales. They are thus forced to turn to other products including butadiene. Furthermore, we are not unaware that it is inevitable that once the war is over there will be a struggle amongst various groups for the control of this new industry. But all such considerations cannot affect this Committee as to its conclusions. We are concerned only with the production of the largest amount of rubber in the minimum amount of time in order to carry the country successfully through the war. It is our firm conclusion that present processes for manufacturing synthetic rubber and the raw materials required (butadiene and styrene) must not at this late date be changed unless new processes can be shown beyond peradventure to have such advantages over those now employed that more rubber would be obtained in the ensuing months than would otherwise be the case. We have found no such process in the course of our investigations.

The Committee finds that there has been considerable discussion between two groups within the oil industry as to whether or not there was a serious conflict between the butadiene program based on butylene and the high octane aviation gasoline program. With the aid of our experts we have examined carefully into this problem and consulted many technologists in various oil companies as well as discussing the matter with the officials of the Office of Petroleum Coordinator. It is our conclusion that, while the possibility of a conflict between the two programs does exist, it need not become serious if the possibility is recognized and if the administration of these two closely related enterprises is properly integrated.

The necessity for the administrative changes along these lines which are recommended elsewhere in this report is further demonstrated by the uncertainty of the stated aviation requirements both in quantity and quality. The evidence clearly indicates that if the present demands for high octane aviation gasoline and butadiene stay where they now are, there need be no conflict.

If and when the armed services should decide that such larger quanties of high octane aviation gasoline are needed, there are ways by which this demand can be met by the industry without diminishing the flow of butylene to the butadiene plants.

It is fortunate that the program for the needed plants is generally in the hands of as competent engineers as there are in the country. Probably the most interesting and satisfying part of our study is the confidence we have acquired in the men from industry who

have the plans in hand and who are satisfied they can lick the problem in the given time. Their competence and experience, their resourcefulness and ingenuity are the best guarantees we have that they can do so. We have been much impressed with the fact that this stupendous undertaking is only possible because of the highly developed skill of our technologists. No one could have examined the facts before us without appreciating the magnitude and scope of the task; no one could have made this study without realizing that because of the short-sightedness and failure to act on technically sound advice we must now proceed with insufficient experience. We venture the statement that never on the basis of so little has so much been involved. Under these uncertainties the only recourse is to provide ample margins when in doubt.

THE PROBLEM OF 1943

The year 1943 is so critical for the rubber situation that the production of 100,000 tons more or less of Buna S might be a determining factor in the success of our military program. In view of the extremely precarious situation in 1943 the Committee recommends the prompt increase of 100,000 tons a year of butadiene over the present schedule, to be obtained by a refinery conversion program. This can be accomplished with a very small expenditure of critical materials. This recommendation is designed to accomplish three ends: (1) fill the gap between butadiene production and polymerization capacity in the early part of 1943 (for the minimum polymerization capacity exceeds that for butadiene production and according to present schedule the two will not come together until the middle of 1943); (2)

Polymerization tanks where raw materials of synthetic rubber are converted into latex
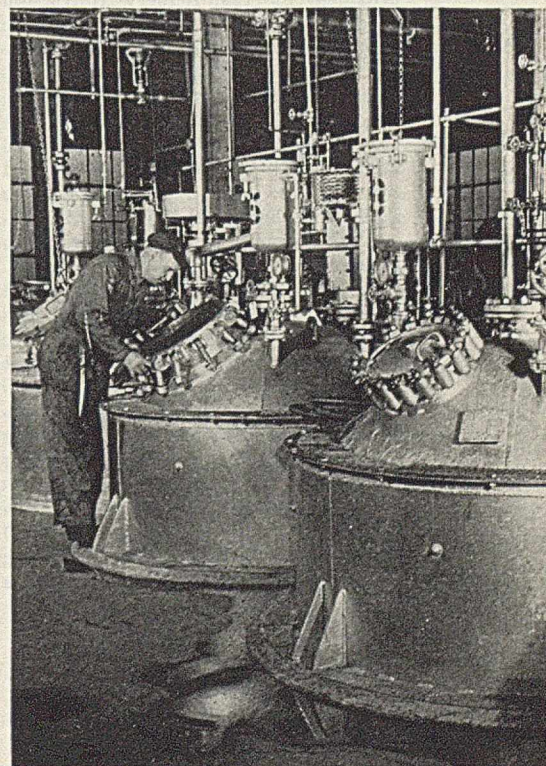
provide a reserve of stand-by capacity for the later years of the program; (3) furnish valuable insurance against contingencies affecting other plants in the program and provide additional facilities to meet possible increased demands of the armed services.

Due to the pressure from various sources there have been, even in very recent days, belated efforts to change from the present butadiene plants scheduled by the government to the refinery conversion processes. The first thought that occurs to the Committee is, "Why now? Why not months ago? Why the sudden activity? And, above all, why substitute at this late date?" We have recommended an *increase, not a substitution,* of a refinery conversion program. We have made this recommendation, in order to produce more rubber during the critical year 1943. We should like to emphasize again that it would be a major blunder to make a further change inside the program at this date by the substitution of one process for another.

To obtain the maximum utilization of the combined refinery conversion program, we recommend a prompt increase in the rate of construction of polymerization facilities and of the styrene plants to balance the program upwards so that the maximum possible amount of Buna S might be produced in 1943. If this expectation and the optimistic estimates of the present schedule are realized, the Buna S produced in 1943 might be as much as 450,000 tons. Even this amount will not provide too large a margin of safety when it is recalled that our "carryover" to 1944, assuming only a 400,000 ton Buna-S production, does not exceed 100,000 tons.

LOOKING AHEAD TO 1944

The present plans call for the building of polymerization plants with a rated output of 705,000 tons of Buna S. If the 100,000 short tons of butadiene (equivalent to 110,000 tons of Buna S) provided by the refinery conversion program are to be utilized when the program is complete, additional facilities for polymerization must be provided and likewise for the manufacture of styrene. While there is evidence that the butadiene plants may produce 15 percent to 20 percent above their rated capacity our experts have found no indication that a similar situation exists with respect to the polymerization plants.

The WPB has fixed the total annual output of Buna S at 705,000 tons. The Committee recommends that this figure be raised now by 140,000 tons, and that this be accomplished by authorizing (a) the construction of the additional polymerization facilities and styrene capacity, to be ready by Jan. 1, 1944, which are required to balance upwards the annual production of the refinery conversion program (110,000 tons of Buna S); and (b) the later construction of a 27,000 ton butadiene

plant and a 30,000 ton polymerization plant to be located near the center of grain production. The Committee recommends that the Rubber Administrator, about six months hence in the light of the situation which exists regarding the best technical process then proven for the production of butadiene from grain, and in the light of the need for additional Buna S which may then be estimated, proceed with the erection of the 27,000 ton butadiene plant from grain and the associated polymerization plant. He should also make whatever arrangements are necessary to produce and ship the necessary styrene from the centers of styrene production. If the needs for synthetic rubber and the production program are in balance, making due allowances for civilian driving, he may then cancel the erection of this additional 30,000 tons of Buna-S capacity.

The Secretary of Agriculture has assured the Committee that no concern need be felt that the expansion of the butadiene from grain program will interfere with our food supplies. After all food requirements that can be anticipated have been met there will be upwards of 1,250,000,000 bushels of wheat left in this country.

This additional Buna S, which it will be thus possible to produce in 1944, should provide the margin required for relaxing the restrictions on civilian driving. As we have pointed out earlier in this report, if by the end of 1943 the synthetic rubber manufacture is in satisfactory shape and the military needs for rubber have not increased, it should be possible to allocate considerable quantities of Buna S for civilian needs. We shall not need the 140,000 extra tons of Buna S until 1944, when it will be required for tires for passenger cars. Without at least half this amount in that year, a great many passenger cars would be forced off the road; for it is at that time that we shall have to begin to repay the rubber which we have been borrowing so to speak, by running our cars without a tire replacement and recapping program during the past eight months.

EXTRA POLYMERIZATION FACILITIES

By delaying the construction of the extra polymerization facilities for six months we shall in all probability prevent a serious conflict between this eventual expansion of the Buna-S program and other aspects of the war program. There is every reason to believe that the shortage of critical materials will be less acute six to eight months from now, and this will certainly be true in regard to facilities for fabricating special chemical equipment.

Our recommendation for additional 27,000 tons of butadiene capacity to be located near the center of grain production is made with this time schedule in mind. This plant (together with the corresponding 30,000 ton Buna-S plant) need not be started for another six

months. There will be relatively little cost to the war effort involved in its construction for the reasons just given in regard to the easing of the situation in respect to the fabrication of equipment. Furthermore, another advantage will accrue. At that time—six months hence—it will be possible to judge the relative merits of two processes for the manufacture of butadiene from grain which are not now in the Government program, namely, the Publicker process using alcohol and that employing butylene glycol developed by the Department of Agriculture in Peoria. This latter method involves a special fermentation of grain. These two processes should be carefully compared with the alcohol process developed by the Carbide and Carbon Chemical Corp., and now a major part of the government's plans. At present insufficient data are at hand for an evaluation. A few months from now this will no longer be the case.

ALCOHOL FROM GRAIN

It is clear to the Committee that new facilities for producing alcohol from grain must be provided. More alcohol may be required for the production of butadiene in plants under construction, if not, the extra capacity will be useful in the explosives program. The estimates we have obtained from the most reliable sources vary, but in all likelihood a considerable quantity of additional alcohol must be on hand in 1943 and 1944 to meet both the synthetic rubber and the explosives program. We recommend that these facilities be erected on a site near the grain producing states and located on water transportation. By the use of recently developed apparatus, alcohol plants can be constructed with little expenditure of critical materials.

If the Rubber Administrator should decide that the plants for the production of the additional 30,000 tons of Buna S which we recommend should be constructed during late 1943, they should be located near the center of grain production and such units should if possible be operated under the control of an independent local group. Diversification of the synthetic rubber industry both from the point of view of geography and control seems important to the Committee. Another element in the competition would be provided if this recommendation is carried out.

We may sum up our recommendations in respect to the Buna-S program as follows:

(1) There should be no further changes in the plans now laid for the construction of the scheduled plants—the time to freeze has passed in view of the urgency of 1943.

(2) The authorization of an additional 140,000 tons of Buna-S capacity per year.

(3) Proceed immediately with a conversion of refinery plants to pro-

duce a total of 100,000 tons of butadiene by this process, this being in addition to the butadiene now planned from other processes in the present program.

(4) Promptly make an adjustment in the construction rates of the present styrene and polymerization plants, in order that the maximum amount of Buna S may be produced in 1943.

(5) Expand the polymerization and styrene facilities to be ready on Jan. 1, 1944, to balance upwards the entire program.

(6) About six months hence, in the light of the situation which then exists regarding the best technical processes then proven for the production of butadiene from grain, and in the light of the need for additional Buna S rubber which may then be estimated, proceed as indicated with the erection of a plant to produce an additional 27,-000 tons of butadiene from grain through alcohol or butylene glycol and with the erection of an associated additional polymerization plant to produce 30,000 tons of Buna S, both to be located near the center of grain production. Also make whatever arrangements are necessary to produce and ship the necessary styrene from the centers of styrene production.

(7) Proceed promptly with the erection of an alcohol plant to produce 100,000,000 gal. of alcohol per year, by the use of recently developed apparatus. This plant could be erected on a site near the grain producing states and located on water transportation.

Finally, as a further margin of safety, considered only from the point of view of filling military needs, *we recommend the construction of an additional plant for the production of neoprene to the extent of 20,000 tons a year capacity. We make this recommendation because* neoprene is the one synthetic material of a quality to be the full equivalent of natural rubber for combat and heavy duty tires, either by itself or in combination with Buna S.

MATERIALS OF CONSTRUCTION

The relatively high cost of this substance in terms of critical materials required for the construction of the plant and electric power need is offset by its special significance in the rubber program. As an insurance against the distant possibility that we may be cut off from all supplies of natural rubber, we feel that the expenditure involved to provide an additional margin of safety is not too great.

Four large rubber companies already have developed their own polymerization facilties, each one differing somewhat from the others. Each represents the best efforts of a separate group of keen technical men. Last May, Rubber Reserve decided to standardize all the new polymerization plants which were to be constructed; this means, in essence, also standardizing the operation.

The design that is now ready is a compromise of the ideas of four separate technical groups. It may or may not incorporate the best ideas of each; on this point grave doubts have been expressed to the Committee. At all events, no one has ever operated such a standardized plant. The need for the immediate construction of one such standard plant so that experience with its operation can be obtained at the earliest moment is evident. It is our recommendation, therefore, that one of the standard plants now on the schedule be rushed to completion as quickly as possible.

OPERATION OF POLYMERIZATION PLANTS

The recognition of the importance of technological competition leads us to make two recommendations in regard to the operation of the polymerization plants:

First, one or more corporations controlled by the smaller rubber companies and chemical companies interested in polymerization should operate a certain number of these standard plants.

Second, at the same time, to keep the competitive urge to improve the new art of polymerization, we recommend that as part of the program each of the four large rubber companies be allowed to expand their facilities according to *their own design*, if they so prefer. We feel sure that the pride of authorship, as strong among technical men as among artists, under these conditions will yield in a short time a rich harvest to the Nation. Adoption of this second recommendation would not retard the program, for the expansion should be provided in that portion of the program we have recommended which requires additional polymerization facilties to be ready about Jan. 1, 1944, to balance the refinery conversion program.

The Nation as a whole is endeavoring to provide for the development of essentially novel manufacturing operations on a vast scale. How this program is managed and the spirit in which it is carried forward seem to us of great significance. Unlike the production of ammunition, the enterprise has implications for the postwar period. For a double reason, therefore, the Nation is concerned lest special groups play too large a part in the construction and operation. For the rapid development of the new art this Committee is fearful lest the influence of governmental policy serve to discourage the beneficial rivalries of the best brains in industry. We believe, therefore, that on the one hand there should be complete interchange of information and, on the other, as much competition in research, development and operation as possible. Such, after all, are the conditions applying in the field of laboratory science

where during the last hundred years tremendous strides have been made. Competition and cooperation in this new national effort we believe, should go hand in hand.

In concluding this section of the report which deals with the synthetic program, the Committee wishes to make special mention of the fact that there are a number of materials in the offing which give promise of considerable significance in the future development of rubber substitutes.

In particular, flexon, which is very similar to butyl rubber, is now undergoing careful tests to determine its utility in the manufacture of tires and as a recapping material. Flexon has an advantage over butyl rubber, in that it can be made more quickly and the plant involved does not require any large amount of critical materials.

The production would be limited, however, by the amount of solid carbon dioxide (dry ice) that would be available. The process is a wasteful one from the point of view of isobutylene, a raw material which is also of great value to the aviation gasoline program. As the tests of flexon stand today, the Committee does not feel that it can recommend the inclusion of any large production in the present program. However, in the course of a relatively short time the art of manufacture may be improved and one of the chief present drawbacks, namely, the lack of uniformity in different samples, may be overcome. If later tests prove the usefulness of this substance, its production then could be undertaken in considerable quantities.

OTHER RUBBER SUBSTITUTES

Another rubber substitute which we are not recommending in our program but which is nevertheless in an interesting state of development is the material known as "noropol", prepared by a series of chemical reactions from soya bean oil. The process of manufacture seems entirely feasible, but the tests have not yet gone far enough to demonstrate the worth of the material in the manufacture of tires or recaps. It will undoubtedly have value as a substitute for rubber in certain mechanical goods.

Several other developments of a similar nature have been called to the Committee's attention, but all are as yet in the laboratory stage. The Committee hopes that experimentation will continue and facilities be provided so that these new substances which show real promise may be tested thoroughly and eventually find their proper place in the national economy. Necessity requires the country to stop tampering with the present synthetic rubber program in order to produce the maximum amount of usable material in the coming year. It would nevertheless be most unfortunate if this situation should prevent the development of other materials or new methods of manufacture.

Saving Drafting Time With "Dizzy Diagrammatics"

H. E. PILKINGTON *Engineering Design Division, E. I. duPont de Nemours & Co., Wilmington, Del.*

―――――― *Chem. & Met.* INTERPRETATION ――――――

This, in the recollection of *Chem. & Met's* staff, is the first paper on the mechanics of drafting ever published in this magazine. As such it had to have a special significance to the chemical industry. Our author's "Dizzy Diagrammatics" is nowhere nearly as dizzy as the name suggests, nor as a first glance at a drawing so produced would indicate. The first glance may be startling, but once the engineer has tried out the system for himself, he will begin to see how its use can save some 30 percent of drafting time on a complete plant lay-out design, and still gain results in clear portrayal that are impossible with conventional drafting methods.—*Editors.*

"DIZZY DIAGRAMMATICS" is a simplified method of plant lay-out design which I, and those under my supervision, have been using quite successfully for the past few years. It is a diagrammatic arrangement showing clearly and specifying completely each piece of equipment, valve, fitting, control, and so on. Each piece of equipment, run of pipe, etc., is shown in its true relative position although in some cases the run of pipe is foreshortened or lengthened to avoid unnecessary confusion.

Considerable opposition and criticism of this type of drawing arose before it was officially accepted. Prior to its development our usual design procedure had been a mechanical arrangement drawing, locating and specifying each piece of equipment. This mechanical arrangement drawing actually consisted of three separate tracings, each 30x42 in., including one sheet of plans, one of elevations, and one of sections. Approximately 60 man-hours of work was required for each. In addition, these drawings were traced over, the equipment shown in light lines and the piping, valves, controls, etc., drawn in and specified. These tracings each required another 50 man-hours.

We found that it was possible to save 100 man-hours on each contract (each such set of drawings) by using the new diagrammatic arrangement in place of the three piping drawings, and by adding the larger and more important piping to the me-

chanical arrangement and naming but not specifying this equipment. Not enough was added to the me-

chanical arrangement to make it confusing. Needless to say, this large time saving overcame all opposition to the method.

During the last three years when millions of dollars worth of defense work has been designed, the economy of this type of drawing has been definitely proven. No time study has been made of these defense contracts but I venture the opinion that the savings have been several thousand dollars. The saving in time alone has been great enough to warrant the adoption of this method by engineering concerns.

Our engineering design division is not the only department which benefits from this type of drawing. The young men and women in the pro-

Fig. 1—Illustrating the principle of "Dizzy Diagrammatics," by comparing the mechanical arrangement with the diagrammatic method
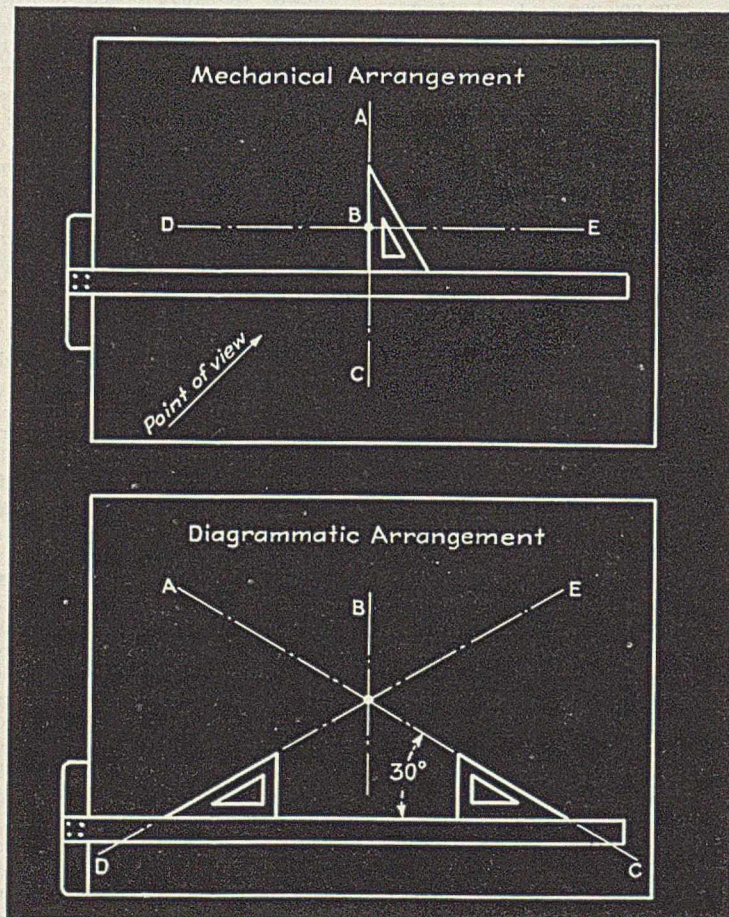
curement department, several of whom cannot read complicated piping drawings, have found these diagrammatic arrangement drawings a wonderful help. To them this type of drawing is a complete bill-of-material from which they can easily pick each item to be ordered.

