STAND BY FOR FURTHER ORDERS!

Wᴇ ғɪɴᴅ increasing uneasiness among young chemical engineers who have difficulty in seeing how they are actually helping in the war effort. Some of them feel they should throw overboard their technical and professional training in order to enter the armed forces. A still larger group would like to go to work for the government in some chemical engineering capacity, or to transfer to a more essential type of industrial employment, yet to do so they feel they may be accused of merely seeking to dodge the draft. Nothing could be farther from the truth.

Chemical engineers in any kind of war work—and that includes a great many activities beside making munitions—are probably serving the Nation better in their present jobs than they would in almost any capacity with the Army or the Navy. Chemical engineers working in other than war industries should continue where they are in preparation for the time when greater numbers of experienced men will be needed and cannot be obtained except by transfer from existing industries. Just as the distilling industry has been completely converted to war production, so there will be an inevitable switch-over to war activity on the part of most of our other chemical and process industries. Meanwhile the men working in these plants form the only real chemical engineering reserve we have in this country. They should be kept in active training in their chosen profession. This means, of course, that the individual should not only work as hard as he can at his regular job, but should try actively to improve himself in other lines of chemical engineering which he, himself, can recognize as of increasing importance in the war effort.

Dean Frank C. Whitmore of Penn State, who has become a past master in educating local draft boards, likes to call their attention to just two figures, viz., 27 millions and one-quarter million. The first refers to the total number of men up to 35 years of age who have registered in the Selective Service System. The second number is slightly greater than the present total enrollment of the National Roster of Scientific and Specialized Personnel, which includes chemists, physicists, chemical engineers, bacteriologists, geologists and other scientifically trained men from the graduating classes of 1942 up to the age of about 80 years. If we are to lose this war, he holds that it will not be because of the 27 millions but because the quarter million is either too small or we have not used it as effectively as we should.

Of the quarter million only about 60,000 are chemists and chemical engineers. The fact that even during the worst days of the depression only about a thousand of these were ever unemployed would seem to prove that they are needed to carry on the normal peace-time operations of the country. But the tremendous expansion of chemical and metallurgical industries and the intensive application of war research and development now call for a much larger proportion of technically trained men. When the new synthetic rubber, magnesium, aluminum and like munitions plants get into full swing in 1943, the number of chemical engineers needed for supervision and control will be far in excess of the available supply, even with the complete diversion of those still engaged in fields not directly connected with the war program. So it is vitally important that we have no more voluntary desertions or actual robbing of the chemical engineering ranks, motivated by misguided patriotism on the part of local draft boards or the recruiting officers of the Army and Navy.

Fortunately, there seems to be no such misconception or confusion in this matter in the attitude of General Hershey and his ranking associates in Selective Service Headquarters in Washington. Likewise the public utterances of Administrator Paul V. McNutt, chairman of the War Manpower Commission seem to hold promise of a far better appreciation of the key importance of the technically trained men on whom the war machine

depends for its design, construction and operation. And, finally, there is the tiny, but gradually growing idea of a technological high command to muster all of our scientific and engineering resources for war roles of technology. So, in the welter of confusing counsel, we urge that chemical engineers should stand by their guns a while longer. New orders of attack are in the making.

PATENTS AND RE-SALE PRICES

PATENTS are not yet a "lost art" but, under recent court decisions, they seem to have less value than formerly. Certainly the Supreme Court in a case decided May 11 makes it clear that a patent does not in any way extend a right to control re-sale prices.

The case in question had to do with multifocal eye-glass lenses. But it might just as well have been some industrial chemical. The producer sold his patented product to distributors under contracts which attemped to do two things: first, the contract gave a license to utilize a patented method of processing; second, the contract prescribed the price at which the finished product should be sold to the wearer of the eyeglasses.

The Supreme Court of the United States in this case says that by sale of the article made under a patent, the owner of the patent clearly has exhausted his monopoly. The court repeats what it considers a long-time policy fixed by all United States courts, that the right to control stops when the ownership of the patented article passes to the customer.

Those who seek to maintain re-sale prices of their trade-marked and nationally advertised goods must, therefore, fall back on the Miller-Tydings Act as their sole authority in federal statutes. When they cannot clearly meet the conditions of that law, they will be regarded by the courts as violating anti-trust statutes whenever they undertake to control re-sale prices. There seems to be no hope for exception from this generalization in the Court's finding, regardless of whether the patent be on a chemical product, a device, or a process of making either.

COOPERATION OR COLLUSION?

BETWEEN patriotic cooperation and illegal collusion, the line is very vague. This is unfortunate. Many worthwhile efforts that would save scarce goods or services are not being made because of this doubt in the minds of thoughtful industrialists.

It was hoped that the President's admonition to Assistant Attorney-General Arnold would result in the laying aside for the duration of zealous prosecutions which try to make criminal acts out of every cooperative gesture of industry. But this ardent trust buster is not to be deterred, even by the President's implied warning. Industry must, therefore, frequently take a chance on apparent violation of the law in order to get things done.

There remain only a few activities which Mr.

Arnold does not question. The work of technical committees, the formulation of specifications, and most of the types of constructive trade-association activities are rarely attacked. Not so, however, with many other highly desirable efforts.

Right now the chemical industry must, despite this difficulty, try to find some way in which to cooperate in handling goods in transport. The shortage of transportation is so serious that the industry may have to take the chance of incurring Mr. Arnold's wrath in order to move goods that are absolutely vital to the war effort.

Such cooperation may often become practicable, and legally defensible, if care is taken regarding negotiations and arrangements. In planning transportation, every step should be taken in close cooperation with and with the official knowledge of the Office of Defense Transportation. O.D.T.-Boss Eastman must be asked to furnish technical aid, both to protect the industries and to see to it that each industrial effort harmonizes with the comprehensive national program. And tentative agreements so reached can then be submitted with some assurance to the Department of Justice for review and criticism.

Similar arrangements with respect to the sharing of raw materials must be made in cooperation with the W.P.B. Some governmental agency must be drawn in early in all cooperative efforts. Even then Mr. Arnold may not be happy. But we still believe, and certainly hope, that the Federal Courts will not share Mr. Arnold's zeal in undertaking to make every cooperative effort an illegal thing *per se*.

MANPOWER CONSERVATION

IN THE nation's drive for war production, we sometimes think of time and material as the only irreplaceable factors that limit the output of our machines. We lose sight of the fact that last year a rising toll of accidents claimed the lives of 101,500 persons, permanently disabled another 350,000 and injured 3,750,000. In terms of production, industry last year lost, from accidents alone, 460,000,000 man-days of work. That is enough time and energy to have built twice as many battleships as are to be found in the American and British navies combined. To cut that toll by 20 percent, which is well within the experience and expectancy of a well ordered safety program, would buy us ten battleships of the "North Carolina" class, 2,100 Flying Fortress, or 600 heavy tanks.

No wonder Donald Nelson has gotten squarely behind President Roosevelt's proclamation calling on the officers and directors of the National Safety Council "to mobilize its nation-wide resources in leading a concerted and intensified campaign against accidents and to call upon every citizen in public and private capacity to enlist in this campaign and do his part in preventing wastage of human and material resources of the nation through accidents." No wonder that a group of the nation's leading industrialists, under the chairman-

Some of the beds of bauxite lie close enough to the surface
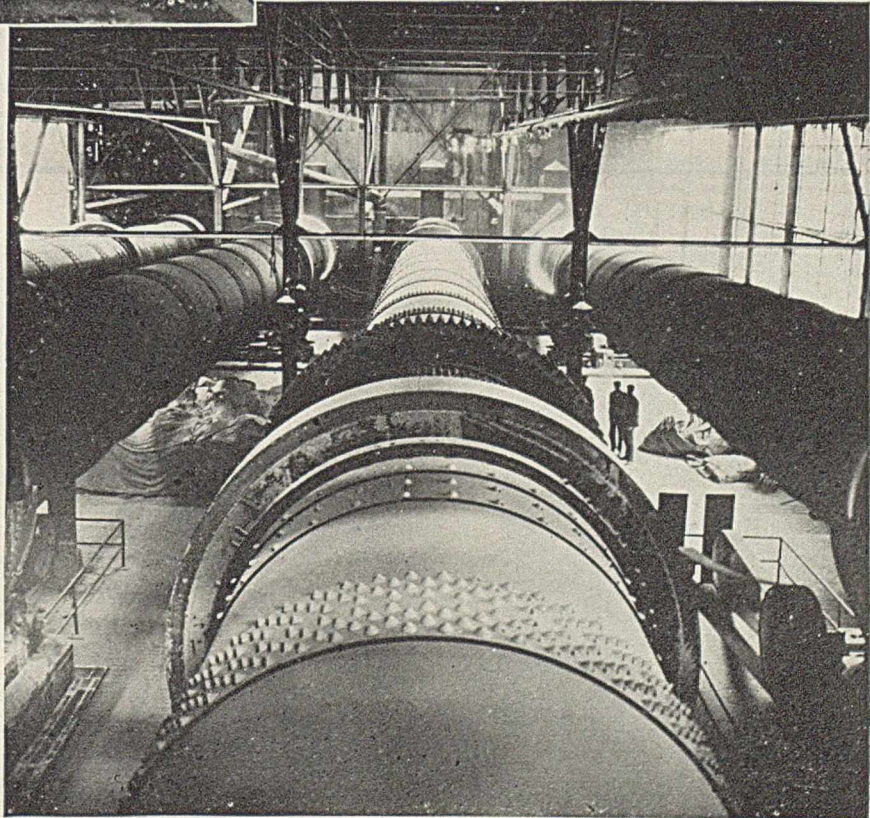to be mined by the open pit method

Large filter presses similar to this one will be used for remov-
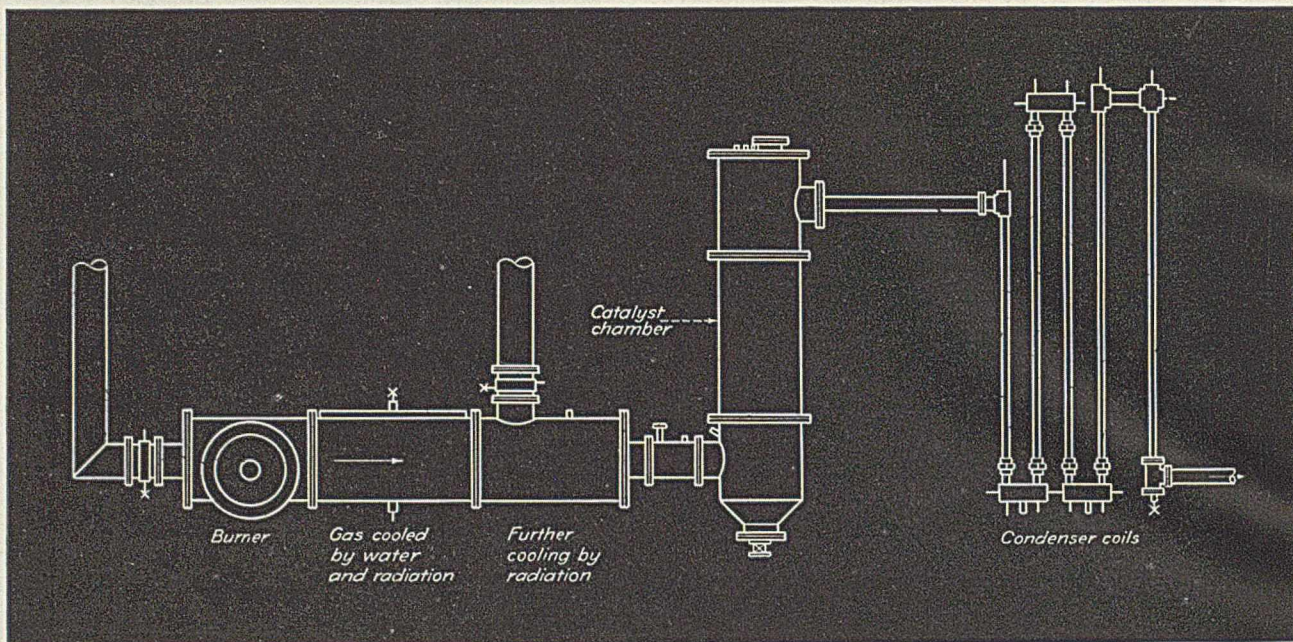ing the impurities from the ore
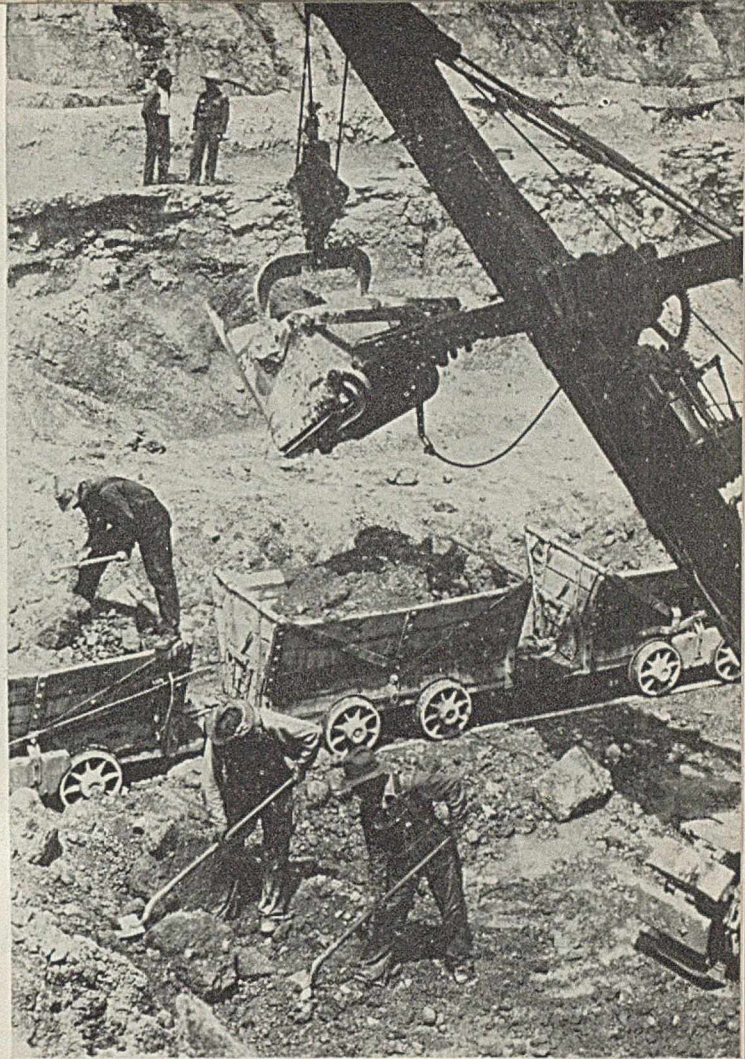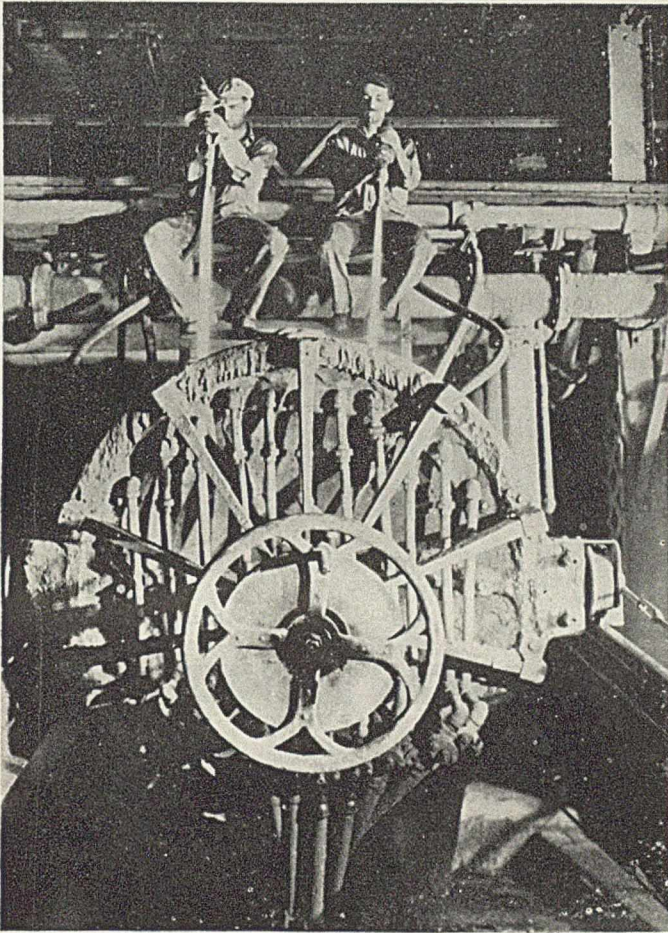
In large rotating kilns the aluminum trihydrate will be
heated white hot to drive off chemically combined water

The alumina will be shipped to an-
other plant nearby where it will be
reduced to metallic aluminum

This pilot plant solved the problem of recovering sulphur from sour natural gas and converting the contaminating hydrogen sulphide from a nuisance to a useful commercial product

Sulphur from Arkansas Sour Gas

JAMES A. LEE *Managing Editor of Chem. & Met.*

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

A method has been successfully developed for the removal of sulphur from the sour gas of Southwest Arkansas which may make available for the first time in the state a source of elemental sulphur for the production of sulphuric acid and other chemicals. Based on estimates of gas reserves the total may be 1,500,000 tons.—*Editor*

SEVERAL GAS FIELDS have recently been discovered in Southwest Arkansas. They are located west of the Magnolia oil fields and south of the fields in Buckner and Louisville, and almost midway between the Rodessa development in Southwest Arkansas and Northwest Louisiana and the Smackover fields in Arkansas. The fields contain rich deposits of petroleum condensate and natural gas.