Then, in the field, the construction superintendent uses this diagrammatic as a construction manual. From it he can readily point out to his foremen and mechanics the various runs of pipe, fittings, valves and controls. It gives the mechanic who cannot read blueprints a complete photographic picture of the plant as a whole, enabling him to work more intelligently at his own particular job.

Finally, the operating manager, handicapped as he often is at present by inexperienced operators, uses this diagrammatic as a flowsheet, by coloring each pipe line, valve and control shown on the blueprint with a distinctive color, and adding a color key. The print, thus colored, can be pasted on the wall of the operating room where an inexperienced operator can readily trace the different pipe lines and locate the control valves. This has saved many an expensive shut-down.
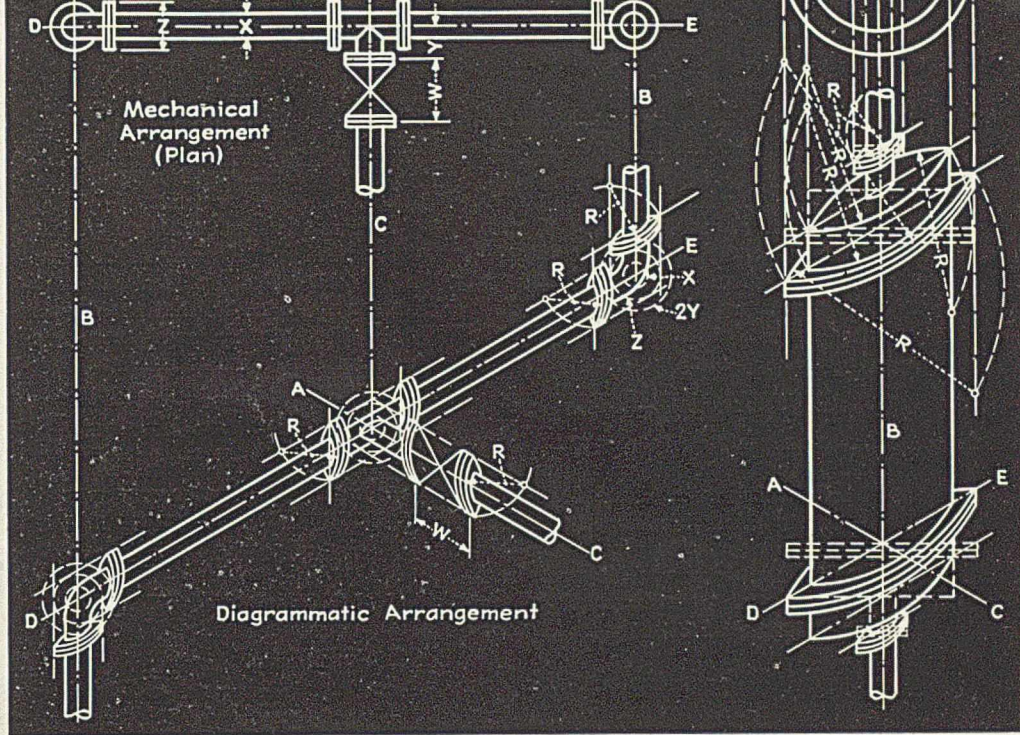

Fig. 2—Diagrammatic method applied to drawing of a simple pipe layout

Fig. 3—Cylindrical vessel is drawn by tracing over an elevation view

The several drawings reproduced here will give a general idea of the diagrammatic as well as the method I have developed to expedite this type of drafting. Diagrammatics resemble isometrics although they do not involve all the laborious and tedious projection. They are much easier to read and are as accurate and more complete for their purpose. When the few fundamental principles are better understood by the average draftsman I believe the system will be more commonly used and will re-

Fig. 4—The vessels are drawn as in Fig. 3, but the pipes are lengthened proportionately to spread the equipment

Fig. 5—Portion of an actual diagrammatic which cannot be shown in full, but illustrates clarity of the method
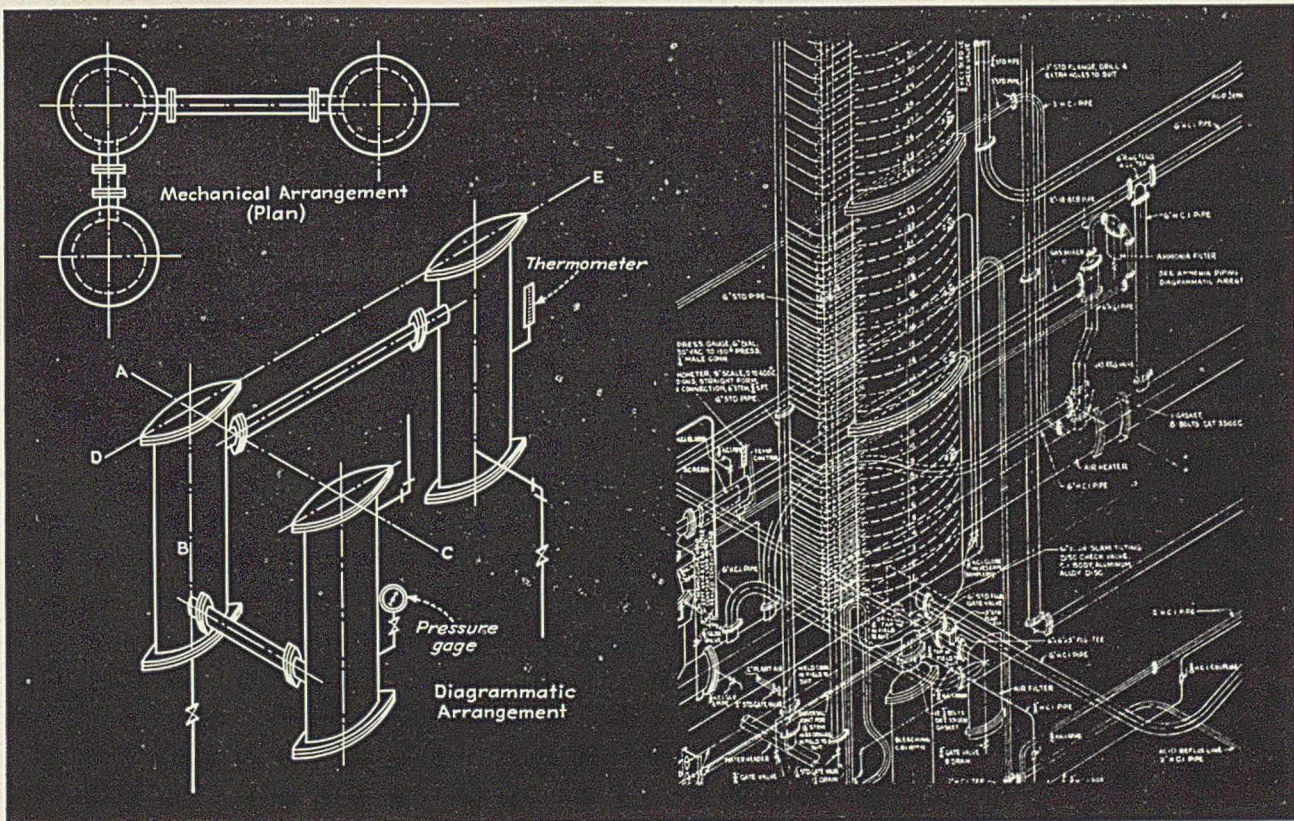
sult in a considerable saving of time and a relative increase in engineering production.

The basic principle of this method is illustrated in Fig. 1. The point of view is optional and may be from the lower left hand or right hand side of the mechanical arrangement. The lower left hand has been found to be the most satisfactory and is used in the following description. In Fig. 1. Point B represents any vertical riser or center line on the mechanical arrangement. Line AC is any line running from the top of the drawing to the bottom, and line DE, any line running from left to right. The corresponding lines are indicated on the diagrammatic arrangement and are at an angle of 30 deg. to the horizontal.

How to apply this principle and the system used for rapid drawing of the diagrammatics are illustrated in Fig. 2. Here the circle 2Y is drawn with a radius equal to the dimension Y, the center-to-face of fittings. This circle may have to be increased at times to avoid interferences of flanges. Circle Z is drawn equal to the diameter of the flange of the fitting or apparatus. Circle X has as its diameter that of the pipe or apparatus. Parallel lines are drawn tangent to these circles as shown by the dashed lines and are used as construction lines for the diagrammatic, later to be erased from the finished tracing. Radius R is the projected diameter of the flanges. All center lines are identified as in Fig. 1.

A mechanical arrangement drawn to a scale of $\frac{1}{2}$ in. to the foot is the most satisfactory size from which to reproduce the diagrammatic. Dummies of the equipment can be cut from a print of the elevations or sections and pasted on a piece of drawing paper in a position which corresponds to their respective locations on the mechanical arrangement. These dummies should be located in such a way that each piece of equipment will be shown clearly. In some cases this will mean increasing the center to center distance of the equipment along lines AC or DE. For example, Fig. 4 shows how the equipment may be spread to portray each piece plainly and yet retain its relative position.

In Fig. 3 is shown the method of transferring the dummies from the mechanical to the projected view of the diagrammatic. The light dashed lines would not be used in an actual drawing but here represent the dummy visible through the tracing. The projected diagrammatic itself is shown in heavy lines. It will be obvious that the principles are the same as those described for Fig. 2. The letters are also the same.

A general idea of what may be accomplished by this system of drawing is suggested by Fig. 5. Unfortunately the secret nature of this work prevents the reproduction of the full 30x42 in. diagrammatic arrangement of this complete plant.

No attempt should be made to project such items as gages and thermometers, which can be shown as in Fig. 4. This figure also shows how pipe, valves and fittings under 2 in. can be drawn as a single line. The quickest way to acquire facility in this method is to use it. The draftsman will, of course, develop habits and variations of his own which will increase his versatility and his ability to accomplish more with this time-saving system.

Heat Balance Equations for Multiple-Effect Evaporators

M. G. LARIAN

Department of Chemical and Metallurgical Engineering
Michigan State College, East Lansing, Mich.

────────── Chem. & Met. INTERPRETATION──────────

In calculating the heat transfer area required for a particular multiple-effect evaporator installation, it is necessary to know the heat balance equation applying to the installation. Several cases are possible, and different equations result when the method of feeding the evaporator, and the feed temperature, are varied. In books which describe the derivation of the equations, the method is fairly complex, while in other books the equations may be omitted entirely, or the derivations may not be given. The article below shows a simplified method of setting up these equations.—*Editors.*

IN MULTIPLE-EFFECT evaporator design calculations, the most important quantity to be calculated is the heat transfer area. The heat transfer area is calculated by the simultaneous solution of three equations: (1) The heat balance equation, (2) the heat transfer rate equation, and (3) the capacity equation.

The heat balance equation to be used depends upon the method of feeding the evaporator, and upon the temperature of the dilute feed. There are four different methods of feeding, and the dilute feed may enter the evaporator at a temperature which may, or may not, require preheating in the effect which it enters. In the latter case, the feed may, or may not, flash. There are, therefore, several combinations of conditions possible. The heat balance equations for all these cases are given below. They are based upon the assumption that the radiation losses are negligible. The correction for the radiation losses is made after the heat transfer area calculations are completed.

Evaporators may be fed in the direction of decreasing pressure drop, with the new feed entering the first effect and passing thence to the second, third and later effects, if any. This is known as forward feeding. Or the feed may first enter the last effect, in which the pressure is lowest, and flow forward through each earlier effect to the first, which is known as backward feeding. Mixed feeding is the procedure where the new feed enters some other effect than the first or last. There are various methods of mixed feed depending on the requirements, a common method in the case of a quadruple-effect evaporator being to introduce the new feed in the second effect, from which it flows in turn to the third, fourth, and finally to the first.

The derivation of the heat balance equations for the forward and backward feeding of multiple-effect evaporators is given by Badger[1]. The method, however, could be simplified, and it is the purpose of this paper to do so. Other standard text books

on evaporation[3] or on chemical engineering[2] either do not give the heat balance equations, or if they do, they do not show the derivation.

To illustrate the derivation of the heat balance equations for each of the four methods of feeding (and for the several possible variations of each method depending on the feed temperature), it will be necessary to take only two cases in detail. However, the equations for all other cases will be given below. The methods employed for the detailed cases can easily be applied to the others.

Let L = the latent heat of evaporation, in B.t.u. per pound; Q = the quantity of heat transferred through the heating tubes to the liquid in each effect, in B.t.u. per hour; q = the heat required to raise the temperature of the feed in a particular effect to the temperature of the boiling liquid in that effect, in B.t.u. per hour; and S = the weight of liquid flashed into vapor in the effect, in pounds per hour. In the following, these terms are used with subscripts which refer to the effect number. All equations are based on the heat transferred in and out of each effect in a period of 1 hour.

Case 1, Forward Feed

(a) The dilute feed enters the evaporator "cold". It must therefore be preheated in the first effect. In all other effects the feed liquor will flash. Fig. 1 shows the four effects, with a heat balance written for each effect. The heat balance is solved for $Q_1 - q_1$, and for n effects, as follows:

$$Q_1 - q_1 = Q_2 = Q_3 - S_2L_2$$
$$= Q_4 - (S_2L_2 + S_3L_3) = \ldots$$
$$= Q_n - (S_2L_2 + \ldots + S_{n-1}L_{n-1})$$

(b) The dilute feed enters the evaporator at such a temperature that no preheating in the first effect is required. However, the temperature is not high enough to make it flash. In all the other effects the feed liquor flashes. Here the equation is:

$$Q_1 = Q_2 = Q_3 - S_2L_2 = Q_4$$
$$- (S_2L_2 + S_3L_3) = \ldots = Q_n$$
$$- (S_2L_2 + S_3L_3 + \ldots + S_{n-1}L_{n-1})$$

(c) The dilute feed enters the evaporator at such a temperature that it flashes in the first effect. Likewise, in all the other effects the feed liquor flashes, so that the equation is:

$$Q_1 + S_1L_1 = Q_2 = Q_3 - S_2L_2 = Q_4$$
$$- (S_2L_2 + S_3L_3) = \ldots = Q_n$$
$$- (S_2L_2 + S_3L_3 + \ldots + S_{n-1}L_{n-1})$$

Case 2, Backward Feed

(a) The dilute feed enters the evaporator "cold". Hence, it must be preheated in the last effect. Likewise, in all the other effects the feed liquor must be preheated. This particular case is illustrated in Fig. 2. As in Case 1 (a), a heat balance is made for the individual effects. Then solving for $Q_1 - q_1$,

$$Q_4 - q_4 = (Q_1 - q_1 - q_2) - q_3 - q_4$$
$$= (Q_1 - q_1) - q_2 - q_3 - q_4$$
$$= (Q_1 - q_1 - q_2 - q_3) - q_4$$

Therefore,

$$Q_4 - q_4 = Q_3 - (q_3 + q_4) = Q_2$$
$$- (q_2 + q_3 + q_4) = Q_1$$
$$- (q_1 + q_2 + q_3 + q_4)$$

and for n effects,

$$Q_1 - (q_1 + q_2 + \ldots + q_n) = Q_2$$
$$- (q_2 + q_3 + \ldots + q_n) = Q_3$$
$$- (q_3 + q_4 + \ldots + q_n) = \ldots$$
$$= Q_n - q_n$$

(b) The dilute feed enters the evaporator at such a temperature that it flashes in the last effect. In all the other effects, the feed liquor must be preheated. The equation here is the same as in the preceding case.

Case 3, Mixed Feed

Assume a quadruple-effect evaporator with three effects forward.

(a) The dilute feed enters the evaporator "cold". Hence it must be preheated in the second effect. The feed liquor flashes in the third and fourth effects. It then moves backward to the first effect where it must be preheated. The equation is:

$$Q_1 - q_1 = Q_2 = Q_3 + q_2 = Q_4 + q_2$$
$$- S_3L_3$$

(b) The dilute feed enters the evaporator at such a temperature that no preheating in the second effect is required. However, the temperature is not high enough to make it flash. The feed liquor flashes in the third and fourth effects. It then moves backward to the first effect where it must be preheated, so that:

$$Q_1 - q_1 = Q_2 = Q_3 = Q_4 - S_3L_3$$

(c) The dilute feed enters the evaporator at such a temperature that it flashes in the second effect. Likewise the feed liquor flashes in the third and fourth effects. It then moves backward to the first effect where it must be preheated, giving the heat balance equation:

$$Q_1 - q_1 = Q_2 = Q_3 - S_2L_2 = Q_4$$
$$- (S_2L_2 + S_3L_3)$$

Case 4, Parallel Feed

(a) The dilute feed is at a temperature which is below the temperature in the last effect. Hence, it must be preheated in all the effects, and:

$$Q_1 - q_1 = Q_2 = Q_3 + q_2 = Q_4$$
$$+ (q_3 + q_2) = \ldots = Q_n$$
$$+ (q_{n-1} + \ldots + q_2)$$

(b) The dilute feed is at such a temperature that it must be preheated in some of the effects, e.g., in the first and second, and it flashes in all the others. Hence:

$$Q_1 - q_1 = Q_2 = Q_3 + q_2 = Q_4 + q_2$$
$$- S_3L_3 = Q_5 + q_2 - (S_4L_4 + S_3L_3)$$
$$= \ldots = Q_n + q_2 - (S_{n-1}L_{n-1}$$
$$+ \ldots + S_3L_3)$$

(c) The dilute feed is at such a temperature that it flashes in all the effects, and:

$$Q_1 + S_1L_1 = Q_2 = Q_3 - S_2L_2 = Q_4$$
$$- (S_3L_3 + S_2L_2) = \ldots = Q_n$$
$$- (S_{n-1}L_{n-1} + \ldots + S_2L_2)$$

The terms in the above equations can be readily calculated on the basis of the definitions given.

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Fig. 1—Heat balance on individual effects for forward feed, Case 1 (a)

Fig. 2—Heat balance on individual effects for backward feed, Case 2 (a)
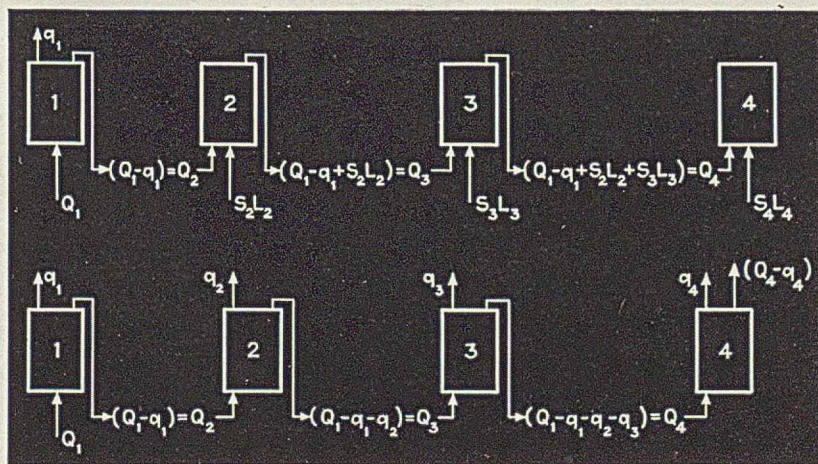
Waste-Salvage Program at Rahway

HOWARD STEPHENSON *American Industries Salvage Committee, New York*

Chem. & Met. INTERPRETATION

Programs for salvage are being instituted throughout the nation and chemical industries, too, are contributing scrap. Because good housekeeping is nothing new to the process industries it might be expected that their contribution would be relatively small. The error of this idea is shown by the impressive record which Merck & Co. made in their salvage campaign.—*Editors.*

TANKS, trench mortars, aerial bombs and machine guns are being contributed to the war effort by Merck & Co., manufacturing chemists of Rahway, N. J. Production of fine chemicals has not been stopped at the company. Merck is making its contribution in the form of salvaged waste. To date, an amount of critical materials sufficient to provide for the equipping of a sizable American task force has been sent to the salvage collector.

As R. E. Tandy, plant defense coordinator in charge of salvage operations states, there are other industries which could more than match their total poundage of scrap. But, as he will somewhat proudly tell you in the next breath, these are plants more or less engaged in the metals trades. Salvage possibilities which exist for them are denied to a chemical manufacturer. Nevertheless, salvage figures which represent a 1,000 percent increase over normal operations and show a total poundage to date of almost a million pounds are indicative of an outstanding job. The salvage campaign of the Merck organization is geared to make a definite contribution to the war effort.

The success of the company's salvage operations is due primarily to the sound organization of its campaign and to careful managerial supervision. When the need for salvaging critical materials became apparent, the management of the company early recognized the urgency of the War Production Board's request to get the nation's waste back into production at the mills and factories turning out war equipment. Response on the part of the officials to the salvaging job ahead was immediate and enthusiastic.

R. E. Tandy, given the responsibilty for organizing the campaign, quickly set about forming a salvage committee composed of one representative from each of the operating divisions of the company. The members of this committee were all hand picked with careful attention being given to their general reputations for getting things done.

Each of these committee members was asked to go through his division and select from each department men who would serve as salvage representatives were also men known to be alert and observing and who had the ability to "follow through." Plans for publicizing the campaign and for an immediate clean-up of the plant were formulated at a general organization meeting of the committee.

The results of the initial clean-up

amazed even the men who supervised it. In three days they had accumulated 50,000 pounds of scrap iron, 20,000 pounds of scrap lead and substantial quantities of other critical materials. Particularly surprised was Mr. Tandy, for as he explains, housecleaning was not a new subject to the Merck company. For many years the company's plants have, in fact, been rather proud of their housekeeping methods. There is, however, a difference between collecting scrap for war and ordinary neatness routines. As they are quick to admit at Rahway, necessity sharpens the eye. Material and parts that had formerly been passed over many times took on a new significance when it could be translated into guns and plates for ships.

A central scrap area in the plant was set aside and plans formulated to arrange for a continuous scrap campaign.

A set of simple open bins at the central area was marked for the segregation of salvaged materials. Red, white and blue containers made from old barrels and drums were placed in strategic spots to serve as depositing places for scrap. Regular pick-up facilities were provided by the yard department which delivered

One of the scrap collection areas set aside at Merck to receive critical war materials salvaged by the company's scrap and waste collection program

the material to the centrally located bins.

Arrangements were made with a local junk dealer to have a weekly collection of all scrap with sales effective on a monthly basis at current market prices.

The publicizing of the program to the employees was accomplished through the education of the supervisors and with the use of posters, most of which are of the company's own design. One of the most successful of these is a kind of progress report of the collection of scrap metal and rubber, which translates the material already collected into the amount of weapons it will make. The imposing list of military equipment which was made possible as a result of their efforts proved a real morale booster for the workers. Their opinion seemed to be that if the waste they turned in could have that direct a bearing on the result of the war, they'd salvage metal for enough shells to raze Tokio.

Not satisfied with ordinary production and waste scrap, the officials of the company made careful inspection of all the buildings. They used a pretty good yardstick in deciding what to discard. Taking the position that if equipment hadn't been used for three months and if a use couldn't be proved for it in the next three, the equipment was eligible for resale or the scrap heap. They disposed of a number of pieces of unused equipment. Attention was given to the possibility of salvaging individual parts of such equipment with an eye to using them as replacements for machines in operations. An excellent haul in old radiators, dead pipe lines and other miscellaneous metal also rewarded their inspection.

To date, the salvage program at Merck has yielded the following amounts of critical materials: 640,292 lb. of iron, 3,213 lb. of aluminum, 1,656 lb. of brass, 6,883 lb. of copper, 78,061 lb. of lead, 5,200 lb. of rubber, 601 lb. of zinc and 25,130 burlap bags, a total of 761,036 pounds.

That such an active program of salvage and conservation must furnish benefits over and above putting the country's waste to work against the Axis is another fact turned up by the Merck campaign. As a result of examining all possibilities for conserving material, Mr. Tandy discovered that laundering mill ends and cotton gloves did more than conserve a considerable amount of cotton and wool. In the report which he sent to Mr. H. W. Johnstone, Vice-President of the company, he was able to ad-

vise that the procedure would save the company about $9,000 a year.

Despite the large quantities of scrap already turned in by the company, officials and workers alike are seeing to it that the salvage program remains active. Each day sees the exploration of some new possibilities, many of which produce new salvage opportunities. All of the organization's plants and branches have been set to work collecting with the idea of adding every available pound of scrap to the nation's stockpiles and they are operating their campaigns

along the same lines as that of the main plant at Rahway.

Officials at Merck are willing to attribute some of their success in their salvage operations to efficient organization. Even more important, however, in their own minds and responsible for the efficiency with which they have conducted their program is the crucial situation of the steel mills in their dependence on scrap to keep the war going. As a result, they are keeping on their toes and letting no opportunity slip to add to their contribution of scrap for victory.

How Refineries Conserve Critical Materials

————————— *Chem. & Met.* INTERPRETATION —————————

In recent months the Office of the Petroleum Coordinator for War, through Max B. Miller, chief of the construction section of the refining division, has issued a number of booklets on "Wartime Plant Design", relating chiefly to the saving of strategic construction materials through materials substitutions in petroleum refineries. The article which follows is an editorial staff summary of several of these booklets, with the emphasis on those suggestions which are equally as applicable to other kinds of process plants.—*Editors.*

THE SUGGESTIONS given in the following have been abstracted from a group of letters from petroleum refineries and equipment manufacturers, received by the Office of the Petroleum Coordinator, and thereafter released to the refining industry.

Many suggestions were made which applied quite specifically to the petroleum industry. Among those more generally applicable were several suggestions made by the Atlantic Refining Co. This company is now ordering universal steel plates in place of sheared square-edge plates. All individual items of critical materials carried in stores are being examined to determine whether less critical materials can be substituted. Various salvage and reclaiming methods are being employed including the plating of chrome pump shafts for reconditioning and the salvaging of flanges which can be re-bored for use as slip-on welding flanges.

Among the suggestions made by the Babcock & Wilcox Co. is the one that two-drum boilers should be used as far as possible instead of multi-drum boilers. Steel casings are not essential for boiler units, even for outdoor plants, which can be covered

with insulation and some form of nonmetallic casing material such as Transite.

Continental Oil Co. reports that in so far as possible all pumps are being designed for out-door installation and the use of standard motors where explosion-proof motors cannot be secured. These are installed in well-ventilated hoods for weather protection. Putting the pumps out-doors saves on building space. Layouts are being made as compact as possible to reduce piping and interconnecting lines to a minimum. Second-hand piping is being used for building framing and reclaimed sucker rods for reinforcing steel for concrete.

A variety of conservation suggestions has been made to its customers by Foster Wheeler Corp. For example, it is proposed to reduce manhole access steel, possibly providing only knee braces suitable for the maintenance crew to rig a wooden flooring. Ladders can usually be substituted for stairways, while fully floored and hand-railed platforms are necessary only for important operating levels. Reinforced concrete can be substituted for steel in many instances and glass blocks for metal

windows. Wood can be substituted for plate and grating trench covers and Transite or concrete for steel in large-sized water and sewer lines. Stacks can be built of concrete.

M. W. Kellogg Co. calls attention to the availability of pre-stressed reinforced concrete tanks in which the concrete is thrown into compression by pulling up horizontal steel circumferential rods in the reinforcing to a predetermined initial stress. This company has employed such tanks in diameters as large as 150 ft. and about 36 ft. high. Kellogg also points out that critical materials can be saved by easing bolting steel specifications which in the past have generally been unnecessarily high.

The Lummus Co., in addition to repeating some of the foregoing suggestions, mentioned the desirability of using treated wood flooring as a substitute for checker floor plates and gratings on many installations. Wood stave pipe is worth considering for above-ground water lines as a substitute for large cast iron and steel pipe.

Standard Oil Development Co. has developed a set of modified specifications granting contractors permission to deviate from regular material and equipment specifications under certain circumstances when the substitution will assist meeting schedules and will be satisfactory from an operating standpoint. For example, bessemer steel can be substituted for open hearth steel for certain purposes, including reinforcing rods, tank steel, condenser boxes, and stacks, as well as minor structural shapes, standard weight lapwelded pipe, floor plates, expanded metal and galvanized sheets. Narrower plates than standard may be used unless this use will so increase welding time as to cause delay in completion of the unit. For service below 800 deg. F., the new NE steels of recommended grade may be substituted for alloy steel bolting for high-pressure, high-temperature service.

The company has materially decreased its requirements for fusion-welded pressure and vacuum vessels, provided, however, that the vessels must still conform to the API-ASME code. The recommendations made at the WPB conference in Cleveland on March 31, 1942, have been adopted including the suggestion that where nickel and chromium are used to extend the life of equipment, the basis of design of new plants shall be an estimated three-year life, without requiring major repairs which might reduce the normal service factor more than 2 percent.

Many savings have been accepted in critical materials used in building structures. For example, the company is confining steel structures to those necessary for support of equipment, reducing steel usage for platforms and stairways to a minimum, using reinforced concrete for support of equipment wherever possible. Pipe lines which are normally provided for extreme operating flexibility or for possible future use are eliminated. Cocks are no longer being used on the discharge side of safety valves and in general the use of valves is being reduced to a point only sufficient to permit adequate hand control in the event of trouble with automatic control devices. The use of spare equipment for standby service is being minimized as is the application of control equipment.

Electrical controls for motors are being simplified and lighting minimized. Safety valves are being allowed to discharge directly into the air at sufficient height, where a hazard is not thus introduced. To a large extent cast iron valves and fittings are being substituted for steel for steam, refinery gas, refinery oil line, and water service, except in the more critical applications.

BUILDING MATERIALS

In building construction, permanent trolley systems for handling heavy equipment are being omitted and instead space is being provided for the access of crawler cranes or for temporary rigging. Some convenience platforms are being eliminated and others reduced in size. Reinforced concrete and wood are being employed wherever practicable instead of steel. For example, wood is being used as far as possible for stringers and treads of stairways, for ladders, railings, platform floorings and some framing. Massive concrete without reinforcement is being used where possible as in foundations and slabs on the ground, or with minimum reinforcement. As far as possible buildings are being constructed with brick walls, with wood roof beams or trusses, with plank roofs and built-up roofing. Wood is being used for door-frames, doors and sashes. An interesting idea for two-story structures is to use reinforced concrete for the lower story and heavy timber mill construction for the upper story.

A variety of other metal-saving suggestions has also been incorporated in the specifications including the use of cement-asbestos sheet material instead of galvanized and coated iron, the elimination of galvanized nails

and metal lath, and the use of coated ferrous materials so far as possible without galvanizing for screening, flashing, and for down-spouts. Terra cotta and concrete are being substituted whenever possible for metal pipes for sewer lines, and non-metallic coated materials for conduits. Instead of conduits, non-metallic sheathed cables are being employed where practicable, together with electric light fixtures eliminating as much metal as possible. Cast iron, rather than copper, is being used for heating coils and convectors for inclosed areas.

Universal Oil Products Co. makes the interesting suggestion that steel can be saved by making the skirts of vessels very short, with the additional required height of the skirts supplied by reinforced concrete. This company claims that concrete pipe trenches with plate covers constitute a fire hazard and that pipes should therefore be buried or run overhead on concrete supports. Universal also suggests that plastic tubing can be used instead of copper for instrument airlines.

According to Standard Oil Co. of Ohio, important savings in alloy materials may be possible through the use of enamelled bubble caps. This company has reported on tests of such caps and has found them to give excellent results under severe operating conditions. For example, in one application cast iron caps lasted only six months but the enamelled caps now used have not required any replacements in more than a year.

A possibility for eliminating a serious bottleneck in large equipment fabrication capacity was suggested by Sinclair Refining Co. Since there appears to be an impending shortage of capacity in stress-relieving furnaces, this company has suggested permitting the construction of towers in sections so that a complete ring with its bubble trays, downcomers and other internal parts can be stress-relieved and shipped as soon as completed, thus permitting field erection and welding of the sections as they are delivered. A tower manufacturer has stated that if all purchasers placing business in his shop accepted towers in sections, production could be increased from 250 to 350 percent.

Along the same line is the idea that it may be possible, through consultation with equipment manufacturers before designs are completed, to effect other changes in design which would greatly increase equipment production capacity without seriously interfering with the installation or the efficiency of the equipment.
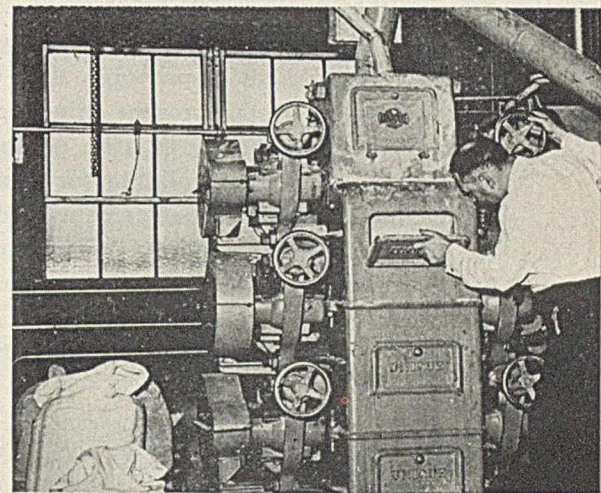
Butylene Glycol from Corn by Fermentation

A SHORT AND economical process for making butylene glycol was recently announced by the U. S. Department of Agriculture. The new method, developed at the Northern Regional Research Laboratory at Peoria, Ill., involves fermentation of farm crops such as corn and wheat. The laboratory is now producing butylene glycol on a pilot plant scale.

A study is being made of butylene glycol as a possible link in the production of butadiene for synthetic rub-

Butylene glycol is recovered from corn fermentation liquors in this experimental still in the pilot plant of the Northern Regional Research Laboratory, Peoria, Ill. Butadiene can be made from the glycol
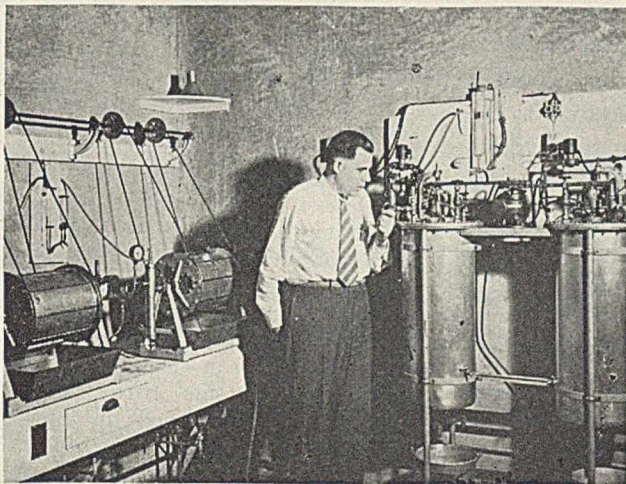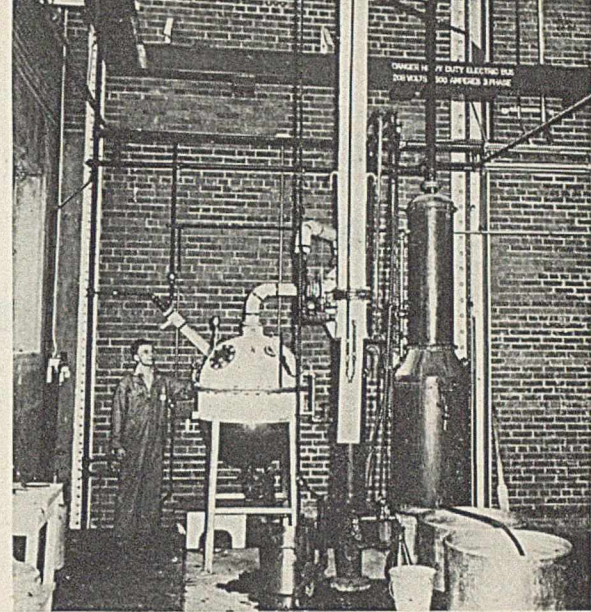
One of the experimental fermentation vats for conversion of corn to butylene glycol, from which excellent yields of pure butadiene have been made on a laboratory basis


Checking the milling of corn for experimental use in bacterial fermentation to butylene glycol by the new process

ber. Three steps would be involved: (1) raw material to butylene glycol, (2) butylene glycol to butadiene, and (3) butadiene to synthetic rubber.

The major problem is conversion of the glycol to butadiene on a commercial scale. Chemists at the Peoria laboratory have succeeded in producing excellent yields of pure butadiene from corn-made butylene glycol in the laboratory, but they have not as yet developed the process to a pilot plant scale. Several industrial concerns are now producing butylene glycol on a pilot plant scale as a result of information developed in the Peoria laboratory. All illustrations on this page are from the U. S. Department of Agriculture, photographed by Forsythe.

View of the pilot plant set up by the Dept. of Agriculture at Peoria, Ill. to test new processes for making industrial alcohol from fermentable farm products
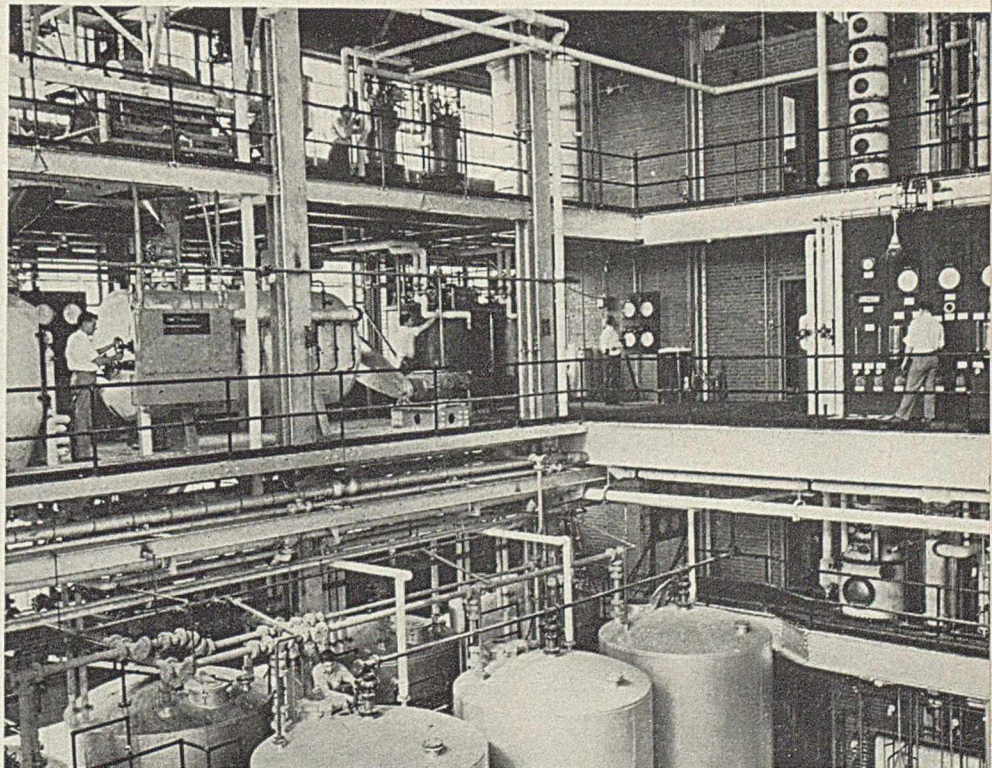
Uses and Properties of Acidproof Cements

JOHN H. S. BARR
Pennsylvania Salt Mfg. Co.
Philadelphia, Pa.