These enormous reserves of gas give the state a source of cheap fuel which Gov. Homer M. Adkins is using with much success in his campaign to attract war industries and to industrialize the state by processing Arkansas' natural resources in Arkansas. They also have another interesting feature. They contain an unusually large hydrogen sulphide content which through the efforts of the Texas Gulf Sulphur Co. has been demonstrated may be converted into a supply of elemental sulphur for the chemical industry of the state.

At present the gas acts as the lifting vehicle in the production of oil or distillate, but it is being wasted when it reaches the ground surface except for a small portion which is used as fuel in well drilling.

The distillate that is delivered at the well mouth along with gas in the Big Creek and McKamie fields is in gaseous form in the producing horizon, and as the pressure in the producing horizon is about to decline, there will be progressive condensation and absorption of the distillate in the producing horizon, the amount being dependent on the reduction in pressure with a corresponding loss in ultimate recovery. It is apparent, therefore, that reasonably uniform withdrawal of distillate and gas is imperative in these fields, and it is preferable that this withdrawal be at a rate somewhat less than the water drive to insure the satisfactory and maximum production of distillate.

These gas fields, because they form a substantial addition to the known gas resources of this section of the country, are of real interest as the source of cheap fuel. The gas, however, is a byproduct of the production of oil or distillate. To prevent the wasting of this valuable byproduct, the state of Arkansas passed an oil and gas conservation law known as Act 105 of the 52nd General Assembly under which the Arkansas Oil and Gas Commission has adopted regulations to prevent such waste and to obtain the greatest possible recovery of its natural resources and to conserve gas for its more worthwhile uses.

While petroleum condensate (60 deg. A.P.I.) can best be recovered by mechanical separators erected at the individual wells, natural gasoline and butane can be recovered through the installation of a central treating plant to serve the entire field. The presence of hydrogen sulphide in the

gas prevents the marketing of the gas and in turn prevents the production of petroleum condensate, natural gasoline and other hydrocarbons.

The hydrogen sulphide content of the gas varies from 30 to 4,500 grains per 100 cu.ft. Such gas to be useful as fuel either for the industrial purposes or for domestic uses must be purified. Gas containing 360 grains of hydrogen sulphide per 100 cu.ft. may not be objectionable when used directly as boiler fuel gas. Higher concentrations of hydrogen sulphide are objectionable because they constitute a health hazard and also may cause severe corrosion of equipment. More than $1\frac{1}{2}$ grains of hydrogen sulphide per 100 cu.ft. of gas is not permitted in domestic gas because of its corrosive effect.

It was suggested that a recycling operation might be set up by means of which pressure could be maintained and the distillate removed which would convert the fields into oil fields. At a recent hearing, before the Arkansas Oil and Gas Commission, it was pointed out by operators and independent engineers that this program would be too costly as the sulphur would first have to be removed from the gas which involves reduction to 600 lb. pressure and then recompressing to 4,000 lb. for injection into the sand.

Because of the extreme "sourness" of the gas, many technical men were skeptical of the ability of any purification process to sweeten it. The Girdler Corp. dispelled all doubts on this score by installing a pilot plant in the McKamie field and demonstrated that the gas could be purified completely and economically.

The Girdler process will be used in two large purification plants, one for the McKamie Gas Cleaning Co. and the other for the Arkansas Fuel Oil Co. The former will be located in the McKamie field and the latter near Kerlin to treat gas from the Macedonia and Dorcheat fields. The combined capacity of these plants will be nearly 100,000,000 cu.ft. of gas per day, part of which will be used to provide fuel for the two aluminum plants under construction elsewhere in the state.

The McKamie Gas Cleaning Co. was incorporated under the laws of Arkansas, on Nov. 12, 1941, for the purpose of constructing a natural gas treating plant having a capacity of 25,000,000 cu.ft. of gas a day. The treating plant will remove restrictions upon the production of valuable petroleum condensate. Unless the treating plant is erected the production of condensate will be curtailed. The plant will produce natural gas for the aluminum and possibly other war plants in the state. It will also produce natural gasoline, butanes, and hydrogen sulphide.

Briefly, the gas will be processed as follows: The hydrocarbons exist in the wells in a homogeneous vapor phase at pressures above 4,000 lb. per sq.in. The gas is brought to the surface and as the pressure is reduced to 800 lb. per sq.in. gage retrograde continuous condensation of heavier hydrocarbons takes place. It is then separated from the distillate at this pressure. Some operators further disengage the gas in a second separator at a lower pressure. The raw gas at separator pressure or upon recompression passes first to the Girbotol plant where it is purified by a water solution of monoethanolamine. Gas originally containing as high as 5,000 grains of H₂S per 100 cu. ft. will be treated and the H₂S content reduced to less than 0.1 grain per 100 cu. ft. so that it will meet the National Bureau of Standards lead acetate test for sweet gas. After purification it flows from the Girbotol plant to a gasoline recovery plant where natural gasoline and butanes are separated. The gas then passes through a dehydration unit which removes sufficient water vapor to prevent difficulties in transmission due to the formation and accumulation of hydrocarbon hydrates. The dehydration unit employs a solution of amines and glycols which is very effective for removing water vapor.

The effluent from the Girbotol pilot plant which contains on an average of 58 percent by volume of hydrogen sulphide, 41 percent of carbon dioxide and 1 percent of hydrocarbons (methane) on the dry basis passes to a second pilot plant erected by the Susearch Corp., subsidiary of the Texas Gulf Sulphur Co., for the conversion of hydrogen sulphide to elemental sulphur. This pilot plant was located on the Cornelius Tank Farm of the Carter Oil Co. near McKamie, Lafayette County. The design and construction of the plant are the results of experiments which had been under way for some time. In connection with the pilot plant, there was also a laboratory for control purposes. The primary function of the plant was to solve by experimentation and research the problem of recovering sulphur from sour gas and conversion of the contaminating hydrogen sulphide from a nuisance to a useful commercial product. The diagram of the plant shown on the opposite page is based on the reaction:

$$2\ H_2S + SO_2 = 2\ H_2O + 3S.$$
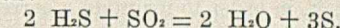
About 25,000 cu.ft. per day of gas are received from the Girbotol plant. One-third of this gas, after being mixed with the proper proportion of air is burned, the combustion of the hydrogen sulphide taking place in a

H₂S is removed from natural gas in this Girbotol pilot plant and sent to Susearch pilot plant for conversion into sulphur

SULPHUR IN ARKANSAS SOUR GAS FIELDS

Name	Reserves*		Daily Production		H₂S per 100 cu. ft. grains	Possible S. daily (in gr. tons)	Total sulphur in gas reserves (in. gr. tons)
	Oil	Gas	Oil (bbl.)	Gas (cu. ft.)			
Atlanta.............	6	10	2,877	4,603,000	1,800	5.26	11,480
Big Creek...........	3	67	241	6,025,000	335	1.28	14,310
Buckner............	8	1	2,504	676,000	167	0.75	106
Dorcheat...........	18	144	1,988	21,027,000	2,400	32.	220,400
Magnolia...........	161	200	18,948	16,845,000	895	9.55	114,200
Macedonia..........	12	184	900	12,150,000	1,900	14.6	223,000
McKamie...........	37	427	3,200	22,080,000	4,500	63.4	1,225,000
Mt. Holly..........	5	10	400	1,600,000	374	0.38	2,385
Jones Pool..........	35	50	13,500	24,300,000	30	0.46	956
Reynolds Pool.......	3	5	2,424	2,133,000	865	1.2	2,758
Village.............	3	10	1,191	5,717,000	374	1.36	2,385

*Oil in millions of barrels; gas in billions of cubic feet.
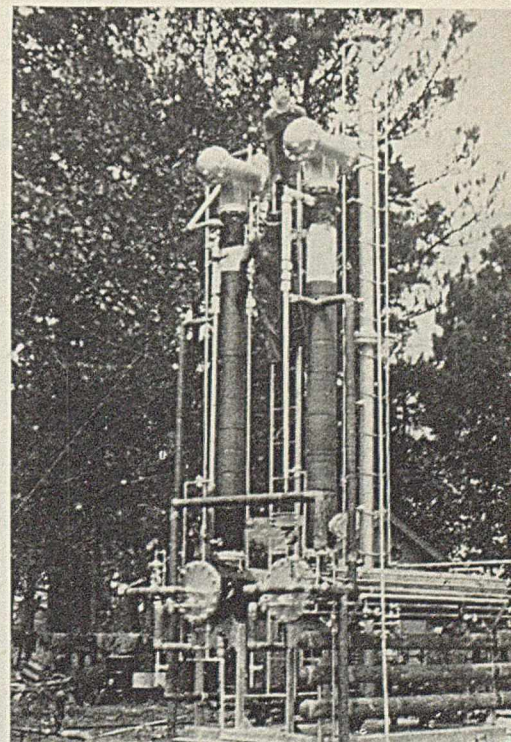
specially designed burner. The products of combustion are then cooled to a selected temperature in a chamber provided with an explosion vent, and are next mixed with the remaining two-thirds of the original hydrogen sulphide gas stream and caused to enter the bottom of the catalyst chamber, which is packed with a catalyst of special composition. The gases enter the catalyst chamber at about 450 deg. F. Here the hydrogen sulphide reacts with the sulphur dioxide to form sulphur and water. The gases leaving the catalyst chamber are immediately cooled and forced through the condensing system where the sulphur is drawn off in a molten state.

As a result of this small scale operation it is proposed when constructing a commercial installation to burn about one-third of the available H_2S acid gas under a small water tube boiler with induced draft fan to supply air and give necessary pressure for operating the system. It may be necessary to install a cooler of some type at outlet of the fan to lower the temperature of the gases further than can be done in the boiler, if steam pressure is to be kept up, before being introduced into the catalyst since it is possible that after a period of operation, the temperature of mixed gases may have to be as low as 250 deg. F. in order to maintain a correct temperature in the catalyst bed. It is also possible that radiation may take care of this need—a great deal depending on the final design. It is also just as true that provision may have to be made to get some hotter gases from the boiler than would be expected of normal operation of the boiler. The burned gases would discharge from the fan through a 30 or 36-in. duct into a catalyst chamber about 15 ft. square and 10 or 12 ft. high. Secondary gas should be introduced into the duct just ahead of the catalyst chamber. Duct and chamber are to be lined and insulated. Provision is to be made for draining possible sulphur from the catalyst. A number of vertical fire tube boilers with two and one-half or three inch tubes are to be used as condensers. The first condenser boiler could be used as a cooler and the steam generated used to maintain proper temperature on the other condenser. A scheme of piping may be worked out as condensers. The tail gases can be discharged to atmosphere through a steam coil lined stack some 30 or 36 in. in diameter and 40 or 50 ft. high.

Results of the pilot plant work demonstrated that more than 80 percent of the sulphur in the hydrogen sulphide can be easily and efficiently recovered in the form of brimstone. All of the data collected, however, have not been thoroughly appraised, hence it is difficult to estimate at this time the cost of converting hydrogen sulphide to sulphur. Whether or not it will be feasible to install a large sulphur recovery plant in connection with each of the gas cleaning plants now projected can only be determined by a more careful survey of all the factors concerned in the development of the natural gas resources of Arkansas.

ECONOMICS

Byproduct hydrogen sulphide has been available in several localities for many years. It has been estimated that 35,000 tons of sulphur in the form of hydrogen sulphide was being removed from fuel gases; however, of this quantity only three-quarters was converted into saleable form. In the smaller plants hydrogen sulphide was burned as fuel since production was too small to justify installation of special equipment to convert it to useful form. In Germany byproduct hydrogen sulphide has been converted to elemental sulphur, but prior to the discovery of the new sour gas fields in Southwest Arkansas such conversion has always proved uneconomical in the United States.

Utilization of the hydrogen sulphide in Arkansas presents peculiar problems. Proposals to convert it to sulphuric acid find some interest because the increasing need for aviation gasoline has resulted in the installation of many new alkylation plants in which sulphuric acid is required. However, acid must be consumed within a radius of about 200 miles to be economical due to high freight rates. The alternative seems to be conversion of hydrogen sulphide to some chemical product other than sulphuric acid or the conversion to sulphur in which form it may be readily shipped greater distances.

Industry is at present engaged in appraising the gas purification situation in an attempt to find a practical and economical outlet for the byproduct hydrogen sulphide. It should be noted that because of the limited quantities of sulphide available in certain areas only that available in the McKamie, Dorcheat and Macedonia, and possibly the Magnolia fields, can be converted economically. The total hydrogen sulphide available from these fields, according to present-day estimates, may be equivalent to more than 100 net tons of sulphur daily. Based on estimates of reserves, the total available may be 1,500,000 tons with the major portion of 1,000,000 available in the McKamie field. Since it is impractical to convert this quantity of hydrogen sulphide to sulphuric acid, other uses must be found. The simplest, of course, would be the conversion of the hydrogen sulphide to elemental sulphur. Plants for such conversion, however, are expensive, therefore they probably can be economically justified only where the gas is high in hydrogen sulphide and the supply large.

Proportioning equipment for air and gas feeds to the combustion chamber of the Susearch pilot plant
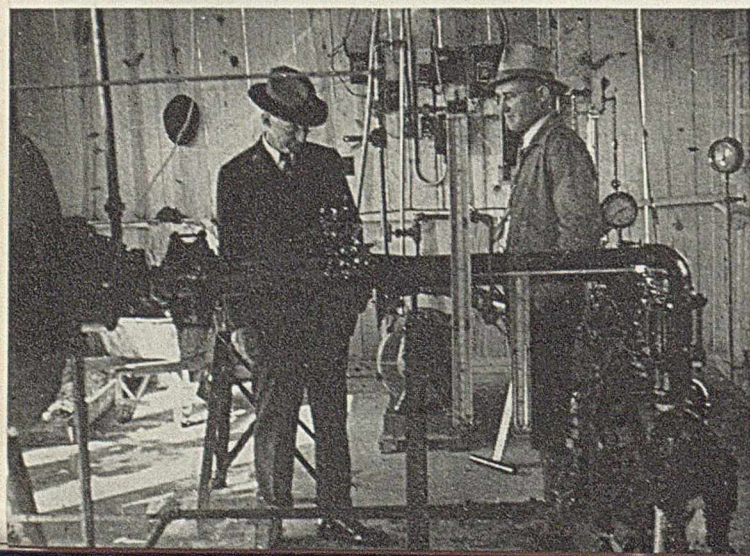
Left to right—Combustion chamber, cooler, mixing chamber (H_2S and SO_2), catalyst chamber, condensers
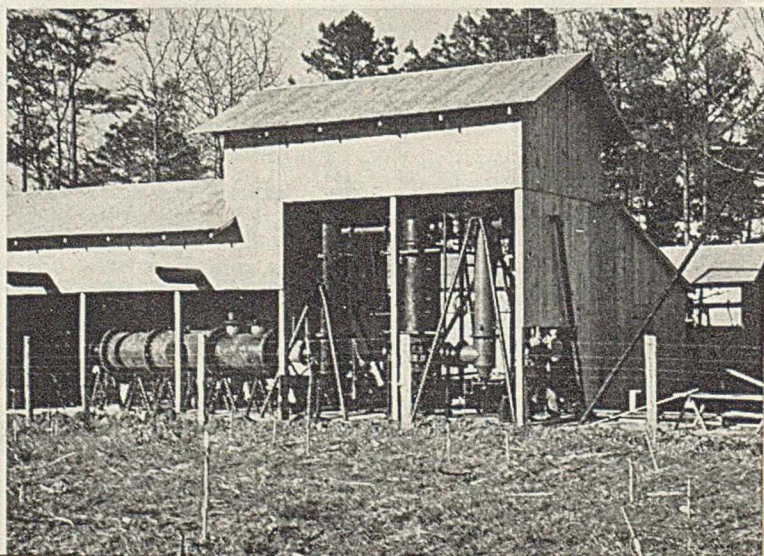
Cooling Tower Psychrometry—III

EDWARD SIMONS

Engineer, Redwood Manufacturers Co., San Francisco, Calif.