Pointing joints with Asplit resin cement in a pulp treating tank

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Chem. & Met. INTERPRETATION

Although ceramicware linings are by no means unusual in chemical industry work, it is probable that their use will be considerably accelerated by the present stringency in metals. Furthermore, the improvements that have been made in recent years in the various cements that are available for bonding such linings, and in the techniques of using the cements, singly and in combination, make this article of particularly timely interest. The author includes data on temperature drops through various lining constructions.—*Editors.*

ACIDPROOF CEMENTS used in construction work to combat corrosive liquids and gases are generally of three varieties—the sulphur, sodium silicate and resin types.

The first, sulphur cements, consist mainly of crystalline sulphur which may or may not have other materials such as silica, carbon or synthetic rubber added to improve the physical characteristics. Such cements are applied by melting and pouring into open joints between the bricks. The material must remain liquid until all of the joint spaces have been filled, so it is always necessary to have joints of appreciable width to provide a volume of hot sulphur sufficient to keep the cooler bricks from causing the cement to solidify. Also it is necessary to provide seals across the surface joints to retain the molten cement until it has solidified.

Sulphur cements adhere quite well to acidproof bricks and also to membraneous materials such as rubber and asphalt. As a rule they are not allowed to come into direct contact with either metals or concrete. Most types shrink upon solidification and, therefore, must be poured a little at a time to compensate for the shrinkage.

Since sulphur cements are combustible, they must be kept from open flames. They are unaffected by water and many acids, but are attacked by some acid conditions which are not harmful to ceramicware. When a sulphur cement contains carbon but no silica, it is not attacked by hydrofluoric acid. Ceramicware, because it contains appreciable quantities of silica, can not withstand HF. Structural carbon is used most extensively for hydrofluoric acid service. Sulphur cements have a linear expansion coefficient of 0.0000083 per deg. F., whereas the coefficient for acidproof brick lining laid in sulphur cement is 0.0000043 (Payne and Duecker, *Chem. & Met.*, Dec. 1939, p. 768).

Since thin joints are not used with sulphur cements, exact sizes and shapes of ceramicware pieces are not required and the installation of acidproof brick linings does not require skilled bricklayers. Sulphur cements when carefully handled may be relatively dense. This presents an advantage as a protection against infiltration of liquids, but is disadvantageous in service where there are temperature variations.

Most of the sulphur cements melt at about 235 deg. F. and since the crystalline structure of sulphur changes and the coefficient of thermal expansion usually increases at about 200 deg. (Payne and Duecker, *Chem. & Met.*, Jan. 1940, p. 20), it is advisable not to use sulphur cements in equipment which will be operated at temperatures above approximately 195 deg. F. It is necessary to make provision for expansion of linings which are of appreciable length. It has been noticed in some cases that the sulphur cements grow continuously after long periods in intermittent hot and cold service. This tendency to grow will, in the course of time, weaken the bond of the crystal structure of the sulphur cement.

SODIUM SILICATE CEMENTS

Sodium silicate cements have been used for many years as a bonding material for chemical ceramicware. They are not readily adaptable for use as a coating material in sizeable areas, but are used principally as a mortar to butter bricks.

Sodium silicate is manufactured in both liquid and powder forms. For acidproof cements, the siliceous powder is usually (but not always) mixed with sodium silicate solution. In refractory cements, however, solid sodium silicate is usually combined with the silica powder and the cement is mixed on the job with water to form a mortar. Acidproof cements which contain solid sodium silicate are relatively expensive. Also they must be packed in tight containers so that they can absorb neither water nor carbon dioxide. When freshly made they react like cements mixed with sodium silicate solution (although they set a little slower),

but if the powder has been allowed to absorb water or CO_2 from the air during storage the final mortar will not have great mechanical strength. These cements do not shrink as much as those made with waterglass solution and in some instances successful small castings have been made from them.

The early sodium silicate cements consisted solely of ground quartz or sand which was mixed to the proper consistency with sodium silicate solution. The mixture was able to set up either by the removal of water alone, or by the reaction of the sodium silicate (usually with an acid) and the subsequent removal of the water. When such a cement solidifies by the reaction of the sodium silicate, the silicate is precipitated as silica and forms a bond, which is no longer soluble in water or in any acid with the exception of hydrofluoric acid. However, if the cement solidifies only by the removal of water, it may be redissolved by subsequent addition of water.

SILICATE CEMENT PROPERTIES

The water in sodium silicate mortars does not react chemically in either of type of hardening, so that when the water is removed, the cement tends to shrink and become porous. This is the principal reason why sodium silicate cements are not used as monolithic castings and coating materials. The porosity is an advantage in some cases, in that it provides a certain amount of elasticity to a ceramicware lining. For instance, the modulus of elasticity of a sodium silicate cement is about 800,000 lb. per sq. in., whereas that of concrete is usually taken at about 1,200,000 lb. per sq. in. However, porosity is a disadvantage if the lining is to contain solutions which infiltrate into the pores of the cement and subsequently crystallize. Many sulphates, for example, take on water of crystallization and expand when they crystallize.

Since the early sodium silicate cements required considerable time or treatment to become solid and since they were water soluble, unless reacted, their uses were limited to applications where time of completion was not a paramount requirement.

The time factor in sodium silicate cements was overcome only a relatively short time ago when the so-called self-hardening type was first patented in this country. Before that time the cements which contained no setting agents reacted too slowly and those which contained acid setting agents reacted too quickly.

These cements are unattacked by acids which do not contain free fluorine. They are most serviceable in acids of relatively high concentration. As a matter of fact, in the course of strong acid service such sodium silicate cements show material increases in strength.

The coefficient of thermal expansion of sodium silicate cements is of the same order as that of steel, namely, 0.0000063 per deg. F. This is the average value between 70 and 500 deg. F. which is the range of customary acidproof construction work.

Silica is, of course, a fairly good electrical insulator and under proper conditions these cements find service in electrical work. It must be remembered that they are porous, however, and unless dried out will retain some of the water from the mortar.

Brick linings should be used against an impervious shell. As a rule the sodium silicate mortar is buttered on to the bricks which are then squeezed into position inside the shell. The most nearly foolproof shell is a steel, rubber-lined tank, but in many cases concrete shells covered with an asphalt membrane have given many years of service. In other instances, ordinary welded steel shells which have been carefully lined with bricks have given their users very satisfactory service.

The joints between brick edges are usually kept as thin as possible— $\frac{1}{16}$ to $\frac{1}{8}$ in. The joints between the back of the brick and the shell are also kept rather thin, but since acidproof bricks are usually low in porosity (1 to 5 percent), and since there is no way for the water to be removed from the cement, there is no shrinkage in the setting of a self-hardening sodium silicate cement in the back joints. The cost per unit of volume of a good acidproof cement

is more than that for a good grade of acidproof brick.

Acidproof bricks in manufacture are subjected to a careful process of vitrification which makes them substantially inert. Silicate cements, however, cannot usually be subjected to vitrification and, therefore, are apt to be more readily attacked than the bricks. This suggests another advantage of thin joints for acidproof brickwork, since the rate of washout of a thin joint is greatly reduced. One advantage in the use of such a mortar is that each brick is handled separately and the bricklayer knows definitely that there are no voids in the lining which might allow acid pockets to form during liquid operations. With molten cements, however, one complete horizontal course is usually laid at a time and the bricklayers cannot be certain that all of the voids in the joints have been filled.

CONSTRUCTION COSTS

When the bricks are handled by buttering with mortar, the shapes should be relatively uniform and the workmen should be trained and experienced in the work. Thus the labor costs of handling a mortar type cement are often higher than those for a molten type cement, but the material costs are lower because of thinner joints. The overall construction costs are practically balanced. Many industries where acidproof cements are used must have uninterrupted service and initial construction costs are not always paramount. For this reason the bricklayers who do this work are usually specially trained for it, and are impressed with the fact that the utmost care is necessary to be sure that the brick lining contains no voids.

Owing to water content in a sodium silicate cement, the final porosity of the joints is usually greater than

Workmen installing a two-course tank lining, using sodium silicate cement

that of molten cements, but some recently developed silicate cements have proven to be unusually dense. The finished lining consists of quite pure silica which will not be attacked by any acid conditions which do not contain free fluorine. Also the lining is resistant to any temperature conditions for which silica itself is suitable.

The great majority of acidproof brick linings are installed principally as a protection against temperature and abrasion. For instance sheet lead is resistant to a great many acid conditions, but when a lead lining is subjected to alternate heating and cooling it expands with increases in temperature. Thus the lead lining has a tendency to buckle and grow so that in the course of time the lead will crack. This trouble is often eliminated by the use of an acidproof brick lining inside the sheet lead. The brick lining has several purposes. In the first place it acts as a heat insulator; second, it keeps the lead in place; and third, it protects the lead from mechanical abuse. In acidproof construction work the sheet lead may be installed inside a shell of wood, concrete, steel, or other material. Thus the lead will act as an impervious membrane which makes the entire vessel liquid tight and corrosion-proof.

In some instances sheet lead is supported by a steel framework, and the temperature drop through acidproof brick lining is considerable, due to the fact that the lead surface is then free to radiate heat from most of its outside surface.

RUBBER LININGS

Rubber linings are also used quite extensively in corrosion resisting construction. The rubber is usually vulcanized to a sheet steel shell, but in some instances shells of wood or concrete lined with rubber have been used. A lining of this type is quite resistant to acid conditions but when subjected for prolonged periods to temperatures above 150 deg. F. tends to crack and disintegrate. Also the coefficient of thermal expansion of rubber is greater than that of most other materials used for acidproof construction. Rubber lined shells are quite often provided with an acidproof brick lining which serves not only to reduce the surface temperature of the rubber but also to protect it from being punctured. When rubber linings are subjected to hot, weak acid conditions, the surface of the rubber has a tendency to form "water bubbles." Although most acidproof
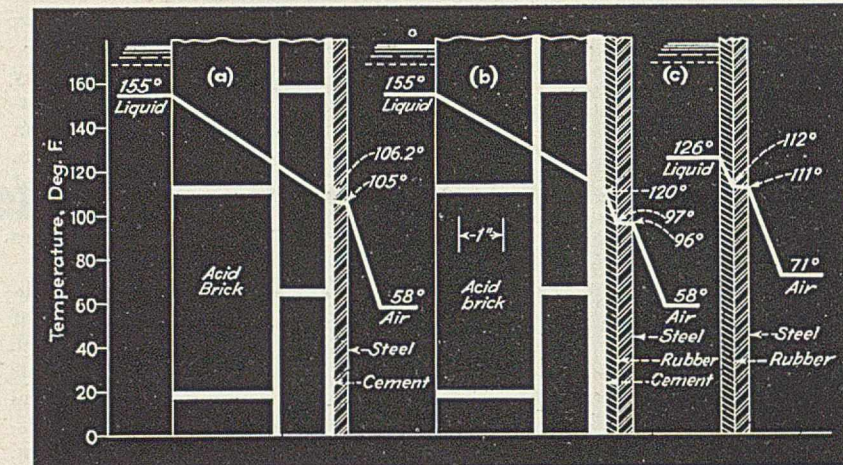

Fig. 1—Three-wall cross sections, drawn to scale, showing calculated temperature gradients through the various courses of material

brick linings are somewhat porous, they prevent the formation of such bubbles.

TEMPERATURE DATA

We recently obtained some interesting readings of temperature drops through acidproof brick linings in one of our plants where there are two tanks, side by side, subject to the same temperature and corrosion conditions, containing hot HCl-salt solutions. Both are constructed of $\frac{3}{8}$-in. steel, one lined with $3\frac{5}{8}$ in. of acid brick (including thickness of the two joints) and the other lined with $3\frac{7}{8}$ in. of brick (including the two joints) plus a $\frac{1}{4}$-in. Triflex rubber lining. The cement is a self-hardening sodium silicate cement. The tanks are sketched in cross section in Fig. 1 (a) and (b). The temperature measurements included the air, 58 deg. F.; the steel surface, 105 deg. in case (a) and 96 deg. in case (b); and the liquid temperature, 155 deg. The amount of heat loss from the tanks was determined from charts supplied by the Harbison-Walker Refractories Co., from knowledge of the steel surface and air temperatures, coupled with the fact that the air was substantially quiescent.

Thus, for the first tank, the heat loss was taken as 82, and for the second tank, as 70 B.t.u. per sq. ft. and hour. We took K for steel as 26 B.t.u. per sq. ft., hour, deg. F. and inch of thickness, and used the formula $(T_1 - T_2)/Q = L_1/K_1 + L_2/K_2 + \ldots$, where $T_1 - T_2$ is the temperature drop across the section in question, Q is the B.t.u. heat loss per sq. ft. and hour as obtained from the charts mentioned, L_1 and L_2 are the inches thicknesses of each course of material, and K_1 and K_2 are the conductivities of the various courses, in B.t.u. per sq. ft., hour, deg. F. and inch of thickness. The conductivity K_1 for the brick lining and cement for the first tank was calculated as 6.2 B.t.u. per sq. ft., hour, deg. F. and inch of thickness. Using this figure for the second tank, Fig. 1(b), the conductivity of the rubber lining was calculated as 1.2 B.t.u. per sq. ft., hour, deg. F. and inch of thickness. For both tanks the temperatures at the boundaries of the various materials were calculated as shown on Fig. 1.

Later confirmation of the coefficient for the rubber lining was obtained from another tank of different construction in the same building. This tank was of $\frac{3}{8}$-in. steel, with a 0.2-in. Triflex rubber lining. As shown in Fig. 1 (c), the liquid temperature was 126 deg. F., the air temperature 71 deg. and the steel surface temperature 111 deg. The chart previously mentioned gave Q as 72 B.t.u. per sq. ft. and hour for these air and steel temperatures. Hence K for the rubber lining was calculated as 1.03 B.t.u. per sq. ft., hour, deg. F. and inch of thickness, and the steel-rubber boundary temperature as 112 deg.

RESIN CEMENTS

Synthetic resins have been known for many years, but as a rule they have been used mainly for the fabrication of molded or pressed shapes. Only recently have they been adapted for use in paints and cements.

Resin cements have advantages over sodium silicate cements in that they are practically impervious and do not shrink on setting. Also they have much greater mechanical strength and elasticity, so that the surface of a resin cement is quite

tough and resistant to wear. They are able to withstand thermal as well as mechanical shocks, and their setting time is readily controlled by temperature. For instance, at 70 deg. F., setting may commence only after 5 or 6 hours, whereas at 100 deg. F. the setting time is shortened to about 30 minutes. At 120 deg. F., at which temperature such cements may readily be worked, they set in about 5 minutes.

Resin cements are not attacked by acid conditions which are not strongly oxidizing, and they are often unaffected by weak alkalis. The temperature of use is limited to slightly above 350 deg. F., especially when there is plenty of oxygen present. Resins are inherently expensive and for this reason are used in acidproof construction work principally to protect surface joints in brickwork where their imperviousness and toughness are most desirable. As a pointing material, resin cements are used in surface joints of bricks which have been laid in such materials as sodium silicate cements, litharge cements, blast furnace cements, or portland cements. They usually will not set properly in the presence of water or alcohol, but adhere quite well to ceramicware and asphalt surfaces, and especially well to rubber surfaces.

COMBINATION JOINTS

When used as a pointing material in joints which have been bonded with alkaline cements such as sodium silicate or portland cement, resin cements adhere quite well after these surfaces have been neutralized by acid. A dilute (10 percent) hydrochloric acid is suitable. After the neutralization it is advisable to dry the joints before applying the resin cement. When portland cement is neutralized by 10 percent hydrochloric acid, bubbling occurs and neutralization should be continued until no more bubbling takes place on the addition of fresh acid.

In many cases, combinations of cements offer the best solution to corrosion problems. Acidproof bricks are often laid with sodium silicate cement, the surface joints being left open $\frac{1}{4}$ in. wide and $\frac{1}{2}$ in. deep, rectangular in section. After this cement has set sufficiently (one or two days) the recesses are neutralized, washed and dried before the resin cement is squeezed into the recess. Instead of silicate cement, a combination of portland cement and resin cement may be used, but this requires an even longer time than the method just described because it is often advisable to allow portland cement to set for a considerable time before it is neutralized preparatory to pointing.

When construction time is of importance, a combination of a resin cement and a molten cement may be used. This usually adapts itself most readily to a two-course lining so that the surface course of bricks may be bonded with resin cement, and the molten cement poured in to fill the joints of the back course, and the joint between the two courses. Thus the resin cement serves several purposes—it acts as a seal to prevent

the molten cement from running away while it is still liquid; it makes up the surface course which is exposed to the most severe corrosive and erosive conditions; and the complete surface course acts as an insulating medium to prevent the molten cement from becoming too hot during operation.

SETTING TIME

As already noted the setting time of a resin cement depends upon the temperature. Therefore, in this type of construction, if the bricks are warmed before being placed (as is recommended practice in the use of molten cements) the resin cement sets sufficiently so that the bricks will remain in place while the molten cement is poured behind them. The heat of the molten cement accelerates this set further so that the final lining can be put into service very soon after the bricklaying has been completed.

The setting of sodium silicate cements also is accelerated by temperature so that these cements, too, may be used in the surface instead of a resin cement. High melting asphalts may often be used as the molten cement in this type of construction.

At the present time the raw materials required to manufacture the sulphur and silicate types of cements are available without priorities, but many of the raw materials required to make resin cements are now under government control. Thus priorities are usually required with resin cement orders.

REFRACTORY MATERIALS

Continued from *Chem. & Met.'s* Materials of Construction Report, September, 1942

Representative Makers of Refractories and High Temperature Mortars

Manufacturer	Principal Types	Manufacturer	Principal Types
Acme Brick Co., Ft. Worth, Tex............	Firebrick and clay, h.t. cements, plastic refrs.	Denver Fire Clay Co., Denver, Colo.........	Firebrick, h.t. mortar, refr. castables, fireclays, plastic, high alumina and sillimanite refrs.
Alberene Stone Corp. of Va., New York, N. Y.	Refractory linings		
American Crucible Co., Shelton, Conn.......	Graphite crucibles, silica and mullite refrs.		
Armstrong Cork Co., Lancaster, Pa.........	Refr. insul. brick, h.t. mortars, 1,800 deg. insul. block and cement	Joseph Dixon Crucible Co., Jersey City, N. J.	Graphite crucibles, stoppers, retorts, sleeve and nozzle brick, clay crucibles
Atlas Lumnite Cement Co., New York, N. Y.	Cement for refr., heat-resisting and insul. concrete	Ehret Magnesia Mfg. Co., Valley Forge, Pa...	H.t. mortar, insulation
		Electro Refrs. & Alloys Corp., Buffalo, N. Y..	Mullite, fused alumina, silicon carbide and magnesia refrs., carbon bonded silicon carbide crucibles
Babcock & Wilcox Co., New York, N. Y.....	Glass plant refrs., h.t. mortars, plastic refrs., insulating firebrick and kaolin refrs.		
Bartley Crucible & Refr. Co., Trenton, N. J..	Graphite crucibles, magnesia and special refrs.	Emsco Refractories Co., Vernon, Calif.......	Firebrick, glass plant refrs., h.t. mortars
Betson Plastic Fire Brick Co., Buffalo, N. Y..	H.t. mortars, plastic refrs.	The Exolon Co., Blasdell, N. Y............	Silicon carbide, alumina refrs.
Botfield Refractories Co., Philadelphia, Pa...	Chrome, firebrick, plastic refrs., h.t. mortars	General Abrasive Co., Niagara Falls, N. Y...	Alumina and silicon carbide
Philip Carey Co., Lockland, Ohio............	H.t. mortars, insulations	General Ceramics Co., New York, N. Y......	Special refrs.
Carborundum Co., Perth Amboy, N. J.......	Silicon carbide, aluminum oxide, mullite and fused cast refrs. and h.t. mortars	General Refractories Co., Philadelphia, Pa....	Fired and unfired chrome and magnesite, firebrick, h.t. mortars, plastic and silica refractories
Champion Spark Plug Co., Detroit, Mich.....	Sillimanite plastic refrs., electric furnace refrs.		
Charlotte Chemical Labs., Charlotte, N. C...	Refractory plastic	Gladding, McBean & Co., Los Angeles, Calif...	Firebrick, h.t. insul. brick and plastics, h.t. mortars, plastic refrs., fireclays, h.t. acidproof brick and cement
Corhart Refractories Co., Louisville, Ky......	H.t. mortars, electro-cast refrs.		
Corundite Refractories, Inc., Massillon, Ohio..	Firebrick, h.t. mortars, plastic refrs., alumina, mullite refrs. and insul. refrs.		*(Continued next page)*

Manufacturer	Principal Types	Manufacturer	Principal Types
A. P. Green Fire Brick Co., Mexico, Mo.	Firebrick, insul. f.b., h.t. mortars, plastic and castable refrs., fireclays	North American Refrs. Co., Cleveland, Ohio.	Regular and super fire clay, high alumina silica brick, insulating firebrick, h.t. mortars, plastic refrs. and fire clays
Harbison-Walker Refrs. Co., Pittsburgh, Pa.	Refrs. of most types incl. reg. and super fireclay, high-alumina, silica, chrome, magnesite, forsterite brick; clays; insul. firebrick and mortars; h.t. mortars	Norton Co., Worcester, Mass.	H.t. mortars, silicon carbide, fused alumina and magnesia, raw materials, cements, refr. shapes
Haws Refractories Co., Johnstown, Pa.	Firebrick of all kinds, silica brick, fireclays	Pacific Clay Products Co., Los Angeles, Calif.	Plastic refrs.
Illinois Clay Products Co., Joliet, Ill.	Firebrick, h.t. mortars, insulating cements, coatings and brick	Pyro Clay Products Co., Oak Hill, Ohio.	Firebrick refrs., h.t. mortars, plastics, special shapes
Ironton Fire Brick Co., Ironton, Ohio.	Fireclay refrs., refr. cements, fireclays	Quigley Co., Inc., New York, N. Y.	Firebrick, insulating refrs., super firebrick, h.t. mortars, plastic refrs.
Johns-Manville, New York, N. Y.	Bonding mortars, castables, ramming mixtures, plastic and insul. refrs.	Ramtite Co., Chicago, Ill.	Plastic and castable refrs., h.t. mortars
Laclede-Christy Clay Prod. Co., St. Louis, Mo.	Firebrick, h.t. mortars, plastic refrs., glass plant refrs., fireclays	Refractory & Insulation Corp., New York, N. Y.	H.t. mortars
E. J. Lavino & Co., Philadelphia, Pa.	Burned and chemically bonded chrome, magnesite and chrome-magnesia refrs., chrome base h.t. mortars	Robinson Clay Product Co. of N. Y., New York, N. Y.	H.t. mortars, firebrick and clay, insulating refrs.
Massillon Refractories Co., Massillon, Ohio.	Refr. insul. brick and special shapes, muffles, smelters, crucibles, and lab. refrs., diaphragms and electrolytic refrs., firebrick, special shapes, glass plant refrs., h.t. cements and mortars, plastic refrs., high alumina, sillimanite, aluminum oxide, silicon carbide, zircon and special refrs.	Ross Tacony Crucible Co., Philadelphia, Pa.	Graphite crucibles and stopper heads, magnesite refrs.
		St. Louis Fire Brick & Insulation Co., Huntington Park, Calif.	Various
		Seaboard Refrs. Co., Perth Amboy, N. J.	Firebrick, h.t. mortars, plastic and insulating refrs., silicon carbide and mullite refrs.
		Chas. Taylor Sons Co., Cincinnati, Ohio.	Firebrick, glass plant and insulating refrs., sillimanite
McLain Fire Brick Co., Pittsburgh, Pa.	Various	The United States Stoneware Co., Akron, Ohio	Plastic and castable refrs., fire clays, special refrs.
McLeod & Henry Co., Troy, N. Y.	Firebrick, h.t. mortars, plastic refrs., fireclays	M. D. Valentine & Bro. Co., Woodbridge, N. J.	Firebrick
Mullite Refractories Co., Shelton, Conn.	H.t. mortars, plastic refrs., mullite refrs.	Vitrefrax Corp., Los Angeles, Calif.	Firebrick, insul. firebrick, h.t. mortars, ref. castables, plastic refrs., fire clays
National Carbon Co., Inc., Cleveland, Ohio.	Carbon refrs.		
Niles Fire Brick Co., Niles, Ohio.	Firebrick, insulating refrs.		

Physical Properties of Refractory Materials

(Compiled by L. J. Trostel, General Refractories Co., Baltimore)

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

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

Maintenance Tips for Engineers

AVOIDING ELECTRICAL CONTROL BREAKDOWNS
HELPS MAINTAIN ESSENTIAL PRODUCTION

E. H. ALEXANDER *Industrial Control Division, General Electric Co., Schenectady, N. Y.*

ANY EQUIPMENT in daily use, upon which industry depends for continuity of service, requires periodic inspection and maintenance. Electric control is no exception to this rule. It is vitally important that controls be inspected regularly and that replacements or repairs be made quickly when necessary.

The selection of electric control for a given application depends mainly upon the factors of available power, surrounding conditions, and starting conditions. Before selecting control equipment, the manufacturer should be consulted if there are any unusual service conditions to be met, such as a damp, dusty, corrosive or explosive atmosphere, or if the equipment is to be subjected to vibration, shocks or tilting.

After the proper control has been selected it must be installed correctly and the necessary adjustments made before putting it into service. Panels must be mounted vertically, so that the contactors will open by gravity when power is cut off, and a proper ground connection must be provided. Before power is applied, each contactor and relay should be operated by hand to see that the moving parts operate freely and without binding. All electric interlocks should be clean and should make good contact when closed.

Resistor boxes should always be mounted with the grids in a vertical plane, and should be so located that free ventilation is permitted. To keep heating at a minimum, it is recommended that 6-in. spacers be used be-tween boxes when stacked, and that the stacks be 12 in. apart.

Adjustments—Contactors are designed to operate properly if the line voltage is within 85 to 110 percent of the panel nameplate rating for a-c circuits, and within 80 to 110 percent for d-c circuits. Wider ranges require special devices.

Where there is a continuous 10 percent increase in voltage, suitable coils should be ordered, because, with this increase in voltage there is an approximate 50 percent increase in wattage, which greatly increases the heating of the coil, and reduces its ultimate life.

The armatures should seal (close) when the proper voltage is applied to the coils and should open by gravity when the power is cut off. All contact tips should, when closed, make line contact near the bottom of the face. On opening, the final break will be near the top. The rolling and wiping motions when closing and opening keep the contacts in good condition.

PREVENTIVE MAINTENANCE

A first consideration in keeping control equipment in proper working condition is to prevent an accumulation of dirt, oil, grease or water on the operating parts of the control. It is, therefore, advisable to carry in stock protective paints for the stationary iron parts, and insulating varnish of the proper characteristics for the coils.

Where the air is saturated with moisture, or subject to the action of corrosive gases, it is well to inspect and paint the various control parts from two to four times a year, depending on the severity of the operation conditions.

It is often desirable to add heaters or lamps within the controller inclosure to prevent condensation of excessive moisture, which for best results should be energized continuously.

Circuit breakers or contactors are usually of very rugged construction. Still, it is best to operate them by hand from time to time and check to make sure that all of the clearances are normal and that parts are working freely. Should parts become worn so that adjustments cannot be maintained, new parts should be used. Adjustment and cleaning, as well as renewal of the tips, is necessary and depends on the frequency with which each device is operated.

Occasional inspection should be made of all nuts and connection wires on panels and resistors, particularly when subject to vibration. Close inspection of pigtail connections should be made periodically since these are of finely woven wire for flexibility, and

Right—Panels should be mounted vertically so that contactors will open by gravity when power is off

Below—Surrounding atmosphere largely determines the inclosure, as in these starters for dusty service
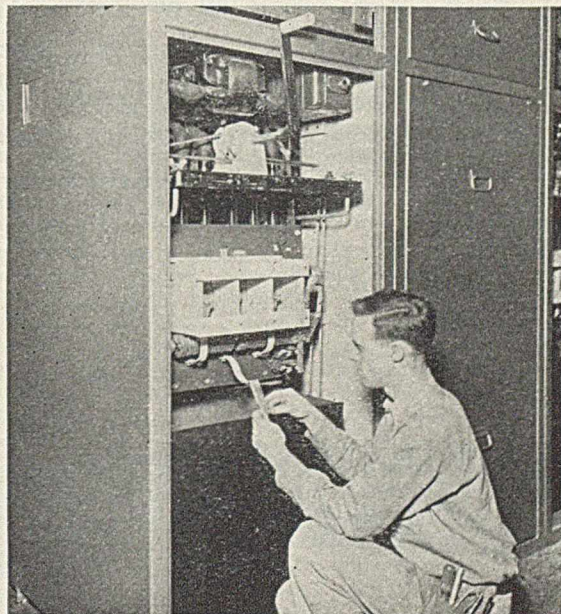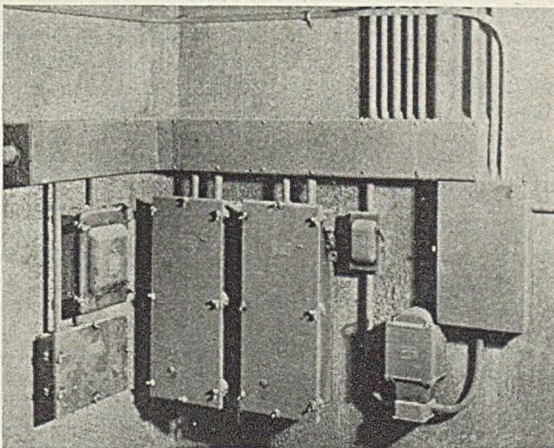
hence are subject to rapid corrosion under adverse conditions.

Float switches should be given the best of care, especially if they are of the moving contact type. The tips should be adjusted and lined up properly and, of course, cleaned if any indication of excessive corrosion is noted. The bearings should be made free to operate and any tendency towards binding should be corrected immediately.

TROUBLE SHOOTING

Troubles are bound to occur in the best of control equipment. Knowing what to do about them when they do occur will save much precious production time.

Contactors—A contactor has several bolted or spring-closed contacts. Excessively high resistance at these contacts is the cause of the very high temperatures, such as 100 to 200 deg. C., that may be reached when the contactor is carrying rated current or less. The most likely point of high resistance is at the contact itself, where the movable tip makes contact with the stationary tips.

However, high resistance may occur at any of the several bolted joints on the contactor. Therefore, if one of these devices begins to develop an excessive temperature, a millivoltmeter should be used to determine which of the several joints has a high-voltage drop across it.

When the copper contact or contacts that have excessive drop across them have been located, correction can be made by opening the contact and removing the oxide with a file (not with sandpaper or Carborundum paper). It is unusual to find a high resistance in a bolted joint unless the contactor has been much over-heated.

The foregoing comments apply particularly to copper contacts because they oxidize readily, and the copper oxide formed has a very high resistance. Depending on various conditions, it may take a short or long time for the formation of sufficient oxide to cause excessive heating under ordinary types of service. However, if sulphur-containing gases are present, a high-resistance film will develop quite rapidly. To prevent this action, the contactor should be mounted in a tightly gasketed inclosing case, or immersed in oil.

When it is desired or necessary to maintain a low resistance of the active contact without servicing, a silver face can be brazed to the two tips. Silver will oxidize and the oxide has a higher resistance than the pure metal, but when heated, silver oxide has the unusual property of reverting back to the metallic form.

Electrical interlocks may fail to make circuit because of oxidation where copper contacts are used. Sometimes such failure occurs because dirt gets between the contacts. By using one hemispherical and one flat tip made of silver, both of these troubles will be overcome.
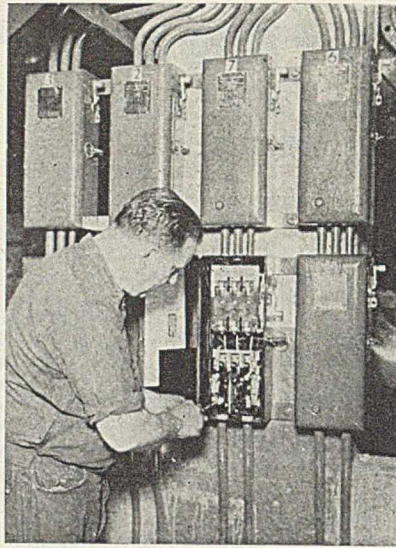
Renewal parts should be kept handy so that replacements can be made quickly

Some maintenance men have the erroneous impression that contact tips that have been roughened by service should be kept smoothed so that they will carry the load. A roughened tip will carry current just as well as a smooth tip.

Of course if a large projection should appear on a tip because of unusual arcing it should be removed, but a tip that has been roughened by ordinary arcing need not be serviced.

Coils—A large percentage of contactor coil troubles can be traced back to heating. Therefore, if the temperature can be reduced coil troubles can be greatly decreased. Since the heating of a d-c coil will vary as the square of the voltage, and the heating of an a-c coil will vary about as the cube of the voltage, it follows that coils should be wound for the voltage that exists on the line. If the ambient temperature is high, this precaution is all the more important.

When an a-c magnet, such as a solenoid, is supplied with constant-voltage excitation it requires a large inrush of current to close the armature. When the armature closes the coil current drops to a normal value. Sometimes, however, armatures may not close because of excess friction or for some other reason and the large inrush current may burn out the coil within a few seconds. Such mishaps can be prevented by the use of a thermal cutout to protect the coils.

Resistors—Resistors are of many types, some of which are more prone to troubles than others. Excessive heating may occur in those having bolted or clamp type joints and the remedy here will be either to insure a clean, tight joint, or in some types, to braze the joint. When cast grid resistors sometimes give trouble by breaking, especially due to machine vibration, the best correction is to replace the grids with an edge-wound or strip re-

sistor which is unbreakable, and is also made of corrosion resisting material capable of withstanding high temperatures without scaling.

Timing Relays—There are many varieties of relay. A number have been designed to operate as a function of time. The one first designed for this purpose was the dashpot type which, however, has certain inherent troubles that have led to the development of other types of timing relays. A dashpot is essentially a close-fitting device that is easily affected by dirt, gumming of the oil, and corrosion of the close-fitting parts. Also the torque of the magnets varies with the position of the solenoid armature in its coil.

If trouble is experienced due to tripping while starting a motor or shortly after getting up to speed, there are three things that can be done: (1) A heavier oil may be used if the relay almost holds. (2) A starting contactor can be used that excludes the overload relay from the circuit until the running contactor comes into operation. Or, (3) The dashpot can be replaced with a temperature type of overload relay.

Temperature Overload Relay—Since the function of a temperature overload relay is to protect a motor under all ambient temperatures, its final temperature should be the same as that of the motor—which is 90 deg. C. Therefore, the relay should just trip if placed in a 90 deg. C. ambient. If a relay does not function correctly, it should be immersed in a pail of water kept at 90 deg. C. and adjusted so that it will. A temperature overload relay does not need any such maintenance attention as outlined for dashpots, but its use does require certain precautions, for example, shielding from strong drafts or sources of heat.

Time Delay Relay—The third type of relay is used for controlling the rate of acceleration of motors and for many other functions where a short time-delay is needed. In the escapement type of relay, a pendulum is used as the governing means, which makes it necessary to mount the relay in a definite position with respect to the motion of the pendulum. To overcome this limitation a new design that has a balanced pendulum has been made available. If the old-type escapements fail to time properly, their mounting position should be checked, or the use of the balanced type should be given consideration.

Corrosive fumes in many plants, such as those manufacturing rayon, coke, sulphuric acid, nitric acid and chlorine, rapidly attack the metal parts of control devices and render them inoperative. Hence, the operating parts are frequently immersed in oil in a container capable of withstanding the corrosive atmosphere. When it is impracticable to oil-immerse a given type of control, the equipment is inclosed in a heavy case with a tight, gasketed cover.

Recent Advances of Catalysis
in Chemical Process Industries

TO EXECUTIVES AND ENGINEERS IN PROCESS INDUSTRIES

Seldom, if ever before in the history of the chemical process industries of this country, have so many important developments been industrialized within so short a period as during the past four years. These developments, largely in the fields of organic chemistry, petroleum technology and synthetic rubber, are characterized by the facts that they are mostly catalytic in nature and that many of them, though conceived in peace, have received their initial industrialization from the war emergency. For it is true now as in World War I that the demands of a war economy initiate and catalyze new chemical developments at an unprecedented rate. This report, lacking the space even to mention many of the industrial advances in chemical catalysis in recent years, deals primarily with catalytic processes involved in this country's programs for producing 100-octane aviation fuel, toluol for T.N.T., and raw materials for synethetic rubbers — all revolving principally around the butane-butylene fractions of petroleum refinery and natural gases. America's most potent secret weapon in this war is catalytic chemistry with butane hydrocarbons as ammunition.

Recent Advances of Catalysis in Chemical Process Industries

SUMMARY AND CONCLUSIONS

Catalysis, that potent force in industrial chemical processes which has suddenly become so all-important in our war effort, is still a comparatively new and little-understood factor for many chemical engineers. In this report, both theory and practice have been briefly surveyed for the benefit of those engineers who would like to know more about catalysis and its role in our war technology.

Dr. Norman W. Krase, an outstanding authority in the entire field, deals with some of the fundamentals of research is catalysis, including the peculiar problems encountered, factors that make for success or failure, and the importance of special requirements for progress in the field. As the complexity of new applications multiply and the volume of research grows at an increasing rate, it is only by giving greater heed to special techniques that catalysis can emerge from an art into an engineering science.

Industrial developments in catalytic chemistry have, in recent years, been focused on petroleum technology and interconversion of petroleum hydrocarbons. High-octane aviation fuels, toluol for more T.N.T., and synthetic rubber processes all depend to a large extent upon petroleum raw materials converted by catalytic processes. Hence, the second part of this report is limited to a brief survey of recent industrial developments in the processes for producing these essentials of war. Voluntary censorship has, of course, limited disclosure of certain operating details and other data.

Basic Considerations

NORMAN W. KRASE *E. I. du Pont de Nemours & Co., Wilmington, Del.*

IN THE FIELD of catalysis there are two factors of major importance. The first is the equilibrium composition that a system attains under selected reaction conditions, the second is the rate at which the composition of the system moves or *can be moved* toward that equilibrium. The problems are, therefore, concerned first with selection of reaction conditions under which favorable equilibrium can be established and second, with means for speeding up the changes in composition that must occur to reach or approach equilibrium.