Chem. & Met. INTERPRETATION

Concluding a series of articles on psychrometry of water cooling tower design, this installment is in three parts. The first presents equations for counter-flow forced convection towers and includes an original short-cut method of problem solution. Second part considers heat as a driving force. The third is a discussion of heat exchange and introduces the new concept of the cycle modulus.—*Editors.*

A SECTION of a typical counter-flow cooling tower is represented by Fig. 5. The rate of cooling in the differential volume dV may be expressed by the equation

$$dQ = KDadV \qquad (43),$$

where K = overall coefficient of heat transfer based upon the mass velocity of the air; D = net effective driving force difference causing cooling in the section; a = active contact area per unit volume of the apparatus; V = tower volume, and Q = rate of heat exchange in the tower.

If the change in the water rate due to evaporation within the tower is neglected and if the specific heat of the water is taken at unity, the energy balance for the differential volume may be written as:

$$dQ = Gdh = L_2 dT \qquad (44),$$

where h is the enthalpy of the air. If D_M is the mean net driving force for the volume V, the heat rate Q, the air rate G, and the water rate L_2, and if K is constant, Eq. (43) and Eq. (44) may be combined and integrated to yield

$$L_2 (T_2 - T_1) = KD_M aV \qquad (45).$$

It may be shown° that the value of D at any point in the tower is $[p_T - p_w + Z(T - t_w)]$, where $Z = (sM_G/r_w M_L) (B - p_w)$. Fig. 6 indicates values of Z for barometric pressures from 22 in. through 30 in. Hg, with barometric intervals of 1 in.

Table IV gives a step integrated solution of a very extreme cooling problem. Fig. 7 shows a plot of the net effective driving force difference versus the water temperature. The data for Fig. 7 are contained in Table IV. If the variation in the net effective driving force difference were linear with respect to the water tem-

perature, the logarithmic mean driving force would apply. However, the variation is not linear, and the use of the logarithmic mean would result in a driving force which would be too large; the size of the designed tower would be too small.

The value of A in Table IV (column 12) is the area exposed per pound of dry air for cooling in a given step. Thus, the summation of the step values of KA is equal to KaV/G. If the basis of the air flow is 1 lb. of air per min., Eq. (45) becomes

$$L_2 (T_2 - T_1)/G = KD_M \text{ (Summation A)} \qquad (46).$$

Therefore,

$$D_M = L_2 (T_2 - T_1)/GK \times \text{(Summation of } A) \qquad (47).$$

The heat given up in the cooling, per pound of dry air, is (0.670 ×

Fig. 5—Diagrammatic representation of a typical counter-flow cooling tower. Fig. 6—Values of Z (see table of nomenclature p. 85) for barometric pressures from 22 through 30 inches of mercury

FIG. 5

Water

Conditions 2

dV

Energy Exchange for dV:
$dQ = Gdh = Ldt$

Conditions 1

Air
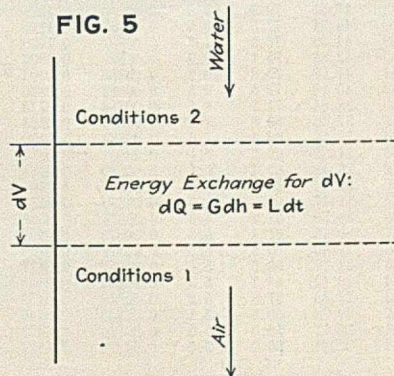
57.0) or 38.19 B.t.u. per lb. of dry air per min. D_M is equal to 38.19 divided by the summation of KA, or,

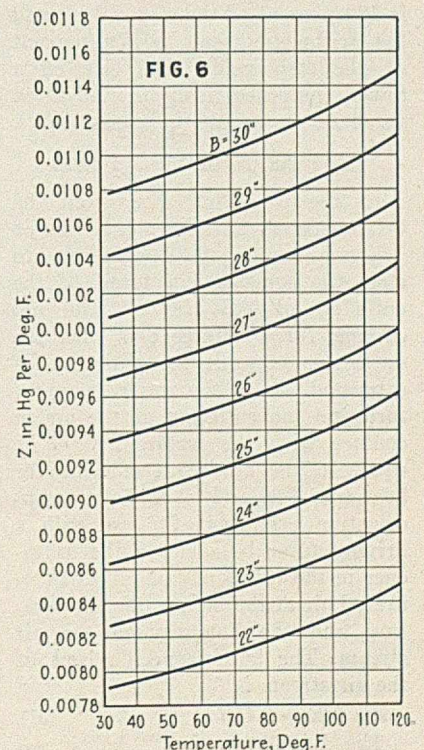$$D_M = 38.19/102.4 = 0.373 \text{ in. Hg.}$$

It has been possible to compute and adjust a method whereby the logarithmic mean of the net driving force differences at the ends of the tower may be used as a basis for computation of an adjusted mean effective driving force difference, D_M. Let D_2 and D_1 be the net driving force differences at the conditions 2 and 1 respectively. Then, the logarithmic mean is

$$D_{l.m.} = D_2 - D_1/\log (D_2/D_1) \qquad (48)$$

The value of the temperature T_x is located as follows:

$$T_x = T_1 + (T_2 - T_1)(D_{l.m.} - D_1)/ (D_2 - D_1) \qquad (49).$$

When T_x has been found, the value of the net driving force difference at T_x is computed; the designation of the driving force is D_x. The value $(R = D_{l.m.}/D_x)$ is computed. The curve of Fig. 8 indicates values of λ for various values of R. When the proper value of λ has been ascer-

FIG. 6

$B = 30''$

$29''$

$28''$

$27''$

$26''$

$25''$

$24''$

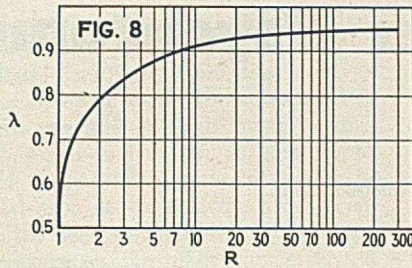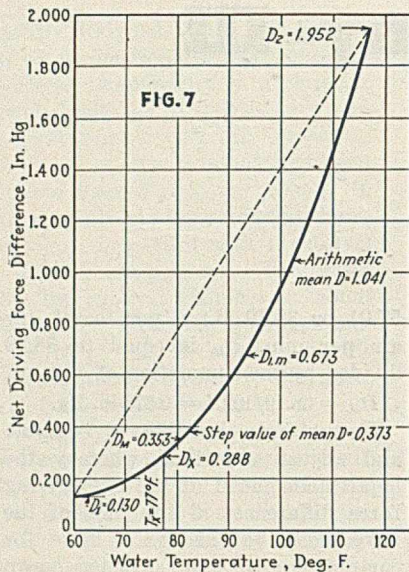$23''$

$22''$

Z, in. Hg Per Deg. F.

Temperature, Deg. F.

Fig. 7—Net effective driving force difference vs. water temperature; data contained in Table IV. Fig. 8—Values of λ for various values of R, used in solution of Eq. (50)

tained, the value of D_M is found by use of the equation

$$D_M = R\,[\lambda D_z + D_{l.m.}\,(1-\lambda)] / (R+0.05) \qquad (50).$$

In the case of the problem of Table IV, the following values appear in solution for the adjusted logarithmic mean driving force difference: $D_z = 1.952$; $D_l = 0.1296$; $D_{l.m.} = 0.6726$; $T_z = 77.0$; $D_z = 0.2880$; $R = 2.34$; $\lambda = 0.811$; $D_M = 0.353$.

The value of D_M is 0.353 in. Hg when calculated by the adjusted method; the value is 0.373 in. Hg when calculated by a step integration. The value calculated by the adjusted method is 94.6 percent of the step value; the logarithmic mean is 180 percent of the step value; and the arithmetic mean is 279 percent of the step value. The size of a tower computed from the adjusted value of D_M would be conservative.

HEAT AS A DRIVING FORCE

In the preceding discussion, the driving forces have been in terms of vapor pressure. It is possible to state the equations in terms of the enthalpy of the air.[10a,11a] The net driving force difference is then the difference between the enthalpy of saturated air at the water temperature and the enthalpy of the air in contact with the water. Let f_c be equal to the surface coefficient for heat transfer, and let k' be the vaporization coefficient for use with a driving force based upon the difference in the values of humidity of saturated air at the bulk water temperature and the humidity in the air stream. The humid specific heat of the air stream is[2e]

$$s = 0.24 + 0.45H \qquad (51).$$

The Lewis equation[17a] holds rea-

sonably well for the evaporation of water into air. It is stated as follows:

$$f_c = k's \qquad (52).$$

The enthalpy of the air is given by the expression[4]

$$h = 0.24\,(t-0) + H\,(1{,}061 + 0.45t) \qquad (53).$$

The latent heat of saturated water vapor in the air at temperature T is the enthalpy of the vapor minus the heat of the liquid above 32 deg. F. It is given by the expression

$$r_T = 1{,}061 + 0.45T - T + 32 \qquad (54).$$

The differential increase in the enthalpy of the air, dh, is the increase in the sensible heat content of the original air-water mixture; plus the enthalpy of the evaporated water, dH, at the temperature of the make-up water, T; minus the sensible heat of the evaporated make-up water above the temperature of the final dry-bulb of the heated and humidified mixture. Thus,

$$dh = sdt + dH\,(r_T + T - 32) - 0.45dH\,[T - (t + dt)] \qquad (55a);$$

or,

$$Gdh = r_T Gdh + Gsdt - 0.45Gdh\,(T - t - dt) + GdH\,(T - 32) \qquad (55b).$$

The mass transfer is (see Fig. 5)

$$GdH = k'adV\,(H_T - H) \qquad (56).$$

The equation for heat transfer into the air is

$$Gsdt = f_c adV\,(T - t) = k'sadV\,(T - t) \qquad (57).$$

Eq. (56) is multiplied by r_T and added to Eq. (57):

$$r_T GdH + Gsdt = k'adV\,[r_T\,(H_T - H) + (0.24 + 0.45H)\,(T - t)] \qquad (58a).$$

From Eq. (55b)

$$r_T GdH + Gsdt = Gdh + 0.45\,GdH\,(T - t - dt) - GdH\,(T - 32) \qquad (58b).$$

A combination of (54), (58a), and (58b) yields

$$Gdh + 0.45\,GdH\,(T - t - dt) - GdH\,(T - 32) = k'adV\,[(h_T - h) - (H_T - H)\,(T - 32)] \qquad (58c)$$

In Eq. (58c), the effect of omitting the expressions "$0.45GdH\,(T - t - dt) - GdH\,(T - 32)$" and "$-k'adV\,(H_T - H)\,(T - 32)$" is small at the ordinary operation temperatures of cooling towers, and Eq. (58c) may be simplified to the form

$$Gdh = k'adV\,(h_T - h) \qquad (59).$$

Eq. (55b) indicates that when the reduction in water rate due to evaporation within the volume is neglected, the energy balance for the differential section of the tower volume may be written

$$LdT = Gdh \qquad (44a).$$

If a mean effective value of the driving force is established, and if integration is performed between the

Table IV—Step integrated solution of an extreme cooling problem

Wet-bulb = 55.0 deg. F.: B_s = 24.0 in. Hg: L_2/G = 0.670 lb. water per lb. air

(1) T	(2) Σ'	(3) t_w'	(4) $T - t_w$	(5) Z	(6) (4)×(5)	(7) p_T	(8) p_w	(9) (7)−(8)	(10) D=(6)+(9)	(11) ΔQ	(12) $KA = \Delta Q/D$
117	63.63	90.7	26.3	0.00898	0.2362	3.169	1.453	1.716	1.952	1.01	0.52
114	61.62	89.4	24.6	0.00896	0.2204	2.911	1.395	1.516	1.736	2.01	1.16
111	59.61	88.1	22.9	0.00895	0.2050	2.672	1.339	1.333	1.538	2.01	1.31
108	57.60	86.8	21.2	0.00894	0.1895	2.449	1.285	1.164	1.354	2.01	1.49
105	55.59	85.4	19.6	0.00893	0.1750	2.243	1.229	1.014	1.189	2.01	1.69
102	53.58	83.9	18.1	0.00892	0.1615	2.052	1.171	0.881	1.043	2.01	1.93
99	51.57	82.4	16.6	0.00891	0.1479	1.875	1.116	0.759	0.9069	2.01	2.22
96	49.56	80.8	15.2	0.00890	0.1353	1.712	1.060	0.652	0.7873	2.01	2.56
93	47.55	79.2	13.8	0.00889	0.1227	1.561	1.006	0.555	0.6777	2.01	2.97
90	45.54	77.5	12.5	0.00888	0.1110	1.422	0.9509	0.471	0.5820	1.68	2.89
88	44.20	76.3	11.7	0.00887	0.1038	1.335	0.9138	0.421	0.5248	1.34	2.55
86	42.86	75.1	10.9	0.00886	0.0966	1.253	0.8780	0.375	0.4716	1.34	2.85
84	41.52	73.8	10.2	0.00885	0.0903	1.175	0.8406	0.334	0.4243	1.34	3.16
82	40.18	72.5	9.5	0.00884	0.0840	1.102	0.8048	0.297	0.3810	1.34	3.52
80	38.84	71.2	8.8	0.00884	0.0778	1.032	0.7701	0.262	0.3398	1.34	3.95
78	37.50	69.8	8.2	0.00883	0.0724	0.9666	0.7342	0.232	0.3044	1.34	4.41
76	36.16	68.4	7.6	0.00882	0.0670	0.9046	0.6999	0.205	0.2720	1.34	4.93
74	34.82	66.9	7.1	0.00881	0.0625	0.8462	0.6646	0.182	0.2445	1.34	5.49
72	33.48	65.4	6.6	0.00880	0.0581	0.7912	0.6310	0.160	0.2181	1.34	6.15
70	32.14	63.8	6.2	0.00879	0.0545	0.7392	0.5968	0.142	0.1965	1.01	5.14
69	31.47	63.0	6.0	0.00879	0.0527	0.7144	0.5802	0.134	0.1867	0.670	3.59
68	30.80	62.2	5.8	0.00878	0.0509	0.6903	0.5641	0.126	0.1769	0.670	3.79
67	30.13	61.4	5.6	0.00878	0.0492	0.6669	0.5485	0.118	0.1672	0.670	4.01
66	29.46	60.5	5.5	0.00877	0.0482	0.6442	0.5313	0.113	0.1612	0.670	4.16
65	28.79	59.6	5.4	0.00877	0.0474	0.6222	0.5145	0.108	0.1554	0.670	4.31
64	28.12	58.7	5.3	0.00876	0.0464	0.6009	0.4982	0.103	0.1494	0.670	4.48
63	27.45	57.8	5.2	0.00876	0.0456	0.5802	0.4824	0.0978	0.1434	0.670	4.67
62	26.78	56.9	5.1	0.00875	0.0446	0.5601	0.4669	0.0932	0.1378	0.670	4.87
61	26.11	56.0	5.0	0.00875	0.0438	0.5407	0.4520	0.0887	0.1325	0.670	5.06
60	25.44	55.0	5.0	0.00874	0.0437	0.5218	0.4359	0.0859	0.1296	0.335	2.58

Summation of KA = 102.41

NOMENCLATURE

a = Area of active cooling surface per unit of tower volume, sq. ft. per cu. ft.

a_I = Area of packing exposed to water flow, per unit of tower volume, sq. ft. per cu. ft.

A = Area of cooling exposed in an integration step, sq. ft. per lb. dry air.

b_e = A function of the cycle modulus, Fig. 10.

b_f = A function of the cycle modulus, Fig. 11.

B = Barometric pressure, in. Hg.

B_e = Barometric pressure used in calculations involving comparison with basic data at 30.0 in. barometer, in. Hg.

c = Height of a packing cycle, ft. per cycle.

D = Net driving force difference, or effective potential, in. Hg.

D_f = Diffusivity, sq. ft. per min.

$D_{l.\,m.}$ = Logarithmic mean net driving force difference, in. Hg.

D_M = Mean net driving force difference, in. Hg.

D_z = Net driving force difference at water temperature T_z, in. Hg.

f_e = Overall coefficient of heat exchange by conduction and convection, B.t.u. per sq. ft., deg. F. temp. diff., and min.

G = Rate of air flow through tower, lb. bone dry air per min.

h = Enthalpy of the air-water mixture, B.t.u. per lb. dry air.

h_T = Enthalpy of saturated air-water mixture at the temperature of the bulk of the liquid, B.t.u. per lb. dry air.