Thermodynamics is of immense aid in selecting favorable reaction conditions. There is no exact science to aid in selecting the means for accelerating chemical reactions. To say that catalysis is an art is trite but also true. It is to be hoped that out of the vast accumulation of catalytic information—past and future—will come a generally applicable explanation of the action of catalysts. That goal appears to be far away. To reach it there must be general appreciation of the peculiar problems met in this field. To illustrate some of these problems, both in academic and

industrial catalysis, let us consider a common case in heterogeneous catalysis.

PROBLEMS ENCOUNTERED

A mixture of gaseous reactants is to be processed over a solid catalyst to produce a desired compound. Thermodynamic calculations based on available thermal data determine the temperature range in which a satisfactory equilibrium composition can be attained. From the equilibrium constant an operable pressure range is chosen. Other operating factors, such as the molecular ratio of reactants, may frequently be determined by considering methods of recovering the product from the crude reaction mixture and the effect of more complete conversion of one reactant on the ease of recovery. The reactant ratio obviously bears also on the problem of suppressing undesirable side reactions that may occur under the operating conditions selected. In some cases, practically complete conversion of one reactant obtained by using a large excess of others will eliminate or greatly simplify the recovery problem. These considerations are, of course, not limited to catalytic reactions only and follow directly from the application of fundamental physical chemical principles. The next problem is the selection of the catalyst and at this point chemical principles cease to be of aid. Experiment is the sole recourse. The point where experiment begins depends on the knowledge and background of the investigator.

In an industrial organization with long experience in the study of catalysis, the background may be considerable and selection of candidate catalysts for experimental testing can be made with reasonable assurance that the substance will be active. Without such a background, the investigator has available only the published results of other workers on the same or analogous systems and the guidance of any theories of catalytic behavior to which he may subscribe. In the words of Wilder Bancroft, "A

good theory is one that leads to an experiment."

SUCCESS-OR-FAILURE FACTORS

These preliminary considerations now bring us to the main problem of catalysis—industrial or academic—and an elaboration of the prime factors that determine success or failure of the investigation. In "success or failure" are included—for the academic worker—the feasibility of others to reproduce his results, while for the industrial worker the term includes the ability to interpret experimental data so that the reaction may be scaled up to commercial operation. It is on this very important point that the main difference between industrial catalysis and any other kind appears. The academic worker ordinarily has no opportunity to test his conclusions on a larger scale or even to extend his work beyond the narrow limitations of laboratory apparatus. He should, however, give full consideration to the possibility of reproduction of his work by others. This is not to disparage the contribution that academic workers can or have made to this field but rather to focus attention on the main desiderata that have made some published work worthless.

Because catalysis is a designation used in lieu of scientific explanation, it is best to approach the problems with complete awareness that *any* factor may be important. Continuing our consideration of a common case of heterogeneous catalysis, we begin experimental work. The catalyst is prepared and the reactant gases processed under selected conditions. Evaluation of the experimental results leads to further experiments to improve them. Such further experiments are designed to determine the effect of selected variables such as catalyst composition, temperature, pressure, time of contact, reactant ratio and others. With each change in conditions, the investigator attempts to develop a better understanding of the catalytic process so that gradually, with accumulated facts serving as guideposts, he reaches a satisfactory solution.

Frequently, at this point, the results are published and become a part of the raw material out of which attempts will later be made to fashion a comprehensive and scientific theory of catalytic action. If the work has been well done, progress has been made toward that desirable goal. If, on the other hand, the materials used in preparing the catalyst were impure or of unknown composition

in respect to traces of impurities, or if the reactant gases contained unrecognized constituents, or the exact procedure of catalyst preparation has not been disclosed, it may be difficult if not impossible to reproduce the results. Deductions based on such results must also be faulty.

In the case of industrial research, the attainment of satisfactory laboratory results marks the beginning of larger scale work which applies rigorous tests of the validity of the conclusions reached. In addition, new problems are faced. The shift from laboratory to plant scale may be accompanied by necessary changes in materials of construction, in the source and purity of gases, in the raw materials for catalyst manufacture, and in the accuracy of control of operating variables. These and other factors are capable of profoundly influencing the results. Let us examine a few of the causes of inability to scale up results.

CATALYST ACTIVITY

A solid catalyst frequently contains several elements. It may be predominantly one metal, such as copper or iron, to which have been added small amounts of other metals, oxides or salts. The composition of a catalyst can be determined with great accuracy by analytical methods. It is a well known fact, however, that catalysts of identical composition may have widely different activities. The explanation must lie in the methods of preparation. For most chemical purposes, a reaction between two compounds in solution may be carried out over a range of temperature and concentration conditions to get a desired product. It is not uncommon in the case of catalyst preparation to find that the temperature, concentrations, order of addition, degree of agitation and similar factors have a bearing on the activity of the final catalyst.

An active catalyst can be ruined by exposing it to certain temperatures or to certain atmospheres without a measurable change in its composition. To define the method of preparation to include *all* factors is a task requiring meticulous attention to detail. Too often results cannot be duplicated because of omission of preparative detail. To say that a catalyst is copper is to say that the minor impurities that frequently accompany copper are of no importance. In a high state of purity copper differs from ordinary copper "promoted" by impurities. Emphasis on purity is applicable equally to reactants.

Initial laboratory work should be done with substances of the highest attainable purity so that an understanding of the chemistry of known compounds is obtained and not that of a fortuitous mixture. The effect of impurities can only be gauged by comparison with the known behavior of pure reactants.

Translation of laboratory results to practical plant conditions raises questions of gas purity that can be answered in either of two ways: (1) rigorous purification of the gas to be processed; (2) development of tolerance in the catalyst to permit processing impure gas.

Experience with a large number of cases establishes the former as a generally superior procedure. For reasons that are not known, a catalyst working on pure gas almost always has a higher productive capacity and a longer life than when used on impure gas. This is not to say that catalysts insensitive to poisoning by impurities are not to be preferred because irregularities in operation of the purification system may subject the catalyst to impurities and cause deactivation. A combination of ruggedness, tolerance for foreign substances, and maximum capacity and activity is an ideal rarely reached in industrial catalysis.

On the other hand, rigorous purification of thousands of cubic feet per hour of gas is a chemical engineering problem of great magnitude and an operation that adds considerably to the cost of the product. As a compromise method of operation that under some circumstances has much

This 500 bbl.-per-day Thermofor Continuous Catalytic Cracking plant saves strategic construction metals and can produce materials for 100-octane gasoline, butadiene and toluol

Courtesy of the Lummus Company
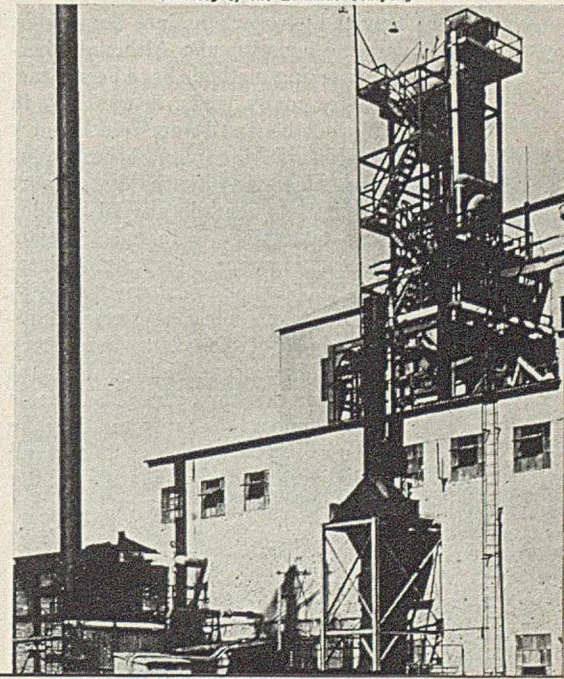
to commend it, we find "guard" catalysts employed. Such a catalyst is rugged and tolerant of small concentrations of poisons difficult to remove from the gas but is also of sufficient activity to cause the desired reaction to occur to a limited extent. The product so formed is separated from the unconverted gas, carrying with it in some cases a considerable fraction of the poisons. The last traces of poisons combine with the guard catalyst, leaving a highly purified gas to be sent on to the converters where the main synthesis of the product occurs. In this way, long life and high activity of the catalyst is obtained and the guard catalyst can be renewed at intervals so as to maintain its protective function.

LABORATORY-PLANT TRANSFER

Transfer of a catalytic process from laboratory to plant may result in uncovering phenomena that are non-existent in the small scale work. Large volumes of catalyst are difficult to maintain at constant or uniform temperature. Uneven flow or channeling of reactants through large cross-sectional areas of catalyst may localize heat effects so that the temperature is raised or lowered to unfavorable levels. Local overheating can cause catalyst deterioration or disintegration. Furthermore, the movement of catalyst particles in a bed by high velocity gas may cause considerable abrasion and powdering.

Such problems are usually not met in laboratory work and when encountered on a larger scale may re-open the whole problem of catalyst development. To meet such situations, there have recently been developed modified methods of operation in which the catalyst is suspended in the stream of reactants for a sufficient period to accomplish the desired conversion and then separated. The recovered catalyst can be discarded or used again with or without treatment to restore any lost activity. These "fluid catalyst" processes have found application in processing petroleum hydrocarbons at high temperatures where carbonaceous deposits tend to form on the catalyst and cause deactivation. Their utility in such cases lies also in the fact that continuous processing is possible instead of a cycle involving intermittent purging and cleaning of a stationary catalyst bed.

The accomplishments credited to catalysis are numerous and important. Both academic and industrial workers have contributed to the progress. As the complexity of new applications increases, as the volume of research on catalysis grows at an increasing rate, we will be well advised to give greater heed to the special requirements for success in this field. Only in that way can this art become a science.

Recent Applications

EDITORIAL STAFF

IN THE FIELD of petroleum technology, few industrial processes have attracted such wide attention within such a short time as those involving catalytic cracking of the heavier hydrocarbons into the lighter, gasoline constituents. Although thermal cracking methods have been practiced for many years, it was only in 1938 that the first large-scale Houdry catalytic cracking plant began operations. However, by the latter part of 1941 there were already 16 Houdry plants operating or in construction, with cracking capacities ranging from 8,000-20,000 bbl. per day.[1] Today, there are even more, the exact number and capacities being a military secret. This process, highly important in our war economy, gives high yields of 80-octane gasoline from distillate fuel oil. It is capable of taking all the hydrocarbons in a wide-boiling range stock and converting them into an unusually uniform gasoline product regardless of the type of raw stock that is handled. The product is highly suitable for blending to 100-octane aviation fuel. Also important for the synthetic rubber program is the fact that this process produces an aviation fuel base stock without drawing upon our vital supplies of butane and butylenes, principal petroleum raw materials for butadiene.

CATALYTIC CRACKING

Among catalytic cracking processes, of course, are others such as those of the Universal Oil Products Co. and the newer naphtha reforming process controlled by M. W. Kellogg & Co., Standard Oil of New Jersey and Standard Oil of Indiana.

Importance of catalytic cracking has been shown by Wilson[2], who stated that within the next few years it is expected that units treating something in the order of 500,000 bbl. per day will be in operation. Such units will be capable of converting about 50 percent of the material charged to the catalyst into 80 motor octane or 90-95 research octane gasoline. These 250,000 bbl. per day of extremely high octane gasoline should be compared with requirements for premium grade motor gasoline for 1941, which was approximately 180,000 bbl. per day.

Within the past two years, definite improvements have been made in operating practice for the Houdry catalytic cracking process. These improvements are the result of new types of catalysts rather than radical changes in basic designs.[1] Major improvements are higher gasoline yields and octanes in the conversion of heavy overheads from reduced crudes, gas oils and the reforming of certain natural stock.

Catalyst used in the Houdry catalytic cracking process consists of a mixture of activated oxides of alumina and silica, the mixed oxides being decidedly superior in activity to either oxide alone. Pressures range from 40-60 lb. per sq.in. and the operating temperature is about 850 deg. F. Certain naturally occurring clays, such as the montmorillonites, have superior catalytic behavior in these reactions compared with other types of natural alumino-silicates.[3]

Catalysts in these cracking processes actually permit rupture of the carbon-carbon linkages in the long hydrocarbon chains, decrease the amount of polymerization to tar and at the same time encourage aromatization and isomerization of the cracked fractions in the desired boiling range. According to Taylor,[3] research utilizing heavy hydrogen as an isotopic tracer shows that active cracking catalysts cause carbon-hydrogen bond exchange at temperatures well below cracking temperatures. This indicates that the dehydrogenation of the hydrocarbon molecules is a condition precedent to the rupture of the carbon-carbon linkage.

As the cracking reaction proceeds, carbon or "coke" is deposited on the surface of the catalyst particles, thus decreasing their activity. It then becomes necessary to revivify the catalyst. Oil vapors are shut off, vacuum applied to purge the system, and then preheated air is admitted to burn off the deposited carbon as carbon monoxide, with the liberation of heat. The staggered use of batteries of catalyst

Table I—Typical 100-Octane Gasoline Blend

Blending agent (88-100 octane).....50%
Base stocks (75 octane)............40
Isopentane 10
Tetraethyl lead (Max. per gal.).... 3cc.

chambers insures the continuous operating cycle. The actual regeneration cycle is short; about 10 minutes on stream, 5 minutes purge, 10 minutes for the regeneration and then a 5-minute purge. The catalyst lasts more than six months and frequently more than a year.

Temperature control in the catalyst "cases" is important. Heat must be supplied to maintain a cracking temperature of 850 deg. F., while temperatures during regeneration must not exceed 950 deg. F. Satisfactory heat transfer can be obtained by using a mixture of sodium nitrite, nitrate and potassium nitrate as transfer fluid in the cases.

FLUID CATALYST

The Houdry catalytic cracking process as described above employs a solid or "lump" catalyst either in a fixed or moving bed. However, in 1941 the Standard Oil Co. of New Jersey announced[4] a new catalytic cracking process which uses a so-called "fluid" or moving catalyst. This, in powdered form, is suspended and flows along in intimate admixture with the oil stream passing through the catalytic system. The catalyst is separated from the reaction products by centrifugal force in a separator of the "cyclone" type and passed through a regenerating system where the coke is burned off with air. The main advantage of this type of catalyst is that it renders the process continuous throughout. Operating pressure is low, probably not more than three or four atmospheres.

The first full-scale cracking plant embodying the "fluid" catalyst principle was completed this year and is now operating successfully.[5] It will be followed by 30 or more units now being built by Standard Oil of New Jersey and others in the industry under license.

Announcement has been made that with slight modifications in operating methods, fluid catalytic plants can be made to produce simultaneously large yields of high-octane gasoline and as much as three times the amount of butenes for butadiene as originally contemplated. This subject of raw material for synthetic rubber production will be discussed later in this report.

Very recently, the Lummus Company announced an important development in plant conversion to catalytic cracking for production of source materials for 100-octane gasoline, butadiene and toluol. According to this, any existent thermal cracking or topping unit can be converted to a "Thermofor" catalytic cracking plant by the addition of a reactor, Thermofor kiln, catalyst elevators and facilities with a saving of approximately 50 percent in strategic materials over a complete unit. Six Thermofor catalytic cracking conversion elements and a number of complete plants are already under construction by Lummus for major oil companies. The process is licensed by the Houdry Process Corp.

According to the latest information[5], there are at least 16 companies known to be engaged in the present program of producing 100-octane fuel by various methods, including catalytic cracking processes. By next year the number will be more than doubled. The proportion in which super-fuel is believed to be derived from the various processes used in its manufacture is given in Table II. However, with the completion of catalytic cracking plants now scheduled, it is expected that well over half of our 100-octane base stock will ultimately be supplied by this process as compared to the 20 percent that is now supplied.

HYDROFORMING PROCESS

Another important recent development[6] in petroleum technology, especially now that this nation is at war and hence needs larger amounts of toluol as well as high-octane fighting fuel, is that of "hydroforming". This is a high-temperature, high-pressure catalytic process that combines dehydrogenation with aromatization, using straight run or catalytically cracked naphthas as charging stock, to produce high-octane gasoline. The conversion takes place in a hydrogen-rich atmosphere.

Most important characteristic of the hydroforming process is the catalyst, which causes ring formation and ring closure in hydrocarbon molecules which have just undergone partial dehydrogenation. Hence the final product contains a high percentage of aromatics as compared to the feed. The first large-scale hyroforming plant, put in operation during 1941 by the Pan American Refining Corp., can take a charge of 40-45 octane number heavy naphtha and reform it with an 80 percent yield into 80 octane gasoline, or by changing operating conditions, can equally as well produce upward of 80 percent arom-

Table II—Present Relative Importance of Processes Producing Super-Fuel Stocks[5]

Base Stock

From natural naphthas...........70%
By catalytic cracking...........20
By hydrogenation................10

Blending Stock

By alkylation...................95
By hydrogenation................ 5

atics, chiefly toluol and xylol. This single unit alone could produce approximately 5,000,000 gal. of toluol yearly.[6] Operation of the process is similar to other "fixed-bed" catalytic processes. As in the Houdry process, coke is gradually deposited on the catalyst, so that eventually it becomes necessary to remove it by burning.[7] However, the lack of very reactive olefin hydrocarbons allows a relatively long cycle of operation before coke or carbon dulls the activity of the catalyst.
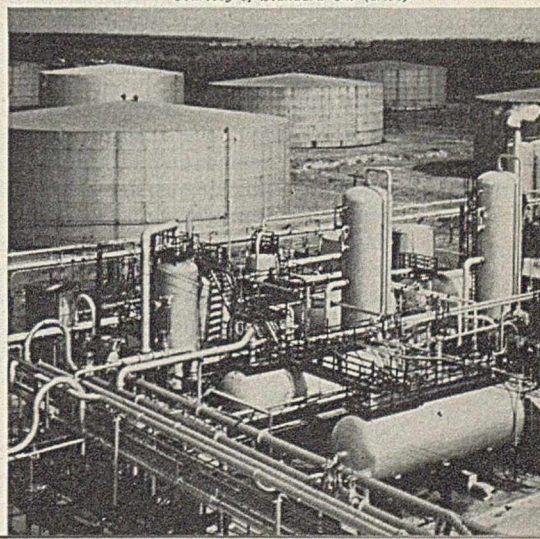
CATALYTIC TOLUOL

Catalytic dehydrogenation-aromatization of hydrocarbons containing six or more carbon atoms can be obtained in a temperature range of 840-1,020 deg. F. in presence of a group of catalysts including the oxides of chromium, molybdenum, and vanadium supported on activated alumina.[8] Silica is inactive as a supporting material. Straight-chain hydrocarbons are dehydrogenated and converted to cyclic hydrocarbons with eventual formation of aromatics. Cyclization is accompanied by some decomposition and deposition of carbon, so that the catalyst mass must be revivified by burning off this carbon with air. Yields of toluol from normal heptane as high as 90 percent have been reported. Other products from normal hexane and octane are benzol and xylol, with the latter being formed more easily than benzol.

Although toluol was first produced

Catalytic alkylation plants similar to this Texas unit furnish some 95 percent of the blending stock for America's aviation super-fuel

Courtesy of Standard Oil (N.J.)

in this country from petroleum in 1940, it has been estimated[9] that probably more than some 70 percent of our toluol needs will soon be derived from petroleum raw materials. Catalytic processes as described above will account for most of this capacity. In fact, the largest petroleum plant manufacturing toluol in this country began operations in 1941, employs the catalytic method and has a capacity of nearly 30,000,000 gal. annually. Many other catalytic plants are now under construction at various locations. Thus production of toluol from petroleum raw materials by cyclization and by hydroforming, previously mentioned, represents a major contribution of catalytic chemistry to the war effort. In addition, toluol is obtained from petroleum bases by various simple extractive methods.