H = Air humidity, lb. of water vapor per lb. bone dry air.

H_T = Humidity of saturated air at temperature T, lb. per lb.

I = Cycle Modulus, g.p.m. per sq. ft. per cycle.

k = Vaporization coefficient, or conductance for vapor transfer, lb. water vapor per sq. ft. min., and in. Hg diff.

k' = Vaporization coefficient, or conductance for vapor transfer, lb. water vapor per sq. ft., min., and lb. per lb.

k_G = Vaporization coefficient, lb. moles per min., sq. ft., and atm.

K = Overall coefficient of heat exchange based upon the mass velocity of the air, B.t.u. per sq. ft., min., and in. Hg diff.

L = Water rate through cooling tower, lb. per min.

m = Exponent used in calculation of K in Eq. (77), a function of I

M_G = Molecular weight of dry air

M_L = Molecular weight of water

n = Exponent used in calculation of K in Eq. (78), a function of I.

N_L = The rate of diffusion of water vapor, moles per unit area and unit time.

NTU = Number of transfer units.

p_{AM} = Log mean partial pressure of inert gas, air, atmospheres.

p_G = Partial pressure of water vapor in the main air stream, atm.

p_i = Partial pressure water vapor at the interface, considered the pressure of water vapor in saturated air at T, atm.

p_w = Saturated pressure of water vapor at the wet-bulb temperature, in. Hg.

P_e = Total absolute pressure, atm.

P_G = Pressure of a gas, in. Hg.

q = One tenth of the apparent free convection value for K at $B = 30$ in.

Q = Rate of exchange in a cooling tower, B.t.u. per min.

r = Latent heat of vaporization of water vapor, B.t.u. per lb.

R = $D_{l.\,m.}/D_z$.

R_e = The gas law constant.

s = Humid specific heat air-water mixture, B.t.u. per deg. F., and lb. of dry air.

S = Gross cross sectional area of cooling tower at right angles to the air flow, all packing removed, sq. ft.

t = Temperature of the air-water mixture, or dry-bulb temperature, deg. F.

t_w = Wet-bulb temperature, deg. F.

T = Bulk temperature of the water, deg. F.

T_A = Absolute temperature, deg. Rankine or Kelvin.

T_z = Temperature of water at which D_z occurs, deg. F.

U_e = Average linear velocity of air stream over packing surface, ft. per min.

V_H = Humid volume of air entering tower.

V_G = Molecular volume of air. [17]

V_L = Molecular volume of water vapor. [17]

x = Effective total film thickness, unit length.

Z = General value of f_e/kr, in. Hg per deg. F.

α = A factor to compensate for unwetted packing, equal to $0.30 + 1.90I$.

λ = A function of R used in Eq. (50) for determination of D_M.

Σ = The Sigma Function, in main air stream, B.t.u. per lb. dry air.

$\cong$ = Denotes sensible equivalence.

SUBSCRIPTS

M = A mean effective value.

T = Conditions at water temperature, T.

1 = Conditions at the air entrance and water exit of a counter-flow tower.

2 = Conditions at the water entrance and air exit of a counter-flow tower.

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proper limits associated with the tower volume, resultant equation is

$$G (h_2 - h_1) = k'aV (h_T - h)_M \quad (60a),$$

where $(h_T - h)_M$ is the mean effective driving force potential.

Eq. (60a) may be re-arranged as follows:

$$(h_2 - h_1)/(h_T - h)_M = k'aV/G = NTU \quad (60b),$$

where NTU is the number of transfer units. The height of the packing divided by the NTU gives the height of a transfer unit. The transfer unit corresponds to a change in enthalpy equal to the mean driving force difference. The NTU is a measure of the difficulty of the cooling operation. The use of the enthalpy driving force and the NTU concept offers an approach to a design method similar to the method used in the design of extraction towers.

In Eq. (58c), the quantity "$h_T - H_T (T-32)$" is the sigma function for saturated air at the temperature T. The quantity "$h - H(T-32)$" is the sigma function of the air stream less the heat of liquid above the wet-bulb; practically, it is the sigma function of the air stream. The heat added to the air stream per pound of dry air is, from Eq. (27),

$$\Sigma_2 - \Sigma_1 \cong L_2 (T_2 - T_1)/G \quad (27a).$$

Therefore, it is possible to set up a practical design equation in terms of the sigma function of saturated air at the temperature of the bulk of the liquid and the sigma function of the main air stream. The equation is stated as follows:

$$G (\Sigma_2 - \Sigma_1) = L_2 (T_2 - T_1) = k'aV (\Sigma_T - \Sigma)_M \quad (60c).$$

THE COEFFICIENT OF HEAT EXCHANGE

The coefficient of heat exchange is in terms of B.t.u. per min. per sq. ft. of contact area per in. Hg of driving force difference. It is the product of the mass transfer coefficient, or conductance, and the latent heat of the vapor. Coffey and Horne[13] made tests to determine the value of this coefficient; they proposed a straight line formula for definition of K. In 1918, Carrier[14] presented straight line formulas for K which were for the cases of transverse and parallel flow; a re-plotting of the Coffey and Horne data indicated a close agreement with the resultant plot of Carrier's points for transverse flow. The straight line formulas showed the values of K to be dependent upon the linear velocity of the air stream passing over the wetted surface. At zero linear velocity, the value of K was not zero; the effect of free convection was indicated. These experiments were performed upon evaporators with wick-covered surfaces.[15]

In a cooling tower, the surfaces of the packing are covered with moving water films, and the evaporative action differs from the action which occurs from a wick-covered surface; the surface of a wick, due to its texture, differs from the surface of a water film. As the water passes
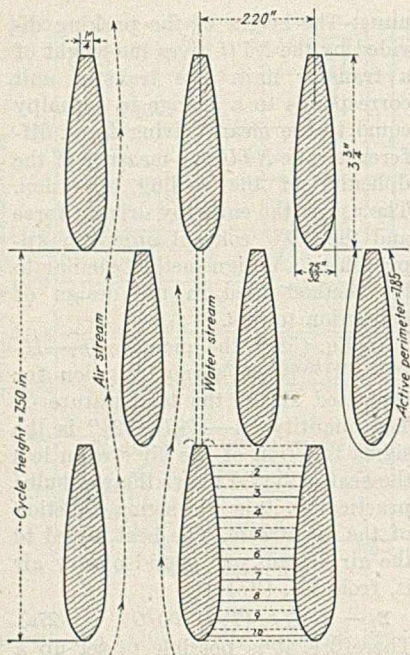
Fig. 9—Ovate packing of the Redwood Manufacturers Co. Clearances at the various sections of the slots are: (1) 1.88 in.; (2) 1.75 in.; (3) 1.63 in.; (4) 1.53 in.; (5) 1.48 in.; (6) 1.44 in.; (7) 1.43 in.; (8) 1.44 in.; (9) 1.60 in.; (10) 1.97 in. Average clearance is 1.62 in. Ratio of U_s to gross velocity over S is 1.36

over the guiding surfaces of the packing, the films are affected by the waves and by the stirring action. Furthermore, the stirring action in the water sheets has an effect upon the rate at which the heat reaches the inter-face of the transfer surface. According to the basic concept of Maxwell,[17d] there is a resistance to diffusion proportional to the number of molecules of the diffusing gas; proportional to the number of molecules of the gas through which diffusion takes place; proportional to the difference between the velocity of the diffusing gas in the direction of net diffusion and the velocity of the second gas; and proportional to the length of the path in the direction of net diffusion.

The following equation[17c] indicates the evaporative rate for true diffusion:

$$N_L = D_f P_a (p_i - p_G)/ R_e T_A x p_{AM} \qquad (61)$$

where N_L = rate of diffusion for water vapor, mols per unit area and unit time; D_f = diffusion coefficient, or diffusivity, (unit length)² per unit time; p_a = total atmospheric pressure, atmospheres; R_e = gas-law constant; T_A = temperature, deg.K. or deg. R.; x = effective total film thickness, unit length; p_{AM} = log mean

partial pressure of the inert gas, air, atmospheres; p_i = vapor pressure of water at the inter-face, atmospheres; p_G = partial pressure of water vapor in the main air stream, atmospheres.

The diffusion indicated by Eq. (61) is for the case of truly stagnant fluid layers. However, even in the turbulent layers, the rate of eddy diffusion may be assumed to be proportional to the partial-pressure gradient, as in true diffusion. And Eq. (61) may be applied with success to the interphase diffusion, involving transfer across both the eddy layer and the laminar layer.

The diffusion may be found from the equation[17f]

$$D_f = 0.0043 T_A^{1.5} (1/M_G - 1/M_L)^{0.5}/P_a (V_L^{1/3} + V_G^{1/3})^2 \qquad (62),$$

where T_A = temperature in deg. K.; M_L = molecular weight of water vapor; M_G = molecular weight of dry air; V_L, V_G = molecular volumes. Eq. (62) gives the value of D_f in sq. cm. per sec.

Let k_G be defined by the following equation:

$$k_G = N_L/(p_i - p_G) \qquad (63).$$

Then, Eq. (63) combines with Eq. (61) to yield

$$k_G = D_f P_a/R_e T_A x p_{AM} \qquad (64).$$

Since D_f varies inversely with P_a and since x does not vary with the pressure, it follows that k_G varies inversely as the partial pressure, p_{AM}, of the inert gas, air.

Let k' represent the vaporization coefficient in the simplified diffusion equation

$$N_L M_L = k' (H_T - H) \qquad (65)$$

where H_T = humidity of saturated air at the temperature of the bulk of the liquid, considered the humidity at the interface, and H = humidity of the main air stream. By the use of the gas laws (see Eq. (5) for air humidity),

$$H_T - H = [p_i/(P_a - p_i) - p_G/(P_a - p_G)]/(M_L/M_G) \qquad (66).$$

Since, in most cases, p_i and p_G are small compared to P_a and since $P_a - p_i$ is approximately equal to both $P_a - p_G$ and p_{AM}, Eq. (66) may be re-written

$$H_T - H = M_L (p_i - p_G)/M_G p_{AM} \qquad (67).$$

From Eq. (65),

$$k' = N_L M_L/(H_T - H) \qquad (68).$$

But, from Eq. (63),

$$N_L = k_G (p_i - p_G) \qquad (69).$$

Therefore, by substitution of (69) and (67) in Eq. (68),

$$k' = k_G M_G p_{AM} \qquad (70).$$

Inspection of Eq. (70) indicates that k' varies as the product $k_G p_{AM}$. However, since k_G varies inversely as p_{AM}, the product $k_G p_{AM}$ does not vary

with variation in the partial pressure of the inert gas, air.

Let k represent the vaporization coefficient in the simplified diffusion equation in which the vapor pressures are in inches of mercury:

$$N_L M_L = k (p_T - p_a) \qquad (71).$$

Then, Eq. (65) may be combined with Eq. (71) to yield

$$k (p_T - p_a) = k' (H_T - H) \qquad (72).$$

Let B equal the barometric pressure in inches of mercury. Then, in form similar to Eq. (66),

$$k (p_T - p_a) = k' [p_T/(B - p_T) - p_a/(B - p_a)] (M_L/M_G) \qquad (73).$$

If $B - p_T$ is assumed equal to $B - p_a$,

$$k = k' M_L/(B - p_a) M_G \qquad (74).$$

Since $B - p_a$ approximates the value of the barometric pressure, k varies approximately inversely as the barometric pressure, since k', M_L, and M_G are independent of pressure variations of the inert gas.

The value of k multiplied by the latent heat of evaporation is equal to K, the coefficient of heat exchange for cooling tower action when the driving forces are in terms of inches of mercury pressure.

Nusselt[16a] has shown experimentally that, in heating air in the range from 1.1 to 16 atm., the mass velocity of the air is the controlling factor in the determination of the coefficient of heat transfer by convection. The control by the mass velocity is independent of pressure changes. The Lewis equation indicates that k' varies directly as f_c, and indirectly as the humid heat, s. Therefore, k' varies with the mass velocity of the air; and k must also vary with the mass velocity of the air. Colburn and Hougen[16b] found that the vapor diffusion coefficient varied as the mass velocity to a fractional power. Sherwood[17b] cites experimental support for the mass velocity control.

The exponents of the mass velocity which are used in the determination of coefficients for convection indicate the approximate values of the exponents of the mass velocity to be used in the determination of K. The unit mass transfer conductance[18] varies with the 0.37 power of the air velocity for normal flow of the air, with the 0.56 power for transverse flow, and with the 0.80 power for longitudinal flow. The data on transverse flow over pipe coils[11b] indicate valuations of the exponent which vary from 0.45 to 0.65. London, Mason and Boelter[10b] stated a value of 0.48 for streamlined packing. Niederman, Howe, Longwell, Seban, and Boelter found that the exponent was 0.5 for the wetted wall of a spray tower.[19]

Comparative investigations indicate that there may be variations in K due to changes in the water rate. The writer has found that these variations may be considered in design by the use of the cycle modulus, I. The cycle modulus is defined by the equation

$$I = 0.120 \, L_2/Sa_Ic \qquad (75),$$

where I = the cycle modulus, gal. per min. per sq. ft. per cycle; L_2 = initial liquid rate, lb. per min.; S = gross cross sectional area of the tower at right angles to the air flow (the open area with packing removed), sq. ft.; a_I = the area of packing surface per unit volume of tower, ft. per cu. ft.; c = the cycle height, ft. per cycle. If, in a symmetrically packed tower, the water passes through a first section at right angles to the direction of flow and continues through the tower until it passes a second parallel section which cuts the packing so that the sectional elements of the cut packing are in perfect alignment with similar elements cut by the first section, the water has passed through the height of one cycle.

The streamlined Ovate[9] packing of the Redwood Manufacturers Co. (U.S. Patent 2,207,272) is shown in Fig. 9. The air flows over the surface with transverse flow. The cycle height of this packing is 7.50 in., or 0.625 ft. The effective perimeter is 7.85 in.; only this perimeter is considered active. The narrow, flat width at the trailing end is considered inactive for cooling design, since this trailing end is blanketed. However, the total perimeter is considered in the computation of the cycle modulus. Thus, the value of a is 11.42 sq. ft. per cu. ft. and the value of a_I is 11.78 sq. ft. per cu. ft. When the value of I is less than 0.370 gal. per min. per sq. ft. of cycle surface, K should be multiplied by a factor, α (alpha), to compensate for unwetted surface:

$$\alpha = 0.30 + 1.90I \qquad (76).$$

Fig. 10 is used for ovate packing when the linear velocity exceeds 300 ft. per min. The formula for K is as follows:

$$K = b_f \, (12.8 \, U_s/V_H)^m (30)/B_s \qquad (77),$$

where U_s = the average linear velocity of the air over the cooling surface, ft. per min.; V_H = humid volume of air entering the tower; m = an exponent, a function of the cycle modulus; b_f = a coefficient, a function of the cycle modulus.

Fig. 11 is for the computation of K for ovate packing when the linear velocity of the air is less than 300 ft. per min. The values of K resulting from the use of Fig. 11 are influenced by an apparent free convection effect, which is represented upon the chart by the curve for q. Ten times the value of q is the apparent free convection value.

The formula for K is as follows:

$$K = [10q - b_c \, (12.8 \, U_s/V_H)^n/10] \, (30/B_s) \qquad (78),$$

where q = a function of the cycle modulus, one tenth of the apparent free convection value of K; n = an exponent, a function of the cycle modulus; b_c = a coefficient, a function of the cycle modulus.

The exponent m of Fig. 10 for forced convection is 0.63 for a cycle modulus of zero. This value is in agreement with the value of the exponent used for drying calculations.[11c] For a cycle modulus of zero, the values of $10q$ and n from Fig. 11 show agreement with the results of Carrier. The data of Figs. 10 and 11 are for the Ovate packing with streamlined shape. Data for the packings of absorption equipment have been given in which 0.8 is the value of the exponent.[10a,17b] The values from Fig. 10 indicate values of the exponent which approximate 0.5; this exponent is in accordance with recent work on packed towers.[20] The values of K for ovate filling may be used

for transverse flow conditions with rectangular packing sections and cycle heights up to 16 in.

The reciprocal of k' for ovate filling plotted against the reciprocal of the mass velocity of the air to the exponent $m = 0.5$ gives a line which is practically straight and which passes through the origin.[17h] The indications are that the liquid film resistance is negligible and that the gas film is controlling. Dwyer and Dodge[20] indicate that the diffusion coefficients should be nearly independent of temperature.

Since the values of the exponent m for convection and diffusion show agreement with the values of the exponent for ovate filling, it is suggested that designs involving transverse flow may be made using the data for ovate packing with the cycle moduli determined from Eq. (75). The effect of the water drops is slight, and the neglect of the drop-surface effect introduces a conservative element into the design. When packings have blanketed surfaces,[12] the value of $10q$ for the cycle modulus in question may be used for the portion of the surface which is exposed to the reduced air flow. The actual blanketed surface area may be considered as a reduced area acting with the full conductance of the fully efficient surfaces.

In a spray tower, at constant barometer, the conductance of the area exposed by the spray does not vary with the air rate;[19] the principle variation in K is due to change in the liquid rate. Therefore, in comparing the actions of a spray tower at various air rates, the spray conductance varies as the zero power of the mass velocity of the air. Thus, a change in the air rate in a spray tower affects the driving force, but the constancy of the conductance tends to stabilize the tower action.

Fig. 10—Values for use in Eq. (77) for computation of K when linear velocity exceeds 300 ft. per min. Fig. 11—For use in Eq. (78), these values are used when linear velocity of air is less than 300 ft. per min.
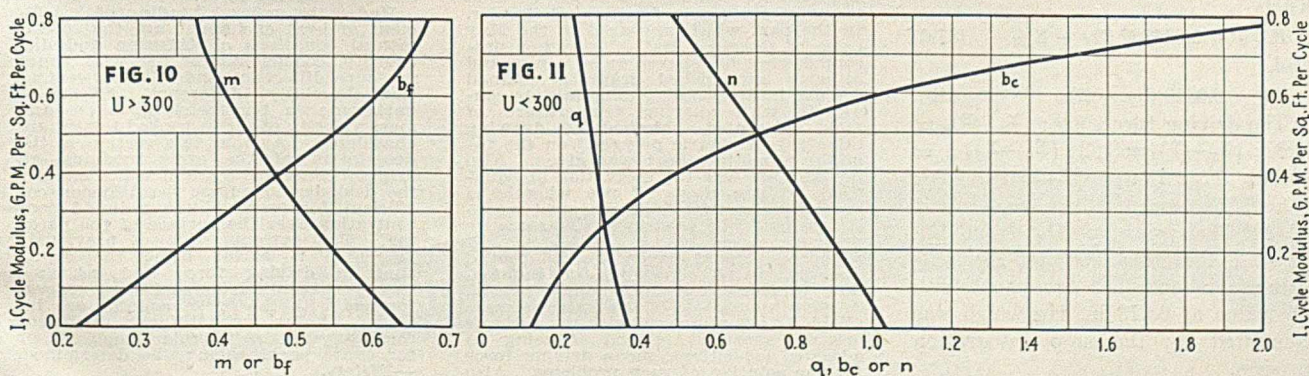
When water is sprayed into air, some of the very fine drops are completely vaporized,[10a,19] and therefore contribute nothing to the cooling of the circulated liquid from which they are sprayed. The relationship of the Lewis modulus does not often hold in spray installations; the heat content of the air is increased and the cooling potentials are reduced. Furthermore, the liquid within the drops is not subjected to mechanical stirring; heat must pass from the heart of the drop to the film by means of convection and conduction. The coefficients of mass transfer and heat transfer appear to decrease as the temperatures of the liquid and the gas are increased.

In some of the literature,[11a,19] the logarithmic mean driving force difference is used in the computation of the coefficient of mass transfer. At the higher inlet water temperatures, the log mean driving force potential is too great, and the calculated coefficient is less than the coefficient which would be calculated from a true mean value. Therefore, when the log mean potential is used without adjustment to the true mean, the coefficient that corresponds to the method of computation should be used.

From Eq. (74) it may be shown that

$$k' = 1.61k \,(B - p_w) \qquad (79).$$

K is the product of k and the latent heat. If the average value of the latent heat is taken at 1,050 B.t.u. per lb.,

$$k' = K \,(B - p_w)/652 \qquad (80a);$$

or, since $(B - p_w)$ approximates B,

$$k' = KB/652 \qquad (80b).$$

The step solution of Table IV is for a barometric pressure of 24.0 in. Thus, for the problem of Table IV, the following solution by means of the sigma function driving force difference shows the agreement of the method with the vapor pressure driving force method.

From Eq. (80b), with a value of B equal to 24.0 in., k' equals $0.0368K$. Then,

$$KD_M = 0.0368 K \,(\Sigma_T - \Sigma)_M \qquad (81a).$$

and,

$$D_M = 0.0368 \,(\Sigma_T - \Sigma)_M \qquad (81b).$$

The driving forces are: $(\Sigma_T - \Sigma)_2 = 61.97$; $(\Sigma_T - \Sigma)_1 = 3.62$; $(\Sigma_T - \Sigma)_{l.m.} = 20.57$; $T_s = 76.6$; $(\Sigma_T - \Sigma)_s = 7.99$; $R = 2.57$; $\lambda = 0.822$; $(\Sigma_T - \Sigma)_M = 10.00$. The value of D_M from Eq. (81b) is therefore 0.368 in. Hg. This value is in excellent agreement with the value of 0.373 in. Hg which was computed by the step integration process.

Since k' is practically independent of variation in the barometric pressure, and since the sigma function driving force is a reliable approximation for design, Eq. (60c) is indicated as an efficient means of calculation for use in design calculations and calculations for the comparison of operation under various conditions.

CONCLUSIONS

1. The adjusted logarithmic mean driving force difference may be used to compute the mean effective driving potential. The method gives reasonable accuracy of solution, and the long and tedious process of step integration is replaced by a short-cut method.

2. The relationship expressed by the Lewis equation makes possible the establishment of a driving force system which is in terms of enthalpy differences. The adjusted logarithmic mean driving force method applies to the solution by enthalpies.

3. K is inversely proportional to the log mean pressure of the inert gas, air; it is approximately inversely proportional to the barometric pressure.

4. k' is practically independent of the partial pressure of the inert gas, and is, therefore, practically independent of variations in the barometric pressure.

5. The cycle modulus is used as a basis for the determination of K at various liquid rates; a decreased cycle modulus is indicative of thinner water sheets.

6. K and k' vary approximately as the 0.5 power of the mass velocity of the air for transverse flow of the air over the packing.

7. K (for packed surface) is nearly independent of temperature. For spray surface, the conductance appears to decrease with increase in temperature.

8. The driving force based upon the sigma function difference is indicated as a reliable factor for practical design. For practical calculations, k' is independent of variation in the barometric pressure; k' varies with the mass velocity of the air. When the sigma function basis is used, the transfer unit corresponds to a change in the sigma function of the main air stream equal to the mean effective driving force potential expressed as a sigma function difference.

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REVIEW AND SUMMARY

After an introductory review of psychrometric principles, the first of this series of three articles discussed the straight-line formula of Goodman for enthalpy and latent heat, and the energy equation for cooling tower operation in terms of the sigma function of Carrier. In the part which appeared in the May issue of *Chem. & Met.*, the author presented what is believed to be a new and hitherto unpublished graphical method for use in determining outgoing air conditions with varying temperature of make-up water. Method of drawing this "psychrometric polygon" on the familiar humidity chart was given. Also in this part was the derivation of equations with methods of use whereby a humidity chart for 30-in. barometer conditions could be used at any barometric pressure.

In the present paper are differential and integrated equations for counterflow forced convection cooling towers. A step-integration of an extreme case (Table IV) is compared with the author's original short-cut method of using an adjusted logarithmic mean driving force for the solution of such problems. Also considered is heat as a driving force. (In the author's previous series vapor pressure was used as the driving force; temperature was converted to vapor pressure.) Consideration of the driving forces in terms of the sigma function indicate that it is superior to the enthalpy driving force.

Under the general heading of "coefficient of heat exchange" are the fundamental equations of diffusion and diffusivity, coefficients for use with vapor pressure difference and with concentration (humidity) difference. Effects of variations in barometric pressure and mass velocity of air in packed towers are considered. Also in this section is the description of the cycle modulus—an original concept the use of which enables the designer to adjust the diffusion coefficient for practically any liquid concentration over the surface of the packing. The extreme problem previously presented is solved using the sigma function driving force and adjusted values of the diffusion coefficient. Curves for use with the cycle modulus are included. Value of the diffusion coefficient for staggered rectangular packings or for ovate packings may be determined.—*Editors.*

Southwestern Chemical Resources and Trends

TO EXECUTIVES AND ENGINEERS OF CHEMICAL ENTERPRISES

With every effort being made to locate new sources of raw materials and sites for new war-time production, the accompanying presentations of the natural resources of each of the states of the Southwest, Arkansas, Louisiana, Oklahoma and Texas, by leading authorities, should be of timely interest. This region west of the Mississippi River and north of the Gulf of Mexico is the richest in natural resources of any in the entire country. Due to this attraction, to the fact that the area is still comparatively undeveloped industrially, and because it is generally recognized that production costs are lower than in the East and Middle West, most of the leading chemical companies have already moved in, while others are known to be considering decentralization in connection with their post-war planning. In addition to these discussions of resources the report also includes a survey of trends in the industrialization of the Southwest.

Southwestern Chemical Resources and Trends

SUMMARY AND CONCLUSION

Every few years *Chem. & Met.* has reported to its readers the trends in the industrial development of the South. These reports generally emphasized the states east of the Mississippi River. However, the wealth of mineral resources west of the river, and the tremendous strides in development of that area recently have made it necessary to devote an entire report to the Southwest.

Some of the conclusions that stand out are as follows:

This section has the greatest wealth of natural resources of any in the United States. With the discovery of oil came industry, and with the finding of natural gas and development of other resources came an acceleration of the movement. And since the resources had greatest appeal to the process industries, most of the activity has been by this group.

The war program is advancing industrialization of the Southwest at a tremendous rate, bringing chemical organizations to the area who otherwise would not have come for many years.

Many of the plants are making products for which there has long been a need. And producers of aluminum, magnesium, synthetic rubber and organic chemicals are finding it more economical to manufacture at the source of raw materials. Therefore, the post-war retrenchments are not likely to be as serious in the Southwest as in other sections of the country.

The SOUTHWESTERN STATES (Arkansas, Louisiana, Oklahoma and Texas) are benefiting by a wave of industrialization which began several years ago and is being given enormous impetus by this second world war. The movement has been favored by an abundance of excellent natural resources, especially fuel, by cheaper transportation and a milder climate, and by lower taxes and labor costs than in the East and Middlewest. Most of this recent expansion in the area has been within the process industries for it is this group that stands to gain most from the crude petroleum and natural gas for both fuel and sources of many organic chemicals, the sulphur, salt, bauxite, and a long list of other minerals that are the bases of many of the chemical industries. This section probably has a greater array of natural wealth than any other.

In the present emergency, the Southwest is benefiting from the decentralization of defense industries. This policy may be partially explained by the federal government's desire to avoid a repetition of the experience of the first world war, when concentration of war industries in the Northeast caused considerable congestion, and delays in transportation, but more correctly by the advisability of processing the raw materials at or near their source. Although, as a general policy, the government is now locating war plants at inland points several hundred miles from the coast lines, this rule has to be disregarded in some cases, such as the plant for producing magnesium from sea water.

General engineering construction in the Southwest has been at a greatly accelerated rate recently. In 1941, $949,502,000 were spent for new buildings, which compares with only $227,741,000 for 1938, a comparatively normal year. As great as was the building construction last year it was small compared to the rate during the current year when it has been 240 percent greater than in the corresponding five months of 1941. Much of this new construction was for process industry plants. From the accompanying map it may be seen that a large percentage of funds spent last year was for government financed plants and equipment.

The total war contracts for the Southwest, according to the National Industrial Conference Board in the period from June, 1940, to Jan. 1942, reached $2,242,000,000 which had been awarded as follows: Arkansas $214,000,000, Louisiana $355,000,000, Oklahoma $348,000,000, and Texas $1,325,000,000.

Arkansas—This state has a great abundance of natural resources and is ripe for industrial development, but until quite recently it has been content to extract bauxite, petroleum, natural gas and other minerals and ship them out of the state to be processed. However, the present administration at Little Rock has seen the need for greater industrialization and has had considerable success in its efforts to attract industrial enterprises. Arkansas now has an ammonia plant, two kraft pulp and paper mills, several petroleum refineries, and shortly will have a tremendous plant for converting the enormous deposits of bauxite into alumina, and another plant for reducing the oxide to metallic aluminum.

Louisiana—The area around New Orleans has long been a center of process industries, and more recently other centers of manufacturing have

developed, Baton Rouge, Lake Charles, Shreveport and Monroe.

New Orleans is a large producer of alcohol, cottonseed oil, refined cane sugar, heavy chemicals, fertilizers and other products; and recently to these have been added others, such as cement, printing ink, asphalt emulsion and roofing. The first industry of any importance in Baton Rouge was a refinery for processing the petroleum from the oil fields of this and other states. It became a lodestone attracting other plants, acid, alkali (both electrolytic and ammonia-soda) tetraethyl lead and metallic sodium.

Lake Charles is the location of an ammonia-soda plant using salt and oyster shells from sources nearby. Recently a petroleum refinery has been built to process the oil from the fields in the neighborhood. Shreveport has its natural gas and petroleum. Just to the north at Springhill is the largest kraft pulp and paper mill in the United States. And at Monroe is another large kraft mill, an alum plant and other industries. Other kraft mills are located at Bastrop, Hodge and Bogalusa. And scattered over the state are numerous other process industries plants.

Oklahoma — Although only two generations removed from the Indian settlement period, Oklahoma has made remarkable industrial progress. Today, it is one of the leading producers of petroleum products, with approximately 25 refineries and a large number of natural gasoline plants. One of its cities, Tulsa, is known as the "Oil Capital of the World". However, Oklahoma has diversified industries. Among the most important are: glass containers, cottonseed oil and insecticides. There are several chemical industries, one of the most important is at Tulsa. The products include sulphuric and hydrochloric acids, salt cake and sulphate of potash. At Tallant is located a producer of formaldehyde and methyl alcohol from natural gas. There are only three other producers of formaldehyde in the entire country. Copper sulphate in liquid form for flotation purposes is made in a plant at Cardin. Sodium hypochlorite bleach is made by companies at Bristow, Barnsdale and Oklahoma City. There are two large paint manufacturers at Tulsa and several small ones scattered over the state. Four plants make asphalt emulsions.

Texas—Probably no one needs to be told that the petroleum industry is responsible for much of the industrial progress made by Texas since the discovery of Spindletop near Beaumont in 1901. Directly or indirectly oil has contributed enormously to the trend toward industrialization in the state. There are in the neighborhood of 150 refineries. Several of the largest are producing enormous volumes of chemicals. Others are turning their waste gases over to neighboring plants where they are used in producing synthetic organic chemicals. The utilization of natural gas as a raw material for the manufacture of chemicals has advanced far enough to demonstrate the potentialities in this line.

Until a few years ago the principal industries in addition to petroleum were cotton gins and cottonseed oil mills, cattle, lumber, and sulphur. In 1936, the importance of East Texas pine forests were realized as a source of cellulose. Shortly thereafter a large mill was built on the Houston Ship Channel to produce sulphate pulp and paper, and a newsprint mill was erected at Lufkin. About this time an ammonia-soda plant was located at Corpus Christi.