ALKYLATION FIGHTING FUEL

Though hydrogenation was the original commercial process for making 100-octane blending agent, it has since been largely replaced by a newer method called alkylation, a modified type of polymerization. In fact, some 95 percent of blending stock for super-fuel is now being produced by alkylation processes. The first plant using the catalytic alkylation process in this country was put in operation in 1938 by Standard Oil of New Jersey. However, within the last few years, considerable advances have taken place in the technique of alkylation and it is now possible to produce an alkylate of at least 95-octane number suitable as the major blending component of 100-octane aviation gasoline.[10]

Catalytic alkylation processes usually employ concentrated sulphuric acid as catalyst to promote joining an isoparaffin (such as isobutane) with an olefin (such as butylenes and amylenes). If isobutane and butylene are taken as charging stocks the final product is iso-octane. The process is stated to be the best available for a high yield of 100-octane fuel from a given quantity of olefin. It can produce at less cost than any other process available to the industry at the present.

Catalyst used is 98 percent sulphuric 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 from isomerization of normal butane. Spent sulphuric acid catalyst leaves the unit at a strength of 88-91 percent. The operation is carried out at

Table III—Requirement for Output of Petroleum Industry, Bbl. per Annum[13]

High octane gasoline (100 and over)	91,250,000
Toluol for TNT	6,000,000
Butadiene for synthetic rubbers	3,400,000

Note:—The above butadiene figure is based on the assumption that 225,000 short tons of butadiene requirements will be obtained from alcohol and 423,200 tons from petroleum bases. This total of 648,200 tons of butadiene (Rubber Reserve Corp., as of July 15) was revised to 717,800 tons (American Chemical Society meeting Sept. 9). A recent communication from the Sun Oil Co. places the final production of butadiene from petroleum sources for synthetic rubber at 660,000 tons annually. Of the 476,000,000 gal. of alcohol estimated to be needed for war purposes in 1943, it has been predicted that more than half will be used in the manufacture of butadiene.

atmospheric pressure and a temperature of about 95-123 F.[11] The reaction is rapid and exothermic and appears to take place in two steps. The first involves formation of an alkyl ester such as butyl hydrogen sulphate. This is followed by combination of this material with isobutane and liberation of acid. The higher the ratio of isoparaffin to olefin in the feed-stock, the greater is the yield, the higher the octane number, and the smaller the acid consumption. Hence, this ratio is usually held at 5:1 or higher. Commercial plants often operate with contact time of 20-40 min. Make-up acid may amount to 1-3 lb. per gal. of product, but frequently is less than 1 lb. per gal. of alkylate.

Another alkylation process in commercial operation is the non-catalytic "neohexane" method in which isobutane and ethylene are alkylated at about 950 deg. F. and 3000-5000 lb. pressure to neohexane, which has an octane rating of about 94.[12] This thermal process was announced in 1939.

Universal Oil Products Co. has just announced the development and licensing for commercial operation of a hydrogen fluoride catalytic alkylation process. Installations are under construction in a number of refineries. This process is of war-time importance since it uses more of the available olefins for alkylation than the sulphuric acid process. The hydrogen fluoride catalyst not only causes reaction of isobutane with butylene, but also reacts isobutane with propylene and pentylenes to give additional supplies of alkylate suitable for blending in 100-octane fighting aviation gasoline. Isobutane for the process is obtained by isomerization.

POLYMERIZATION PROCESSES

Industrially, polymerization is older than certain of the other catalytic petroleum treating processes, since it really became a factor in petroleum refining some seven or

eight years ago. Catalytic polymerization is applied commercially to propylene and butylenes to form liquids in the gasoline boiling range. Products' process uses orthophosphoric acid, copper pyrophosphate, and sulphuric acid as catalysts. The Universal Oil Products' process uses orthophosphoric acid on a solid carrier, while the Polyco process (Polymerization Process Corp.) uses copper pyrophosphate. Operating temperatures of both processes range from about 250-400 deg. F. and pressures are about 700-1000 lb. Catalyst life averages about 90 gal. of polymer per pound of catalyst, with 85-95 percent conversion of byproduct propylene and butylene gases from the cracking, decomposition or dehydrogenation operations to polymer gasoline. This polymer has an octane number of about 84, but a blending value equal to 110-130 octane rating. Much of this product finds its way into aviation fuel.

For a number of years the Shell catalytic polymerization process has been converting butylene into octenes by the use of sulphuric acid. The original Shell cold-acid process converted isobutylene, while the more recent hot-acid method polymerizes a portion of the normal butylene along with the isobutylene. Details of the two processes have been given by McAllister.[13] The octenes produced by polymerization are then catalytically hydrogenated to octanes.[14]

Also of industrial importance is the Universal Oil Products Co. process for converting, by catalytic polymerization, the isobutylene fraction of petroleum gases into isooctenes which, by hydrogenation, are converted into iso-octanes. The iso-octanes produced by hydrogenation have octane ratings of 95-98, and some individual octanes have values in excess of 100. Low-pressure hydrogenation, using a nickel catalyst, is employed for the hydrogenation of octene. Actually, the operating pressure is about 75 lb. and the temperature about 325 deg. F. in the catalytic polymerization process of Universal Oil Products Co.

CATALYTIC ISOMERIZATION

Isomerization is a very important adjunct to alkylation, since the availability of normal butane from thermal and catalytic cracking for alkylation purposes is far greater than that of isobutane. The normal butane, however, was useless in alkylation until perfection of the isomerization process for converting it into isobu-

tane, from which alkylate gasoline of high octane rating can be produced. It is in this field that the aviation gasoline-synthetic rubber programs tend to conflict, as normal butane is also the chief petroleum source of butadiene.

The Shell butane isomerization process, used in conjunction with the alkylation unit, passes normal butane in vapor form and anhydrous hydrogen chloride at about 175 deg. through the catalyst, consisting of anhydrous aluminum chloride supported on a granular bed. The hydrogen chloride serves to activate the catalyst and is entirely removed from the product. The process results in almost complete conversion of normal butane to isobutane. The heat of reaction is so low that no special equipment need be used to maintain the desired temperature. The catalyst is rugged, cheaply produced and has long life so that regeneration is not necessary. It is resistant to poisoning, although it is necessary to reduce the proportions of olefins and pentanes in the charge stock to a low figure, since both these produce objectionable byproducts and tend to shorten the life of the catalyst.

STYRENE FROM ETHYLENE

Finally, of tremendous importance in the Buna S synthetic rubber and polystyrene plastics programs, ethylene can be catalytically reacted in the liquid state with benzene in the presence of aluminum chloride (by Friedel-Crafts reaction) to yield ethyl benzene which, in turn, is converted to styrene by dehydrogenation by thermal methods or over catalysts of the copper chromite type.[3] Steam is used as a diluent to improve the equilibrium conversion. Recently[15] there has been reported a catalytic process for reaction of ethylene and benzene in the gaseous state instead of the liquid phase now used by industry. So important is styrene now that the Buna S synthetic rubber program alone, when in full swing, is said to require the production of some 234,200 tons of this material annually.[15] In contrast, only a total of some 2,200 tons of polystyrene resins were produced during 1940. Thus, outside of the synthesis of high-octane fuel, toluol, and butadiene by catalytic petroleum processes, the manufacture of styrene may soon become one of our largest industrial catalytic processes.

Most recent interest in propylene as a raw material for chemicals has centered in the Shell Development Co. process, announced in
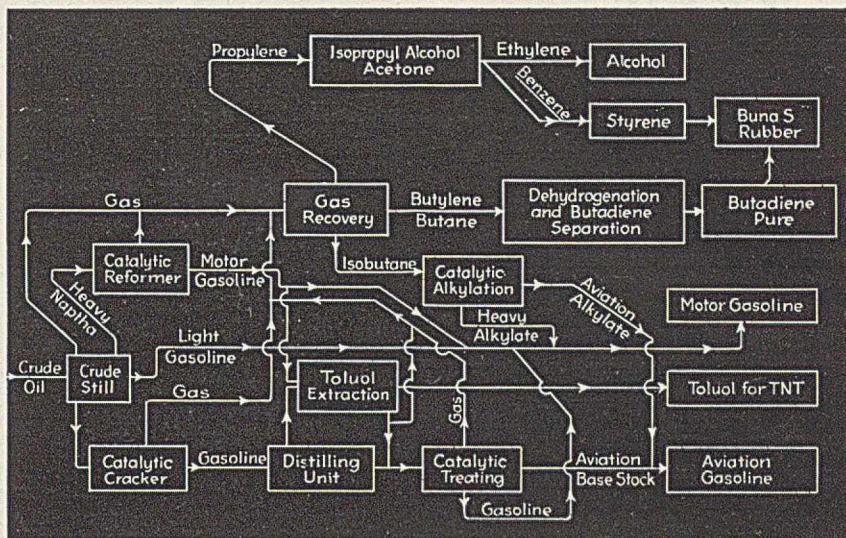
One of the many ways by which raw materials for Buna S rubber, aviation gasoline and tolvol can be produced from petroleum fractions by catalytic methods

the latter part of 1940,[16] for the synthesis of glycerine by chlorinating propylene or propane and then following by hydrolysis. Caustic soda is the usual catalyst in the hydrolysis phase, while 10 percent caustic soda and one percent soda ash accomplish conversion of the glycerine monochlorohydrin to high-purity glycerine. Either alkali or catalytic cuprous chloride can be used in conversion of allyl chloride (one of the chlorination products of propylene) to diallyl ether and allyl alcohol.

This brilliant development of the Shell Development Co. places this country on an independent basis in respect to glycerine, now being used for explosives and in alkyd resins. The process is ready for large-scale production whenever the demand for glycerine or high prices would warrant further development. Williams[17] has described the process in detail.

BUTADIENE FOR BUNA

This leaves for discussion the importance of the C_4 hydrocarbons as raw materials for butadiene and for butyl rubber. There has been a great deal of confusion and political forces involved in the synthetic rubber program, most of which have revolved around the various raw materials and processes for producing butadiene. Synthetic rubbers of the Buna S type contain about 75 percent butadiene. Details of the processes, due to censorship regulations, are still not generally available.

However, in general there are four basic processes for producing butadiene that have reached either commercial or pilot plant production in

this country. They are: (1) thermal cracking of mixed hydrocarbons; (2) catalytic dehydrogenation of petroleum refinery or natural gas butane and butylene; (3) catalytic conversion of ethyl alcohol, usually in several stages; (4) fermentation of grain to 2, 3-butylene glycol and conversion of this to butadiene.

The three processes actually scheduled for commercial production at this time are those of thermal cracking, catalytic dehydrogenation of butane-butylene fractions, and the Carbide process using ethyl alcohol. Although something like 100,000 tons of butadiene per year are expected to be produced from thermal cracking plants, this report will not deal with this non-catalytic process.

One of the commercial methods of producing butadiene to be used in this country starts with the butane as recovered from natural gas recycling plants or from butylene from petroleum reforming or cracking processes. Catalytic dehydrogenation of this butane or butylene fractions gives crude butadiene which must be purified by distillation or extraction processes. In the case of butane, dehydrogenation can be accomplished in two steps by the use of aluminum oxide—chromic oxide catalyst. At a temperature of about 1,100 deg. F. at atmospheric pressure, butylene is formed with liberation of hydrogen. As much as 42 percent conversion per pass has been reported. If the operating temperature is raised to about 1,200 deg. F. and the pressure reduced to 0.25 atmosphere, the butylene is dehydrogenated into butadiene. The catalyst is of the same general type as for de-

hydrogenation of butane and includes an aluminum oxide carrier coated with oxides of chromium, vanadium, molybdenum, etc.

In the Houdry combined two-stage, dehydrogenation catalytic process, the heat required for the chemical change of butane to butylene and from butylene to butadiene is furnished by burning the carbon deposit on the catalyst during the dehydrogenation stages. Regeneration of the catalyst is also accomplished by burning the carbon deposit by passing air through the mass. The useful life of the catalyst is expected to be more than six months. The crude butadiene produced by catalytic dehydrogenation is not sufficiently pure for the rubber polymerization process, and it is this purification problem that has been one of the principal difficulties in the commercial development of butadiene-base synthetic rubbers. However, it is expected that probably some 350,000 tons of butadiene per year will be produced from petroleum and natural gas C₄ fractions.

An earlier process for making butadiene involved the direct chlorination of butylene to the di-chloro compound, and then heating this in the presence of barium chloride to give butadiene and byproduct hydrogen chloride. The use of large quantities of chlorine is the outstanding disadvantage of this process.

BUTADIENE FROM ALCOHOL

One established process for the conversion of ethyl alcohol to butadiene consists of four stages; dehydrogenation of alcohol to acetaldehyde, which is then condensed to aldol; from this 1, 3-butylene glycol is produced by reduction, which in turn is dehydrated to 1, 3-butadiene.

Catalytic condensation of acetaldehyde to aldol (3-hydroxybutanal) can be accomplished by various catalysts such as aluminum hydroxide, iron or zinc oxide, or a suitable alkali. Aldol is reduced to 1, 3-butylene glycol in the presence of Raney nickel catalyst at a pressure in the neighborhood of 800 lb. per sq. in., while this glycol can be catalytically dehydrated to 1, 3-butadiene by heating in the presence of sulphuric acid at 390 deg. F. or by passing it over any one of a very large number of catalysts.

A one-stage catalytic process for this conversion involves flowing 95 percent alcohol through a heated quartz tube at about 750 deg. F. and 0.25 atmosphere pressure in the presence of a catalyst, possibly alumina for dehydration and zinc oxide for dehydrogenation.

Table IV—Typical Reaction Mixture for Buna S Rubber

Butadiene	80 parts
Styrene	20
Glue	5
Sodium alkyl naphthalene sulphonate	5
Water	100
Polymerization Agent	0.5–1.0
Orientation agent	0.5–1.0

The Publicker Commercial Alcohol Co. reports the conversion of better than 33 percent of 190-proof ethyl alcohol into butadiene by the Szukiewicz process, which consists essentially of a single pass of alcohol over a catalyst at elevated temperature. Ethylene, butylene and hydrogen are byproducts of the process. The availability of the catalyst material is one of the favored claims of this method. This process originated in Poland and is understood to be used commercially in Russia.

FERMENTATION METHODS

Another process proposes to use a fermentation reaction to produce butanol from grain, to dehydrate this alcohol to butylene, which is then dehydrogenated to butadiene. This process evidently does not appear attractive enough to be included in the present rubber program.

Another new process just announced (see page 95, this issue) involves grain fermentation with *Aerobacter aerogenes* for less than 40 hours to produce 2, 3-butylene glycol. This, however, must be separated from the "beer." One such method uses butanol as a selective solvent, followed by separation of the butylene glycol from the solvent by distillation. The 2, 3-butylene glycol can be esterified with concentrated acetic acid to form the diacetate which can then be pyrolyzed at about 900 deg. F. to give high yields of butadiene. An overall conversion of 88 percent has been obtained on pilot plant equipment. The butadiene obtained can be used without further purification in making synthetic rubber. This process has been studied by the U. S. Department of Agriculture, Joseph E. Seagram & Sons, and others. It is now in the pilot plant stage of development.

Still another process, at present not involved in the synthetic rubber program, polymerizes acetylene in the presence of cuprous chloride and ammonium chloride as catalysts and then selectively hydrogenates the un-

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saturated polymer to butadiene. In Germany, butadiene is obtained by synthesis from acetylene, going through acetaldehyde and catalytic reduction to 1, 3-butylene glycol as previously mentioned.

Catalytic synthesis of styrene, the other principal ingredient of Buna S rubber, has already been mentioned. In the actual polymerization of butadiene and styrene (or acrylonitrile) to form buna rubber, a mixture of the two ingredients are emulsified with water by means of soap or other wetting agent. Polymerization catalysts, usually oxidizing agents such as hydrogen peroxide, sodium perborate, ammonium persulphate or organic peroxide, are added together with an orientation agent to exert a directing influence to favor formation of linear polymers. Usually some chlorine-containing compound, such as carbon tetrachloride or hexachloroethane, is used for orientation purposes, but sodium cyanide can also be employed. The emulsified reaction mixture is usually heated at 100–140 deg. F. for 10–15 hours to complete the polymerization. A typical reaction mixture employed in the emulsion process is given in Table IV.

Butyl rubber, of which this country plans eventually to produce 132,000 tons yearly, is a copolymer containing isobutylene with some 5 percent butadiene. Polymerization is accomplished[3] by use of a boron fluoride catalyst at temperatures below 32 deg. F.

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Machinery, Materials and Products

Self-Cleaning Exchanger

READY REMOVAL of scale and sludge deposits from the tubular heat transmission elements is the feature of the Paracoil self-cleaning tubular heat exchanger which has recently been announced by Davis Engineering Corp., 1064 East Grand St., Elizabeth, N. J. As shown in the accompanying illustration, the heat exchanger is equipped with a hand wheel at one end. The shaft of the hand wheel extends through a stuffing box and is provided with a screw thread to effect longitudinal motion of the shaft. The inner end is connected to an assembly of baffles through which the U-shaped heat transfer tubes extend. The tubes, through which the heating or cooling medium flows, are connected to a divided tube sheet at the end of the exchanger opposite to the hand wheel so that both inlet and discharge connections for the tubes are made at that end.

When it is desired to clean the heat exchanger, the hand wheel is rotated so as to move the baffles a short distance longitudinally along the tubes, thus scraping the outside of each tube and loosening the solids so that they can be carried away by the flow of liquid outside the tubes. Thus it is unnecessary either to take the exchanger down for manual cleaning, or to take it out of service for one of the various solvent methods of cleaning sometimes employed. This equipment is built in various commercial sizes and in a variety of materials to resist the corrosive action of the substance being heated or cooled.

Aneroid Manometer

A MANOMETER for flow and liquid level measurement has been developed by Taylor Instrument Cos., Rochester, N. Y., which employs a metal-bellows pressure responsive element instead of the usual mercury and float system. Aside from the advantage that there is no mercury to be blown out due to line surges, the new manometer releases mercury required elsewhere for the war effort.

Instead of a stuffing box, the new instrument employs a torque tube assembly which gives a completely closed system and is designed to eliminate friction and lubrication. The metal bellows is built to withstand high over-range without damage. Under steady flow conditions the instrument is said to be accurate within 1 percent of full scale range, this type of construction being available for all manometer-type indicating and recording meters and controllers. It is built for standard ranges between 20 and 500 in. of water and the range can be changed on the job by substituting pre-calibrated torque tubes.

Tandem Timer

To PERMIT practically any timing sequence that may be desired, Industrial Timer Corp., 113 Edison Place, Newark, N. J., has developed a new tandem timer which is available in six

Self-cleaning tubular heat exchanger

Aneroid type manometer

New tandem timer

Diaphragm pump for heavy slurries

models offering settings from $\frac{1}{4}$ second to 2 hours and 45 minutes, with longer time cycles available in specially built equipment. The new equipment consists of a control unit and two timing elements. The latter are individual synchronous-motor-driven, automatic-resetting timers having a graduated dial and knob for selection of the timing period. The control cabinet is a box into which the two timers are plugged and contains the starting and repeat or single-cycle switches. It also contains single-pole, double-throw load relays controlled by the timers. In a typical set-up, the timer might control one circuit for, say, 4 seconds and the other circuit for $2\frac{1}{2}$ seconds in sequence, after which it either repeats or shuts down, as desired. Pilot lights show which circuit is being energized.