In the period between June, 1940 and January 1942, contracts for war plants and facilities for the four states of the Southwest reached $737,000,000

TOTAL: 7,049 MILLION DOLLARS

WASH. 168
OREG. 33
MONT. 2
N. DAK. ★
MINN. 85
ME. 11
IDAHO ★
S. DAK. ★
WIS. 120
VT. 3
N.H. 25
MASS. 134
N.Y. 434
MICH. 568
109
WYO. ★
IOWA 110
R.I. 16
CONN.
NEV. 79
UTAH 183
NEBR. 75
ILL. 517
IND. 466
OHIO 519
PA. 686
143
127
N.J.
COLO. 50
KANS. 110
MO. 326
W. VA. 178
VA. 179
DEL. 6
MD.
D.C. 14
CALIF. 314
KY. 39
N.C. 10
ARIZ. 11
N. MEX. 2
OKLA. 107
ARK. 157
TENN. 122
S.C. 24
GA. 21
MISS. 24
ALA. 261
TEX. 381
LA. 92
FLA. 12

★ NO CONTRACTS REPORTED

LESS THAN 2
2 TO 10
10 TO 50
50 TO 200
200 AND OVER

PRIMARY AUTHORITY: WAR PRODUCTION BOARD
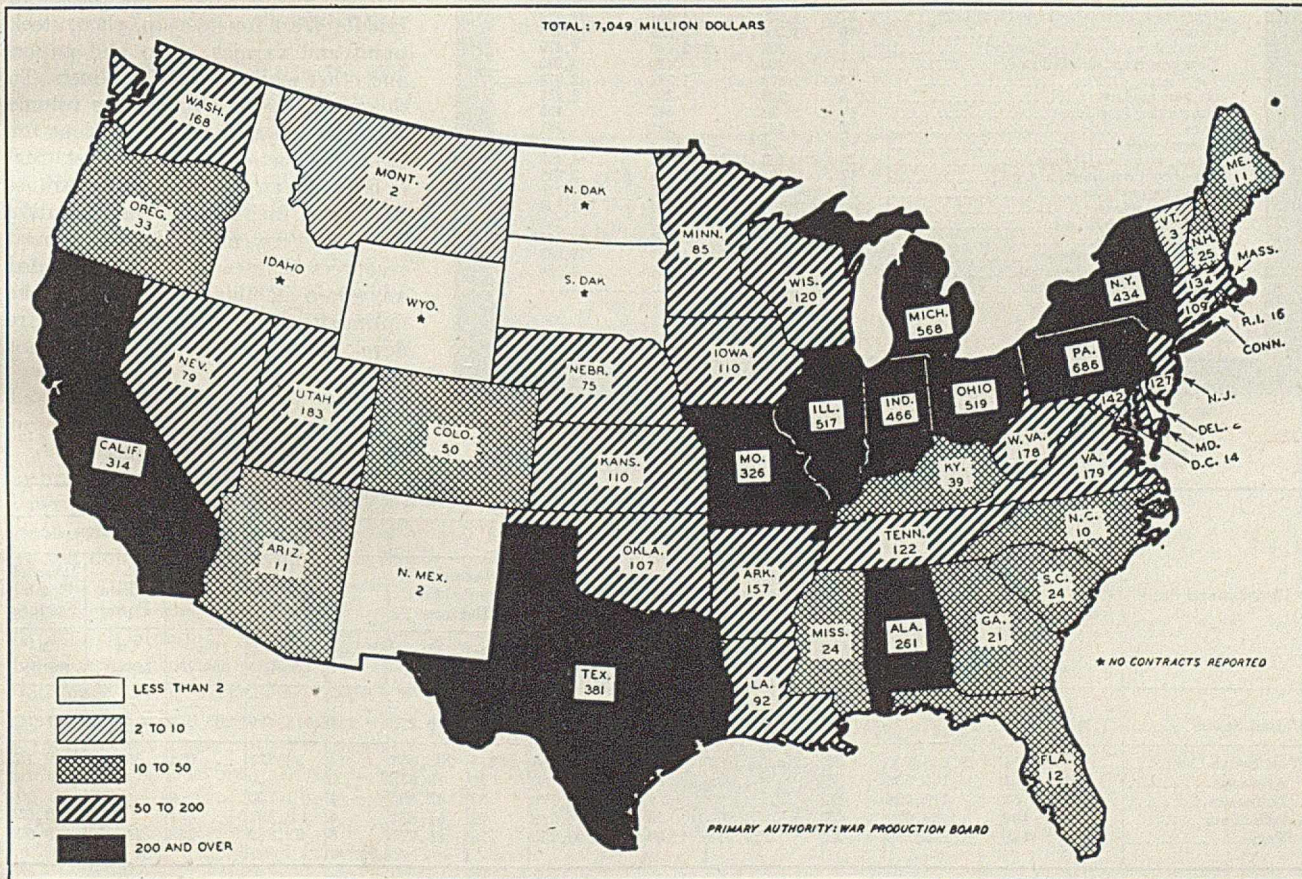
DATA ON CHEMICAL AND ALLIED INDUSTRIES

Source: Census of Manufactures, 1939

State and Industry	Establishments	Wage Earners[1]	Cost of Materials, Containers, Fuel, & Power[2] — $1,000	Value of Products[2] — $1,000
ARKANSAS				
All industries, total: 1939	1,178	36,254	$92,777	$160,167
Cottonseed oil, cake, meal, and linters	26	1,436	14,138	17,341
Fertilizers	8	119	779	1,285
Paperboard containers, n. e. c.	3	102	283	508
Petroleum refining	6	612	11,034	14,328
Chemicals and allied products	15	229	828	1,679
Products of petroleum and coal	3	61	381	726
LOUISIANA				
All industries, total: 1939	1,861	71,218	$365,179	$565,265
Bone black, carbon black, lampblack	6	211	859	2,094
Cane sugar refining	7	3,247	58,110	66,674
Chemicals not elsewhere classified	11	1,269	11,628	32,507
Compressed and liquefied gases[3]	13	93	262	1,024
Cottonseed oil, cake, meal, linters	24	732	6,388	7,824
Fertilizers	12	524	3,288	4,652
Insecticides and fungicides[5]	7	18	60	152
Liquors, rectified or blended	5	21	172	296
Paints, varnishes, lacquers	13	166	1,369	2,084
Paper and paperboard mills	8	2,536	18,253	25,650
Paperboard containers, n. e. c	9	622	2,675	4,538
Perfumes, cosmetics	5	31	194	403
Petroleum refining	13	2,629	95,483	109,627
Printing ink	4	13	166	441
Pulp mills	7	1,787	8,549	13,817
Roofing, built-up and roll[6]	3	308	2,118	4,156
Wood naval stores	3	307	623	1,419
Paper and allied products	4	59	210	360
Chemicals and allied products	10	497	1,167	3,115
Products of petroleum and coal	1 }	19	....	....
Leather and leather products	2 }			
OKLAHOMA				
All industries, total: 1939	1,606	28,113	$209,050	$312,168
Compressed and liquefied gases[3]	7	44	149	491
Cottonseed oil, cake meal, linters	29	651	4,838	6,142
Glass containers	5	650	1,746	3,341
Insecticides, fungicides[5]	9	25	178	491
Lubricating oils and greases[6]	6	40	578	1,000
Paperboard containers, n. e. c	4	140	759	1,281
Petroleum refining	27	4,278	88,582	106,667
Chemicals and allied products	21	226	1,150	2,387
Rubber products	3	....	....	....
Leather and leather products	2	....	....	....
TEXAS				
All industries, total: 1939	5,376	126,996	$1,077,115	$1,530,221
Bone black, carbon black, and lampblack	37	1,200	4,654	11,123
Cement	10	1,260	3,935	12,726
Chemicals not elsewhere classified	12	703	2,440	6,479
Compressed and liquefied gases[3]	27	192	490	2,033
Fertilizers	17	192	1,387	2,018
Gypsum products	5	326	856	3,226
Insecticides, fungicides[5]	19	38	447	902
Lime	7	181	221	531
Mineral wool	4	30	36	81
Paints, varnishes, lacquers	25	193	2,380	4,457
Paperboard containers, n. e. c	17	404	1,524	2,753
Perfumes, cosmetics	12	94	795	1,180
Petroleum refining	113	18,931	576,381	698,850
Rubber products, n. e. c	7	93	446	816
Soap and glycerin	4	20	104	141
Paper and allied products	16	1,133	4,133	7,952
Chemicals and allied products	20	263	1,324	3,134
Leather and leather products	4	....	....	....

To this plant has been added an electrolytic chlorine plant. Very recently have come a host of other process industries, paint and varnish, soap, glass containers, silicate of soda, etc.

The Southwest is contributing to the war effort. This area, which accounted for only 3.4 percent of the value added by manufacture in 1939, has been awarded 10.4 percent of all government war plants. Much of this has been awarded for construction of plants to produce toluol, butadiene, styrene, ammonia, magnesium, smokeless powder, synthetic rubber, aluminum, picric acid and other materials for the armed forces. Prior to January, 1942, Arkansas had received $157,000,000 for war plants; Louisiana, $92,000,000, Oklahoma, $107,000,000; and Texas $381,000,000. This is a vast change from what happened in the first World War. Industrially the Southwest was neglected and non-industrial facilities were limited largely to air training. Cantonments, other than for air, were mostly in the Southeast.

The retrenchment throughout industry that must follow the cessation of hostilities is not likely to be as serious in the Southwest as in other sections of the country. The area has within its boundaries a large population which has always depended mainly upon the East and Middle West for its soap, glass, steel, paint and varnish, pulp and paper, and other manufactured products. To this ready market for a large volume of goods add attractive conditions for their production, the cheapest fuel to be found anywhere, adequate transportation facilities, splendid native born workers, mild climate, natural resources that can not be duplicated anywhere in this country, and the optimistic view point of the future development of the Southwest is not difficult to see.

POWER IN THE SOUTHWEST
Preliminary as of November 1, 1941

Division and State	No. of Companies	No. of Plants	Total Capacity Kilowatts	One Type of Prime Mover — Water Power Number	Capacity	Steam Power Number	Capacity	Internal Combustion Engines Number	Capacity	Combination of Two or More Types — Total Number	Capacity	Water Power Capacity	Steam Power Capacity	Internal Comb. Engines Capacity
United States	1,786	3,872	43,491,371	1,399	11,949,170	1,124	29,777,436	1,132	846,276	217	918,489	266,683	504,098	147,708
West South Cent	184	414	2,235,720	32	277,893	99	1,718,568	272	201,037	11	38,222	654	25,416	12,152
Arkansas	26	51	155,536	5	67,008	17	69,850	29	18,678	0	0	0	0	0
Louisiana	37	63	419,126	0	0	9	373,770	53	43,606	1	1,750	0	850	900
Oklahoma	58	102	428,920	3	58,800	23	314,698	72	51,832	4	3,590	424	516	2,650
Texas	63	198	1,232,138	24	152,085	50	960,250	118	86,921	6	32,882	230	24,050	8,602

ARKANSAS' natural resources herald
important industrial developments

L. A. HENRY *Director of State Planning Board, Little Rock*

ARKANSAS has long been a producer of bauxite, petroleum and other raw materials for the chemical process industries, but strangely the vast natural resources have been shipped out of the State to be processed. However, this situation is changing. The State appears to be in a state of transition. Governor Homer M. Adkins is actively leading a campaign to industrialize Arkansas and already much progress has been made in this direction.

Pine forests are being converted into pulp and paper in local mills, petroleum is made into numerous products in refineries near the fields, sands are converted into glass, cottonseed oil is processed, and soon the tremendous deposits of bauxite will be converted at nearby plants into alumina and aluminum. The momentum of this trend should be accelerated as the advantages of low cost fuels and the vast potential natural resources of Arkansas become better known.

Bauxite—The largest bauxite producing area in the United States is in central Arkansas. Here the ore occurs in two separate districts—one in Saline County and the other in Pulaski County. The former is by far the larger. The mineral has been mined in the state since the turn of the century. Much open-cut mining still continues, but where the overburden has become too thick for open-cut work, drifts and tunnels have been extended underground followed by sinking of shafts.

Arkansas is now producing approximately 1,000,000 long tons of bauxite ore annually. In 1941, this state was responsible for 95 percent of the domestic production. At the present time a major plant is under construction which will convert the bauxite to alumina. This plant will be in a position to supply alumina not only to the Arkansas reduction plant, which is also now under construction, but also to other aluminum plants throughout the nation. While the entire output of the new metal plant will go directly into the war effort, after the war is over this industrial development will provide an important supply of aluminum for local industrial applications.

Petroleum—Minerals of greatest present economic importance in addition to bauxite are petroleum and coal. These three accounted for about 82 percent of the total value of all minerals produced during 1939. In the southern part of the state there are 28 oil and gas producing fields in six counties; 15 are strictly oil producing fields and 13 produce both oil and gas.

Coal—The area of workable coal lands within the state containing semi-anthracite and bituminous coal is estimated at between 300 and 350 sq. miles. Known reserves of coal are considered adequate for protracted periods.

Natural Gas—There are tremendous reserves of natural gas in the state. In 1939 and 1940 the southern fields of Big Creek, Dorcheat and McKamie were discovered. The total developed reserves of this area at the present time exceed 850 billion cu.ft. and are steadily being increased through the discovery and development of new fields. These newly discovered gas reserves offer industry large supplies for fuel or raw material.

The gas is of the sour type, carrying a hydrogen sulphide content which varies from 300 to 4,500 grains per 100 cu.ft. It readily yields to a purification treatment at low cost. Following the desulphurization process the gas is in every respect the equal of sweet gas.

Sulphur—The large reserves of natural gas of the sour type may soon be the source of a supply of sulphur for the production of sulphuric acid and other chemicals. See page 80 of this issue for further information.

Rutile and Brookite—Arkansas is now forging ahead into first place in the United States as a producer of these ores, from which titanium oxide is recovered. A single operation produced uniformly 4,250 tons over a period of eight years. (1934-1941). The available ores are by no means exhausted, there being ample assured supplies to sustain long time opera-

Arkansas is the principal source of bauxite in this country, but also has many other natural resources that are beginning to attract the attention of the process industries managements
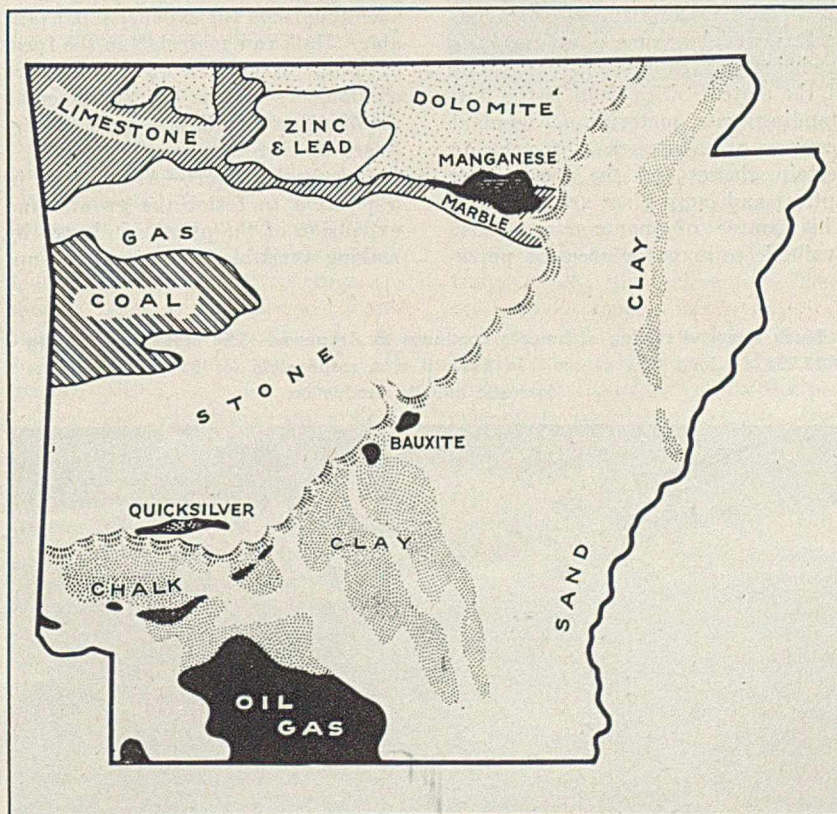
tions of several plants equal to or exceeding capacity of the present operations. These ores lend themselves to cheap methods of mining.

Abrasive Materials—Raw abrasive materials such as tripoli or soft silica, novaculite, a variety of chert or massive silica, and chalk for finer abrasives and polishes are available in commercial quantities. In addition to the above, reserves of bauxite are available for the manufacture of aluminum oxide abrasives. At the present time the demand for aluminum metal has limited the amount of bauxite which is made available for abrasives manufacture.

Cement Materials—The resources of cement materials in Arkansas have never been fully utilized. High-calcium limestones, calcareous marls, and fossil shale beds constitute an adequate source of calcium oxide. Large deposits of clay can be drawn upon as a source of Al_2O_3 and silica. Low-grade iron ores are available as a source of iron oxide. Raw materials for a variety of special cements are available. This includes bauxite for aluminous cement, gypsum for rapid setting cements, and dolomite for refractory patching.

Ceramic Materials—A variety of clay types is now being used by ceramic industries in Arkansas. Brick, tile, sewer pipe, and pottery clays are the most prominent types. High grade kaolins and bentonite are available for a variety of ceramic uses. The materials for the manufacture of glass and glass products are being worked in the northern part of the state. Silica sand is the outstanding raw material. Abundant reserves of manganese for coloring certain glasses and for decolorizing optical and lamp glass are available. This source of manganese is also available to manufacturers of porce-

lain enamel and to manufacturers of colored brick, pottery, and tile.

Fertilizer Materials—The leading potential raw material for a fertilizer industry is the phosphate rock deposits of northeastern Arkansas. The possibility of a cheap source of sulphuric acid from the sour gas fields of southern Arkansas brings considerable attention to these phosphate deposits for the first time. The consumption of super-phosphate in the area west of the Mississippi River is great enough to absorb large quantities of locally produced fertilizer.

Quantities of the agricultural lime have been produced in northern Arkansas for many years. Supplies of dolomite to be used as a filler in fertilizer are very extensive. In the southern part of the state widespread deposits of both chalk and green sand marls are available for use in fertilizer manufacture.

Paint Materials—A wealth of raw materials for paint manufacture are known in Arkansas. It is possible here to mention only such basic raw materials as cottonseed oil, mineral pigments (ochers, umbers, siennas, and terra verte), and a variety of filler materials including tripoli, chalk, fuller's earth, and gypsum. The deposits of titanium oxide may eventually provide the basis for a titanium-white production within the boundaries of the state.

Cellulose—The paper industry is already well established although considerable room for expansion is available. Bulk raw materials in the form of pulp wood and rice straw are available as well as are a number of auxiliary raw materials, such as clay fillers and brown dyes.

Plastics Materials—Arkansas is in a position to foster the growth and expansion of the plastics industry by making available its tremendous sup-

plies of natural gas, oil, coal, and timber as essential, primary requirements. Supplies of cotton are available for the manufacture of cellulose acetate plastics. Immense reserves of lignite, a possible source of raw materials for the plastics field, are widely developed in Arkansas. Byproducts from the paper and lumber mills, such as sawdust and other waste, must be considered as a possible source of material. Fillers, dyestuffs, and similar subsidiary products required by the plastics industry are also present.

Manganese—Two districts in Arkansas are now producing manganese for the steel industry. The largest of these producing areas lies in Independence County in the vicinity of Batesville. The ore from this district ranges from high-grade oxide material containing over 70 percent manganese to low-grade carbonate ores containing a minimum of 18 percent manganese. Construction of a beneficiation plant to treat the low-grade ores is now being planned by the War Production Board. The reserves of low-grade ore are known to be in the neighborhood of 500,000 tons.

Manganese oxides ores are now being produced in Southwestern Arkansas in what is locally known as the "Western District." No accurate estimate of the reserves in this area has ever been made, but in the aggregate the amount of manganese present is very large. A portion of the production from the Western District is now being purchased by the Metals Reserve Co., and stockpiled at Gurdon, Ark.

Arkansas manganese production serves as a source of raw material for the manufacture of dry batteries, porcelain enamel, building brick, glazed pottery, plastics, welding rods, chemicals, varnish, and floor tile. Electrolytic manganese metal is now produced at Knoxville, Tenn. With the advent of additional power facilities a similar plant for Arkansas becomes a strong possibility.

Mercury—Since its discovery in 1932, the Arkansas cinnabar district has grown steadily. The most important deposits are located in a strip nearly 35 mi. long in Pike and Clark Counties in Southwestern Arkansas. Production of mercury in 1941 was approximately 2,000 flasks or over 150,000 lb. Stimulated by favorable market conditions production of mercury in this state is expected to expand to record highs in 1942. Mercury, one of the few metals which is produced in metal form in

Much open-cut mining of bauxite continues in Arkansas. The state is producing 27,254,000 long tons of ore. In 1941, it was responsible for 95 percent of the domestic bauxite production
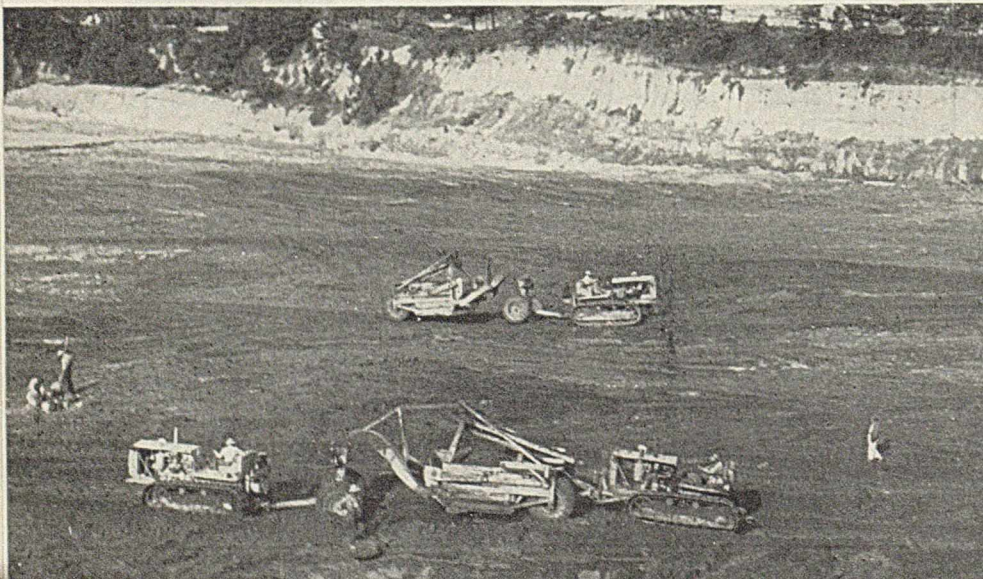
the state, is used in the manufacture of mercury fulminate, for silvering mirrors and for making drugs, paints, and chemicals.

Zinc—Deposits of zinc ore have been found over a wide area in the northern part of the state. The principal minerals are sphalerite or zinc sulphide, and smithsonite or zinc carbonate. Calamine, or zinc silicate, is present in lesser amounts. Unlike the Missouri and Oklahoma districts where lead and zinc are of equal importance, the zinc ores predominate over the lead ores in northern Arkansas. Smelters are now in operation in the vicinity of Fort Smith in northwestern Arkansas which produce slab zinc. In addition to its metallurgical uses zinc is used as a pigment in the manufacture of paint, rubber and oil cloth, and in various chemicals.

Titanium—Extensive deposits of titanium oxide are now being worked in Hot Spring County, South-central Arkansas. The chief titanium minerals which occur in the county are rutile and brookite. The principal

Production of Arkansas' Minerals

Mineral	1940	1941
Barite, short tons...........	12,086	31,238
Bauxite, long tons..........	487,677	956,617
Cement, bbl...............	772,000	915,000
Coal, short tons............	1,310,262	1,528,585
Gypsum, short tons........	16,828	29,286
Glass sand, short tons.......	94,970	109,299
Lead, lb..................	110,000	8,000
Manganese, long tons.......	7,077	7,157
Mercury, flasks 76 lb........	1,221	1,966
Petroleum, bbl.............	25,866,350	26,465,150
Tripoli, short tons..........	1,430	2,083
Zinc, lb..................	880,000	380,000

Mineral Reserves in Arkansas, January 1940

Mineral	Quantity
Barite..................	1,094,397 short tons
Bauxite (green ore).......	25,000,000 long tons
Coal...................	1,510,063,844 short tons
Lead (metal)............	6,600 short tons
Lignite.................	44,019,000 short tons
Manganese..............	205,498 long tons
Manganiferous ore.......	105,313 long tons
Natural gas	
West Arkansas.........	996,213,000 M cu. ft.
South Arkansas........	266,413,460 M cu. ft.
Petroleum..............	320,148,000 long tons
Phosphate rock..........	20,000,000 long tons
Zinc (metal)............	132,300 short tons

use of the former is in the manufacture of a coating for welding rods. Stabilization of the arc in electric welding and the production of a pure weld metal is achieved by the use of titanium oxide coating on the welding rods. In the form of ferrotitanium, titanium is used for purifying steel and is added to some heat resistant steels to prevent a combination of chromium, molybdenum or other alloying elements with the carbon.

Power — Interconnected power transmission systems provide all the important industrial sections of the state with ample power. In addition to the generating capacity now installed within the state, power is available through a pool consisting of 11 large private concerns and a score of municipal plants. Total generating capacity within the pool is 1,600,-000 kw. Surplus from the pool amounts to 235,000 kw. Under construction within the state are steam generating facilities (gas-fuel) for nearly 200,000 kw. and hydro-electric generating facilities for 70,000 kw. Congressional approval of water control projects for construction exist which include 500,000 kw. of hydro-electric generating capacity on the rivers of the state.

Known reserves of coal deposits in Arkansas are approximately three-fourths of a billion tons. Estimated reserves of natural gas in the fields of Southern Arkansas are approximately one trillion cubic feet and the fields are being extended constantly by new exploration.

Such a balance for steam and hydro generation exists nowhere else between the Allegheny and Rocky Mountains which will afford as low-cost electricity as in the potential Arkansas developments.

Climate—The climate of Arkansas is mild at all seasons. No long extremes of hot or cold occur. The average annual precipitation is 48 in. well distributed. There is an average of 105 rainy days and few of these interfere with flying. Fogs are rare. The temperature averages 61.4 deg. F. throughout the year. Extremes of short duration are rarely above 100 deg. or under 0 deg. Because of mild winters, fuel costs for plant heating are low. Air conditioning in summer is not essential.

Transportation — Approximately 5,000 mi. of railroads criss-cross Arkansas. Among these are five trunk line systems interconnecting the industrial middle west, east and gulf coastal cities.

Over 9,000 mi. of highway system, fed by 40,000 mi. of local roads, serve all sections of the state and connect with the major transcontinental road systems in all directions. Of the state highway system, more than one-third is paved and the balance gravelled.

Waterways provide means of freight transportation along the entire eastern boundary and into the interior of the state along the Mississippi, Ouachita and White Rivers.

Commercial airlines operate across the state with several scheduled stops at Little Rock. The airlines afford
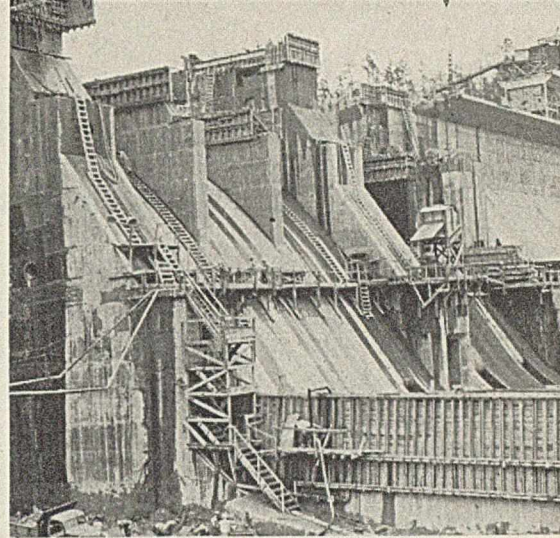
Interconnected transmission systems provide all the important industrial sections of the state with ample power
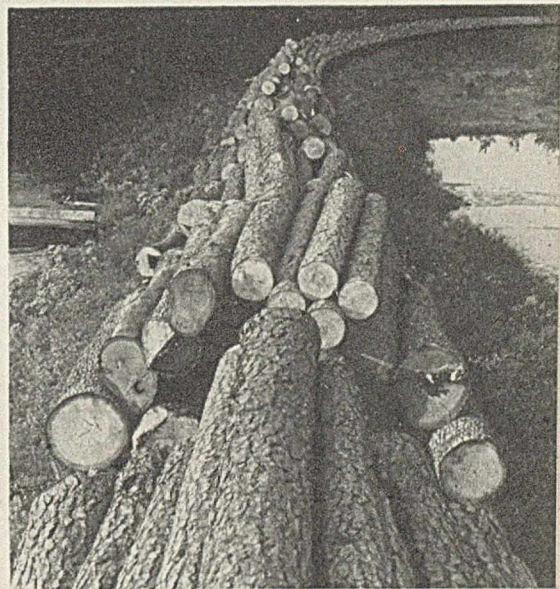
The pulp and paper industry is already well established although considerable raw materials in the form of wood and rice straw are available for expansion

good connections at Memphis and Dallas to all important centers. There are over 30 airports in the state.

Labor—White native labor is pure Anglo-Saxon stock, loyal, industrious, and readily trained. Twenty-five percent of the population is black. Over 99 percent of the population is American born. A large vocational training program is underway for both whites and negroes. The skills learned in defense industry and in the armed services are certain to afford the state many times the number of skilled workmen upon the cessation of the war. Only about 12 percent of those gainfully employed were engaged in manufacturing enterprises, leaving a reservoir of potentially available labor which is capable of broad adaptability.

LOUISIANA'S attractions to industry are difficult to duplicate

JAMES A. LEE *Managing Editor, Chem. & Met.*

LOUISIANA is a veritable treasure-house of the natural resources, sulphur, salt, lime, cellulose, petroleum, natural gas, etc., that are the background of the chemical process industries. To this cornucopia of resources add the temperate climate, harmonious labor conditions, excellent transportation facilities, reasonable fuel and power, and you have a combination of attractions that are difficult to duplicate.

The list of these natural resources is a long and impressive one.

Petroleum—The state's No. 1 natural resource is oil. An average annual production of 100,000,000 bbl. of crude oil gives Louisiana fifth place in the United States. Oil is found in many areas in various parts of the state. In addition to the allowable production the potential capacity of the wells is, of course, much greater. Much drilling in the coastal parish salt domes and in the prospective deeper sands, needs to be done. There is much room left in both the coastal areas and in north Louisiana territory for deeper drilling. Developments at present indicate that several interests are about to begin such programs.

Not only is the crude oil from the Louisiana fields refined within the state but even greater quantities are shipped in for refining from Kansas, Oklahoma, Texas, Arkansas, California, Mexico and Venezuela. The value of refined products turned out by Louisiana refineries annually was estimated, not long ago, at approximately $200,000,000.

Natural Gas—In 1940, there were produced in Louisiana more than 300 billion cu.ft. of natural gas, three-fourths of it was used in its original state, while the remainder was transferred into gasoline and carbon black. Thirty gasoline plants in 15 oil and gas fields annually extract more than 100,000,000 gal. of gasoline from natural gas. The productive fields may be grouped into three general areas, the Sabine Uplift centering around Shreveport in the northwestern part of the state, the Monroe-Richland-Epps gas area in the northeast, and the Gulf Coastal salt dome area along the Gulf shore. Pipe lines distribute the gas to all sections of the state.

Cellulose—More than one-third of the state is forest land. There are 16,211,000 acres of farm woodland and industrially owned tracts. Forest products annually amount to $50,000,000 while the finished products are valued at twice that amount. Pulp and paper consume some of the timber. Largest mills are at Monroe, Bogalusa, Bastrop, Springhill and Hodge.

Among the other materials from which cellulose products are being made should be mentioned bagasse and rice straw. The sugar cane supplies a large tonnage of bagasse which is converted into wall board, and Louisiana is the largest rice growing state in the nation.

Salt—This is one of Louisiana's most valuable natural resources. There is no means by which to determine the reserves of salt underlying the surface, most of which is beneath the parishes of Iberia and St. Mary in South Louisiana and Winn in North Louisiana. However, after a production totalling millions of tons, the surface of these remarkable deposits have hardly been scratched. It is safe to say that the supply will out-date the lives of this and quite a few generations to come. The formation containing salt that in its unmined, natural state is 99 percent pure is usually in the form of a large dome, one or two miles in diameter and thousands of feet deep. There are at least 25 other points besides those mentioned above where salt is to be found in commercial quantities.

Sulphur—Production of this mineral in 1940 totaled 512,935 long tons. It all came from operations at Grande Ecaille, Plaquemines Parish. Louisiana is the second largest producing state with nearly 19 percent of the total domestic output, standing second only to Texas.

Power—Electric power is available throughout the state. In 1939 there were produced 1,885,223 kw., all of which originated from fuel-operated plants since there are no hydroelectric plants. In addition to the expansion of some of these plants which now is going forward, an adequate supply of power is assured by the network of transmission lines with interstate connections.

Sweet Potatoes and Peanuts—Among crops produced on a commercial scale and adaptable to industrial use are sweet potatoes and peanuts. 6,935,000 bushels of the former and 18,800,000 lb. of the latter are raised annually.

Lime—One of the most important mineral deposits of the state is the deposit of limestone at Winnfield, in Winn Parish, in the north central section of the state. This deposit has for years been the source of a large part of the state's requirements of limestone. It is served by three railroads. The existing quarrying plant has a capacity of 24,000 tons per month. The stone has a calcium carbonate content of 98.3 percent and silica of 0.6 percent.

The extensive shell reefs of South Louisiana yielding 97 percent calcium carbonate afford a source of lime as yet little developed. In one recent year 701,555 cu.yd. of oyster shells, much of which was converted into lime, and 194,052 cu.yd. of clam shells were recovered. These deposits are located in Iberia, Vermillion, St. Mary, and Terrebonne Parishes. One deposit has been proved to a depth of over 20 ft. and is estimated to contain over 50,000,000 cu.yd. The Pointe au Fer reef, lying in St. Mary and Terrebonne Parishes is by far the largest deposit of this material yet found, and is estimated to contain approximately 100,000,000 cu.yd. of shells.

Gypsum—In Calcasieu Parish in the western part of the state, beds of gypsum have been estimated to be from 100 to 540 ft. thick. And reliable information indicates gypsum is also available in commercial quantities at Winnfield in Winn Parish.

Lignite—The northwestern part of the state contains extensive deposits of lignite or brown coal, but the abundance of bituminous and anthracite coal available from other fields, as well as gas and oil within the state, have not yet made the exploration of these lignite fields commercially practicable. Lignite in seams varying in thickness from 2 to 8 ft. exists in Caddo, Webster, De Soto, Catahoula, Sabine, Rapids, Bossier, Bienville, Winn, Lincoln, Ouachita, Avoyelles, Caldwell, East Carrol, Iberia, Jackson, Natchitoches, Red River and Claiborne Parishes.