Openable Bag Closure

LATEST among the developments of Bemis Bro. Bag Co., 601 South 4th St., St. Louis, Mo., is the Bemis Rip-Cord closure for the closing of cotton and burlap bags, which provides a simple and easy means of opening the bags without injury. The Rip-Cord is sewn into the closure of the bag with a regular two-thread bag closing machine. Only minor, inexpensive adjustments are necessary to adapt the machine for this purpose. A quick jerk of the Rip-Cord opens the bag instantly without tearing or damaging. Not only is the new closure easier to open, but it is claimed to permit filling the bag fuller than when closure is effected by tying. Thus, ten Rip-Cord closed bags can be piled on a hand truck, whereas only eight tied-top bags can be loaded on the same truck, according to the manufacturer. As compared with a wire-tied bag, the Rip-Cord closure is said to permit using bags 2 in. smaller. The new method is thus claimed to be an important step in bag conservation.
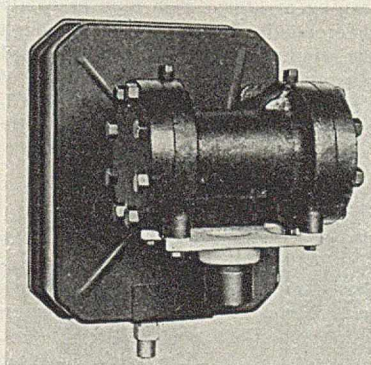
Improved Diaphragm Pump

DELIVERY PRESSURES up to 100 lb. per sq.in., suction lifts as high as 18 ft. and capacities ranging from 1 to 100
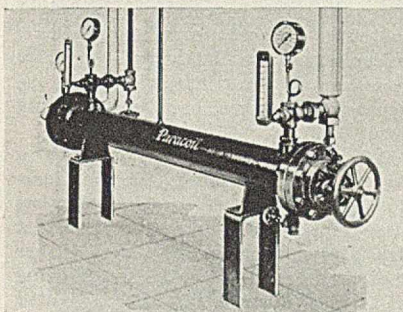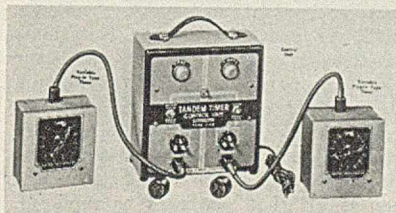
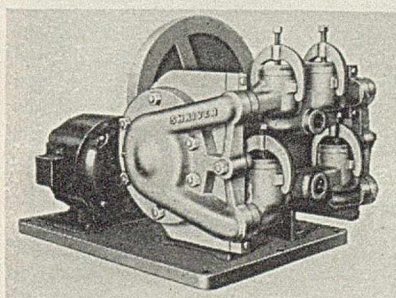g.p.m. are available in a new design of diaphragm pump offered by T. Shriver & Co., Harrison, N. J., especially for the handling of slurries or suspensions containing a high percentage of crystalline or quick-settling solids. The material is fed into the upper manifold through a pair of ball valves, as shown in the accompanying illustration. It then passes into the heads at each end of the pump in a clean, sweeping motion, thereby assuring that with each forward motion of the diaphragm-covered piston, the material will be forced out through the lower pair of ball valves and then through the lower manifold without an opportunity to settle in the pump head.

The principle of the pump is similar to that of this company's other diaphragm pumps, the working mechanism consisting of two double-acting pistons immersed in a bath of lubricating oil, which drive rubber diaphragms separating the material handled from the mechanism. An interesting feature of the pump is the interchangeability of the valve manifolds so that the pump may be fed at the bottom and discharged at the top, if desired.

Welders' Safety Clothing

To PROTECT welders against painful and dangerous exposure to molten metal sparks, American Optical Co., Southbridge, Mass., has developed a wide assortment of welders' safety clothing which is made of chrome-tanned leather. Among the types available are overalls, all-leather pants, aprons, coats, sleeves, gloves and various compete protection combinations. This clothing was designed by an expert welder and is made of as few pieces of leather as possible to eliminate unnecessary seams.

Level Controller

FOR THE HANDLING of all liquids at all pressures, temperatures and specific gravities, the Fisher Governor Co., Marshalltown, Iowa, has developed an improved displacement type level controller known as the Level-Trol. Greater sensitivity, higher action speed, freedom from service troubles and ease of adjustment are claimed for the new controller. This device is used not only in level control, but also for interface level control, level indication and specific gravity control. Instruments are available in five types for all service conditions, with float lengths ranging from 14 to 120 in.

Pneumatic operation is employed, all linkages, pivot points and other sources of friction being eliminated so as to reduce operating power to the minimum. A level position adjustment permits positive controlling of the level at any desired point within the length of the float while a throttling range adjustment makes it possible to vary the amount of level change necessary to move the diaphragm valve from open

Welders' safety clothing
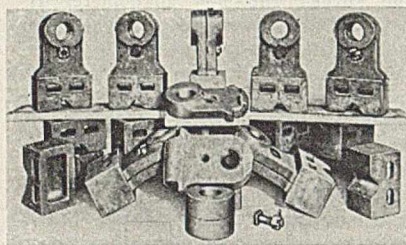
Group of renewable-tip pulverizer hammers

to closed, or vice versa. Among the new design features is a type of construction employing an Inconel torque tube to eliminate stuffing box packing and lubrication.

Renewable Pulverizer Hammers

ASSISTANCE to the metal conservation program is afforded by the new Clark renewable-tip pulverizer hammer recently announced by American Manganese Steel Division of American Brake Shoe & Foundry Co., Chicago Heights, Ill. The hammer consists of a weighted manganese steel head, connected to the rotor by two matching arms or bars of manganese steel. On the lower end of each bar is a hook which engages internal pockets in the head. The bars are bolted together under the head so as to form a one-piece arm. However, when the heads are worn the bars are easily disconnected and disengaged from the head which then is all that needs to be replaced. It is claimed that the new design saves greatly in the weight of discarded parts since about two-thirds of the hammer head can actually be used up before renewing is necessary. Furthermore, the time consumed in removing old and replacing new heads is small. The head cannot work loose and come off the arm as long as the latter is on the supporting rotor pin.

Wood Window Sash

To PROVIDE adequate fenestration for industrial buildings despite priorities on critical materials, the National
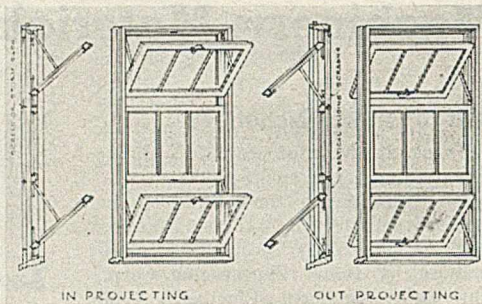
National Projected Wood Sash showing inward and outward projecting ventilators
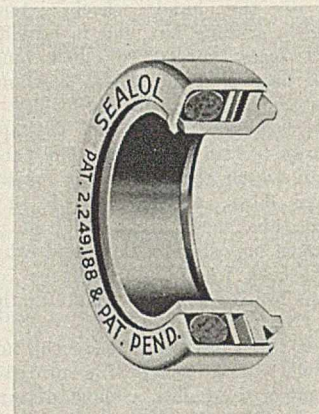
Seal for rotating shafts

Door Manufacturers Association, 332 South Michigan Ave., Chicago, Ill., has announced the new National Projected Wood Sash which has been designed by a well-known firm of architects and engineers. The new sash is offered in 18 standard basic units, each basic unit an opening in itself. These units may be installed individually, or various units may be combined in height and width to meet any window sash requirements. The quantity of metal necessary for the hardware for one complete unit has been cut to only about 3 lb.

All wood used is treated with a preservative against possible deterioration. All frames are completely factory fitted and all sash pre-fitted to exact size. Units are available with either fixed or movable sash, the latter being of two types, namely, bottom-pivoted for inward projection, and top-pivoted for outward projection. Since ventilators are never centrally pivoted, screening or storm sash may be easily and economically installed. Although these windows are especially designed for manual operation, various types of mechanical operating devices are available for long lines of horizontally projected ventilators.

Mechanical Seal

SEALING against pressure is the function of the new Sealol mechanical seal for rotating shafts which has recently been announced by Stevenson Engineering Corp., 45 Willard Ave., Providence, R. I. The initial contact

between the sealing ring and a hardened, lapped surface on the shaft which is being sealed is accomplished by a light corrugated spring. Sealing against the pressure, however, is accomplished by the fluid pressure itself, acting upon two opposing surfaces of the sealing ring, these surfaces having been designed so that the area on the seal side is less than that on the opposite side, and hence a pressure differential is exerted to maintain fluid tightness.

The Sealol consists of five parts, a retainer cup, a synthetic rubber packing ring which tightly seals the sealing ring to the retainer, a thrust washer, a flat corrugated spring and the sealing ring itself. The device is available for shaft diameters ranging from ¼ to 2 in. It is claimed to seal fluids over a wide range of pressures and speeds. The use of balanced pressure is said to minimize frictional heat and power loss, while the seal is claimed to exclude all foreign matter from bearings. This device is applicable to either plain or anti-friction bearings and works equally well in either direction of shaft rotation.
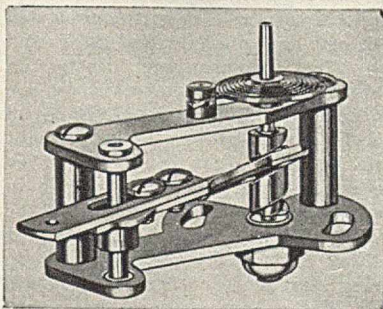
Portable Floodlight

ESPECIALLY for use in combustible areas which cannot have installed lighting, General Electric Co., Schenectady, N. Y., has announced a new portable battery-operated floodlight consisting of a 19x9 7/8x20¾-in. steel box to which is attached a special dust- and vapor-proof lamp housing mounted on a bracket to allow pointing in any direc-

Battery operated floodlight
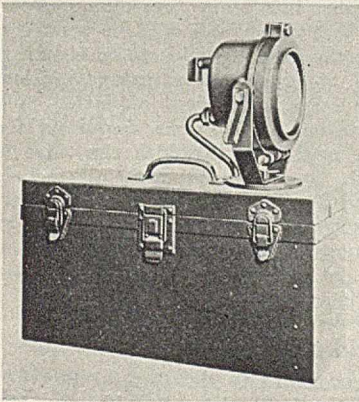
Novel gage movement

tion. A high efficiency glass reflector, combined with pre-focus positioning of the unit's 50-cp. concentrated-filament type bulb, and a diffusive lens, gives a powerful medium-angle floodlighting distribution. Normal burning time is approximately 10 hours and the five-cell storage battery may quickly be exchanged for a charged battery through the use of a polarized connector permanently wired to the battery terminal. The unit is intended for use in such places as powder igloo interiors, powder magazines, freight car and warehouse interiors containing combustibles, and during blackouts, etc.

Gage Improvement

FOR USE in indicating pressure gages, Certified Gauge & Instrument Corp., Long Island City, N. Y., has developed a new type of gearing in the form of a cam and roller movement. As shown in the accompanying illustration, this movement employs a sector-shaped driving cam and a driven helical roller. One end of the pivoted cam is linked to the tip of the bourdon tube while the other end is aligned with and fits freely into the thread of the roller. A hair-spring limits the point of contact between cam and roller to only one side of each element, thus preventing back lash. The new movement is claimed to provide smooth and constant transmission of motion from the pressure element to the pointer, while at the same time preventing jamming of the mechanism in the event of over-travel of the bourdon tube. A simple adjustment is provided for easy resetting of the zero or for calibrating of the gage during use. The calibrating adjustment is effective up to one-half of the total dial length.

Tight-end conveyor pulley
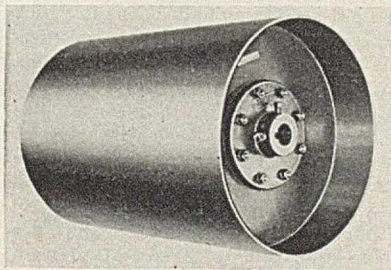
Magnesium welding with Heliarc process

Conveyor Pulley

FOR USE as head and tail pulleys in belt conveyor installations, the American Pulley Co., 4200 Wissahickon Ave., Philadelphia, Pa., has announced the new type N solid-type steel conveyor pulley which is made with tight ends so that no spilled material, dust or water can accumulate inside the pulley. These new pulleys, made in diameters ranging from 6 to 36 in., are rolled from one piece of steel and are welded to form a one-piece cylinder. This cylinder is then closed at a point near either end by a welded-in disk to which removable, interchangeable hubs are secured by stub bolts. Thus, bores can easily be changed simply by changing the hubs. The hubs are provided with a keyway and two set screws for attachment to the shaft. The pulleys are designed for 125 lb. effective belt tension per inch of width of face. Both flat and crown-faced pulleys are available. If desired, pulleys can be provided with a vulcanized-on lagging to give greater gripping power.

Magnesium Welder

IN COOPERATION with Dow Chemical Co., Northrop Aircraft, Inc., Hawthorne, Cal., has developed the Heliarc welding process for the welding of magnesium. The new process required a two-year period of development and has now been made available to war industries. It permits the arc welding of magnesium sheets, extrusions, tubing and castings. It is claimed to overcome previous difficulties in the fabrication of this important light metal.

In addition to being a successful method of attachment for magnesium, the new welding process is said to be suitable for stainless steel, brass, Inconel, Monel and some of the carbon steel alloys. Research progress is reported on its use with aluminum and other carbon steel alloys not hitherto welded in this way. In the new process a shield of helium gas envelops the molten metal. This prevents oxidation and eliminates the use of a flux. The arc in this process is produced directly between a tungsten electrode and the base metal, rather than between two tungsten electrodes as is the practice in atomic hydrogen welding. The welding torch is equipped with a helium valve which is opened just prior to striking the arc. Since helium has over five times the specific heat of air, in motion it prevents heat accumulation around the weld, keeping it cooler and giving better fusion and penetration, with less distortion than other welding processes.

Torches have been designed for this process and will shortly be available to industry. Eventually a type will be available which feeds the filler rod automatically. The process best employs a conventional arc welding machine with a direct-current generator having a 150 amp. output, although

higher output machines which operate at less than 300 amp. may be used if lower current values are obtainable. The average life of a 200 cu.ft. helium tank is about 35 hours of continuous welding with a medium size torch. Rather pure helium must be used.

Loose Pulley Oiler

A NEW wick-type lubricator announced by Oil-Rite Corp., 3466 South 13th St., Milwaukee, Wis., has been designed specifically for the lubrication of loose pulleys, clutches and similar rotating machine parts. The oiler is constructed to deliver a constant and regulated amount of filtered oil to the shaft or bearing while the pulley is in operation and to prevent oil waste while the pulley is idle. The lubricator consists of a simple glass reservoir mounted on a hollow metal stem which is sealed from the oil in the reservoir except for two small ports at the top. Inside the stem is a cylindrical felt wick which extends through the pulley hub to rest directly on the shaft. A compression spring wrapped around the wick holds it firmly in position against the shaft. As the pulley rotates, centrifugal force throws the oil against the top of the reservoir and into the two ports in the stem, thus admitting oil to the wick which conducts it directly to the shaft. A small plug is provided, the adjustment of which regulates the area of the oil ports and thus controls the amount of oil delivered.

Equipment Briefs

INDUSTRIAL GLOVES Co., Danville, Ill., has recently perfected a type of light-weight horsehide glove designed particularly for use by women in industry. This general-purpose work glove is light and flexible, having an open back to provide coolness. An elastic web band across the opening keeps the glove snug. Three sizes are available. The new gloves may be purchased in pairs, all rights, all lefts, or in any combination of rights and lefts.

To MEET present-day demands for explosion-proof timers suitable for operation in solvent- or gas-containing atmospheres, the R. W. Cramer Co., Centerbrook, Conn., has developed a line of instruments meeting such specifications. These instruments are available for panel board mounting with the setting knob and dial projecting, and can be provided with a small relay when it is desired to control the timer from a remote-located momentary-start button.

FOR USE in maintenance and construction work, Lewis-Shepard Sales Corp., 245 Walnut St., Watertown, Mass., has developed a 40-ft. telescopic portable elevator which not only raises materials for installation or lowers
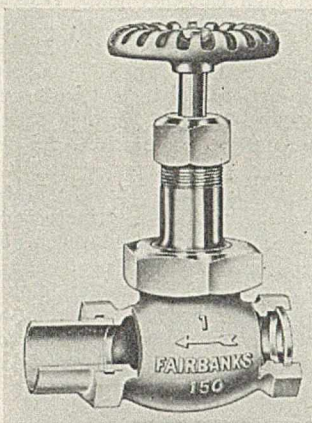

Brazed-joint valve

them for removal, but also gives an elevated working platform. The lifting speed is approximately 30 ft. per min.

UNUSUALLY quick action is claimed for a new three-way valve of the butterfly type manufactured by R-S Products Corp., Wayne Junction, Philadelphia, Pa. This valve is designed for mixing and quick interchange service and is adapted to fully automatic control by means of an air diaphragm motor or hydraulic cylinder. It is built of cast steel or cast iron for pressures up to 600 lb., or various other metals may be substituted. The vane is of a special self-cleaning, double-beveled, stream-lined design which is claimed to seat wedge-tight against the body of the valve, thus producing tight shutoff as well as positive control of volume and pressure.

A NEW "GIANT" photoelectric cell of the self-generating type, having a current output of 4,000 microamp. at 100 ft.-candles illumination, and developed for light-sensitive applications in which the sensitive element is at a considerable distance from the control room, has been announced by Emby Products Co., 1800 West Pico Boulevard, Los Angeles, Cal. The unit consists of seven sensitive disks mounted in a single element $7\frac{3}{8}$ in. in diameter. This company's photoelectric cells feature an output in excess of 450 micro-amp. per lumen and, due to a special process, are said to be permanently stable and able to withstand temperatures up to 70 deg. C. Three different sensitivity ranges are available to meet requirements in various application fields.

ACCORDING to a recent announcement of the War Department, the Chemical Warfare Service has developed a new dust respirator for military use in sandy and dusty areas which is also adaptable to industrial and peacetime uses. The new respirator is light in weight and fits snugly over the nose and mouth. It consists of a filtering felt mounted on a rubber frame with an inlet and outlet valve. There are no
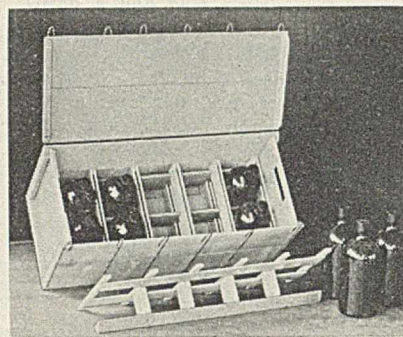
New acid shipment box

lenses since the respirator is intended to supplement goggles. The unit is also suitable for filtering certain kinds of non-toxic smoke.

A NEW high-wet-strength filter paper, designated as No. 755-2, has been announced by Henry E. Jacoby, 205 East 42d St., New York, N. Y. This paper is intended to be used over the filter cloth in filter presses, particularly in cases where the filter cake is to be saved. It is claimed that no trouble is encountered from lint adhering to and contaminating the cake. At present the paper is available only in widths up to 24 in.

Brazed-Joint Valve

FAIRCOSEAL is the name given to a new line of bronze valves manufactured by the Fairbanks Co., 393 Lafayette St., New York, N. Y. These feature pre-inserted rings of Sil-Fos silver brazing alloy in the port openings, instead of threads. With this feature, the valve and pipe can be easily brazed together into a one-piece piping assembly by the application of an oxy-acetylene flame. The joint so produced is said to be able to withstand tension, compression, torsion, vibration and corrosion to the same degree as the pipe or tube with which the valve is used. Suitable tube materials include copper, yellow or red brass, copper-nickel and Monel, in such services as steam, oil, hot and cold water, compressed air, certain acids, and certain refrigerants.

Acid Shipping Box

ACCORDING to the General Box Co., 510 North Dearborn St., Chicago, Ill., many producers of acids are now meeting shortages in containers by shipping their products in bottles protected by a new design of General All-Bound box. The accompanying illustration shows the flexible separators which are employed to avoid breakage. Boxes of this type are said to reduce freight costs by being light in weight. They are easily handled and save time in the shipping room, according to the manufacturer, since they are assembled without nails and come in one piece, saving storage space because they are stored flat.