Cottonseed—Since 1880, from a

small beginning, the crushing of cottonseed has developed into a very important industry. The crush for a typical year amounts to 232,682 tons with a value of $10,823,000, a little more than one-half is cake and meal, 106,545 tons, with a value of $3,819,000, hulls 63,000 tons with a value of $516,000, and linters 49,498 bales with a value of $950,000.

Sugar Cane—This crop flourishes in the fertile delta lands in the "Sugar Bowl" of the southeastern section. Louisiana has the distinction of being by far the largest producer among the states, Florida contributing a much smaller amount. Highest production of sugar cane in history was the 1938 crop of 6,237,000 tons, valued at more than $16,000,000. The cane supplies material for the 77 raw sugar mills of the state, molasses for the alcohol plants and bagasse for the wall board industry.

Transportation — Facilities are available for every type of transportation. Rail, bus, water and air traffic lanes reach every section of the state, making travel quite convenient and providing the means by which every product and raw material may be shipped. Great strides in this direction have been made by Louisiana within the past few years. She has more than kept pace with the nation in this respect.

Water transportation has long been splendid. Blessed by an inland waterways system, the extent of which is unequalled in any state in the country, crossed by the Intracoastal Canal, and situated on the Gulf of Mexico, with the mouth of the great Mississippi River within its boundary, it is no wonder that the state's water transportation system is one of her most valuable possessions. Steamships from every quarter of the globe enter Louisiana's ports, and barges and steamboat service reach nearly every section of the state through the courses of the myriad of navigable rivers and bayous.

Twelve important railroad systems offer fast and efficient service through which every section of the country can be reached. They traverse the state. These railroads, like steamboats and steamships, have played an important part in the development of Louisiana.

Thirty-five motor freight lines and the same number of passenger bus lines operate over the extensive system of highways and bridges which comprise 40,000 miles, of which there are 2,350 miles of concrete, 1,600 miles of asphalt and 14,000 miles of gravel.

Labor—Conditions in the state, both from the standpoint of the manufacturers and the industrial workers, are extremely satisfactory. There have been very few labor disputes. Ninety-five percent of the population is native born, 28 percent of the native born being negroes. The supply is adequate.

Soybean—Only ten years ago soybean production was practically negligible. But today there are raised on an average of 1,500,000 bushels of soybeans annually—the fifth largest production in the United States.

Louisiana offers the process industries salt, sulphur, lime, petroleum, natural gas, and a variety of other resources. New Orleans has long been a center of production of alcohol, cane sugar, cotton seed oil and other products
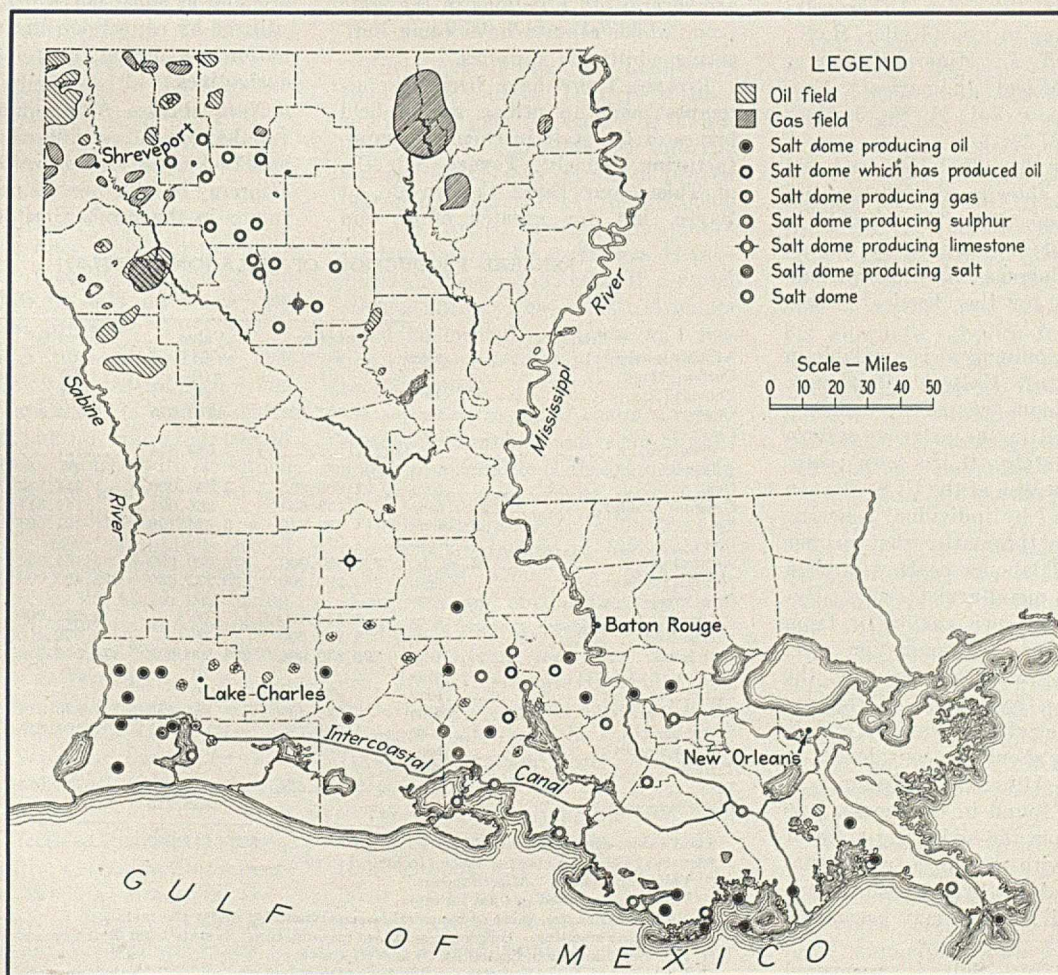
OKLAHOMA offers exceptional inducements to process industries

ROBERT H. DOTT, A. L. BURWELL, J. O. BEACH *Geological Survey,*
Norman, Oklahoma

FEW STATES can offer the chemical process industries a greater variety of basic mineral raw materials, or a greater quantity of cheap fuel, than Oklahoma. Water supplies are adequate, at least in certain areas; transportation is ample; and sufficient labor for most operations should be available, although some technical skill would have to be imported for some types of industries.

Oklahoma's position in respect to its ability to supply industry with basic raw materials can be comprehended clearly by measuring the relative importance of the geologic raw materials as determined by a consideration of the various factors involved. Such a study has been made for many of the more important industrial chemicals and the raw materials classified in order of their relative frequency in use. (Keller, R. N., and Quirke, T. T., "Mineral Resources of the Chemical Industries," *Economic Geology,* Vol. 34, No. 3, May, 1939, pp. 287-296).

If we take this tabulation, and add information showing the quality and extent of each material available in Oklahoma, it is immediately apparent that Oklahoma offers exceptional inducements for the chemical manufacturer.

Coal—Steaming coal is available in nearly all of Eastern Oklahoma. Semi-bituminous coal for smokeless fuel is mined in the extreme eastern part of the state. It has been established by research at the U. S. Bureau of Mines and by individual concerns interested in the matter that proper blends of Oklahoma coals will yield satisfactory metallurgical coke. Byproducts from such coking or from low-temperature carbonization certainly hold promise. So too, the preparation from coal of ion-exchange material for water treating, and the like, should be considered.

Sulphur—Although sulphur, as such, is not found in Oklahoma, it is available from the adjoining state of Texas and with moderate transportation costs. Also, byproduct sulphur from sour oil and gas may become of importance.

Mineral Salt—Salt is recovered from springs and plains on a minor scale, and production could be increased should demand arise.

Limestone—Extensive deposits of rock of "high-calcium" classification occur in several areas. The purity of lime from these sources is sufficiently high for most chemical requirements. Burned lime is made in three plants. In addition to stone for block and crushed material, there are a number of impure limestones which contain the proper proportions to serve as high-grade wool-rocks, and one plant is in operation, using local stone. The state has two cement plants, one with a carbon dioxide byproduct unit.

Sulphide Ores—The Miami District of northeastern Oklahoma is recognized at present as the leading source of lead and zinc sulphide ores. There are several other regions in the state from which reports have come indicating additional supplies.

Brines—There have been two attempts made to utilize the oil-field brines of the state in chemical manufacturing, namely—Texaco Salt Co. at Tulsa, and Texas Carbon Co. at Sayre, but far greater effort and capital have been expended on disposing of the brines which are produced with the petroleum oil than in conversion to industrial uses.

Iron Ores—Moderate quantities of iron ores are present as limonite, hematite, and titaniferous magnetite. There are relatively small scale operations in limonite deposits of Arbuckle Mountains to supply requirements of cement plants for special cements, and some ore has been shipped to foundries in the state. Some consideration is being given to their use in blast-furnace operations in Texas and elsewhere.

Petroleum—Although large quantities of refined products are being made within the state from petroleum, 60 percent of the state's production is pipe-lined to outside refiners. From the crude oil within the state are made gasolines of several grades, burning oils, fuel oils, gas oils, lube oil, and paraffin wax, as well as special solvents for the paint, lacquer, and insecticide trade.

From casinghead gas—the gas produced from oil wells, with petroleum—is extracted the dissolved high-gravity gasoline, as a condensate. Byproducts include such fractions as butane, pentane, propane, etc., which are sold as such, but which should be utilized by conversion through chlorination, oxydation, etc., into various derivatives.

Natural Gas—Although natural gas (methane) is considered primarily as a fuel and a very desirable one, one company in Oklahoma is now a major factor in the production of acetalde-

MINERAL PRODUCTION OF OKLAHOMA, 1937-38*

Products		1937		1938	
		Quantity	Value	Quantity	Value
Asphalt (native)...............tons		(¹)	(¹)	(¹)	(¹)
Carbon, black................lb.		(¹)	(¹)	(¹)	(¹)
Cement.......................bbl.		(¹)	(¹)	(¹)	(¹)
Chats........................tons		3,991,700	$410,675	1,504,900	$216,370
Clay:					
Products...................		....	583,334	....	572,289
Raw........................tons		(¹)	(¹)	(¹)	(¹)
Coal.........................tons		1,600,295	3,841,000	1,244,732	2,947,000
Gypsum (crude)...............tons		159,639	266,091	141,341	231,910
Lead.........................tons		29,840	3,521,120	21,004	1,932,368
Lime.........................tons		(¹)	(¹)	(¹)	(¹)
Natural gas...............M. cu. ft.		296,260,000	32,039,000	263,164,000	27,391,000
Natural gasoline..............gal.		492,290,000	20,272,000	468,499,000	14,373,000
Ores (crude), etc.:					
Zinc........................tons		6,644,400	(⁶)	4,249,000	(⁶)
Zinc-lead...................tons		3,787,600	(⁶)	3,072,400	(⁶)
Petroleum....................bbl.		228,839,000	283,500,000	174,994,000	209,500,000
Pumice.......................tons		(¹)	(¹)	(¹)	(¹)
Salt.........................tons		(¹)	(¹)	(¹)	(¹)
Sand and gravel..............tons		934,499	414,495	823,814	354,486
Stone........................tons		1,098,790	1,149,624	(³)1,101,320	(³)1,338,858
Sulphuric acid(⁷)............tons		(¹,²)	(¹,²)	(¹,²)	(¹,²)
Tripoli......................tons		(¹)	(¹)	(¹)	(¹)
Zinc.........................tons		135,696	17,640,480	112,924	10,840,704
Miscellaneous(⁸).............		....	4,338,213	....	3,636,013
Total value, eliminating duplications.		....	$367,444,222	....	$272,860,078

*Source, 1939-40. Report of Okla. Geological Survey.
(¹) Value included in "Miscellaneous."
(²) Value not included in total for state.
(⁶) Not valued as ore, value of recoverable metal included under the metals.
(⁷) From zinc smelting. Sulphuric acid also manufactured in state from Gulf Coast sulphur.
(⁸) Includes minerals indicated by (¹) and (²) above.
(³) Exclusive of dimension stone, value for which is included under "Miscellaneous."

hyde, formaldehyde, acetone, acetals, and methanol, all by catalytic oxidation of natural gas.

Potassium Minerals — Potassium minerals are not produced in Oklahoma but eastern New Mexico is the largest producer in the United States. An Oklahoma chemical company is now converting such material into potassium sulphate for the trade, and making muriatic acid as a byproduct.

Gypsum—Gypsum, including alabaster variety, is present at the surface over a considerable area in western Oklahoma. Present operations include quarrying of raw rock gypsum to supply the needs of cement plants in the Southwest; one manufacturing plant making several gypsum products, such as plaster, wall board, etc., and a calcining plant.

Lead Ores—Oklahoma lead ores are chiefly the sulphide mineral galena; considerable quantities are mined in the state, but at present little or no chemical use is being made of these ores locally.

Sand—Various grades of sand are widely distributed over the state, but the higher silica, glass sand grades are found in three main areas: Arbuckle Mountains, southern row of counties east of Ardmore, and small areas in northeastern Oklahoma. Three operators are engaged in quarrying glass sand in the Arbuckle Mountains to supply a large portion of the requirements of the Oklahoma and north Texas glass industry. However, these sands are not used in chemical industries at present.

Phosphate Rock—There is probably a sufficient quantity of phosphate rock for local use only, but there is no utilization at present.

Magnesium Minerals—There are abundant, thick deposits of high-grade dolomites in Arbuckle and Wichita Mountains, but no industrial use at present, except as used with limestone for crushed stone, and one small operation for agricultural use.

Zinc Ores—Zinc sulphide is mined in large quantities. Three smelters are operating in the state, producing slab zinc with cadmium and sulphuric acid as byproducts. Small amounts are used for galvanizing.

Barium Minerals—Some prospecting and minor mining of barium sulphate is reported, but no processing of this material is going on in the state.

Titanium Ores—Considerable quantity of titaniferous magnetite is present in the Wichita Mountain area, containing up to 16 percent titanium oxide. Possibly some black sands in that area contain recoverable ilmenite.

Mineral wool filters for removing impurities out of sulphur dioxide gas in sulphuric acid plant of Ozark Chemical Co.

But no industrial processing is done.

FUELS AND POWER

Fuels can be had in abundance from three sources: coal, petroleum, and natural gas. An estimated 55 billions of tons of minable coal underlie Eastern Oklahoma; estimated proven petroleum reserves of 1,035,820,000 bbl. are located in 42 of the state's 77 counties; and natural gas is produced in these same and half a dozen other counties. New industrial plants could be located in almost any section of the state within easy reach of fuel supplies.

Coal—Two ranks of coal are represented, bituminous and semi-bituminous. Low-volatile coals are mined in the eastern area, chiefly in Haskell, Latimer, and Le Flore Counties. The principal production of high-volatile coal comes from the McAlester, Henryetta, and northeastern districts.

There is some variation in sulphur and ash content—coal from the eastern, McAlester, and Henryetta districts being somewhat lower in both, than are coals from the southwestern (Coal County) and northeastern districts.

There is probably ample labor and facilities available to step up production without any great shifting of labor and equipment from other areas. Average value of coal produced in Oklahoma was $2.36 per ton in 1938, and $2.11 in 1939. (Min-

erals Yearbook, U. S. Bureau of Mines).

Petroleum—Production of petroleum during the past ten years has ranged between 153,000,000 and 228,-000,000 bbl. per year.

Natural Gas—Oklahoma has extensive reserves of natural gas, and during the past several years has been producing at the rate of about 270 billion cu. ft. per yr. Largest available supplies at this time are probably in Caddo and Grady Counties, but adequate supplies for industrial use can be obtained in almost any desired location, either from local production or through the extensive gathering and distribution systems of distributing companies. Natural gas for industrial use can be purchased at low rate.

Electric Power—Commitments for defense-training establishments, ordanance and other war industry plants, and a proposed pooling of power from Oklahoma and Arkansas, to supply an aluminum reduction plant in the latter state, has decreased the power reserve, but it has been stated by persons in position to know, that a considerable reserve of firm power is still available.

The state is served by several public utility companies, a 60,000 kw. hydro-electric plant in northeast Oklahoma, and several communities have municipally-owned generating plants. The public utility lines are

interconnected with each other, and with the hydro-electric plant, so that electric power is available in all parts of the state.

In discussing the availability of power for industrial use one should not overlook the possibility, in certain industries at least, of utilizing off-peak power, which is always available in large quantity and at low cost. Consideration also should be given to the fact that Oklahoma probably is in no different position than other sections of the country in regard to power shortage. If new plant construction in the nation demands construction of new generating capacity, Oklahoma's abundant and

Oklahoma Petroleum Refineries

Number of refineries May, 1941.....	25
Daily capacity crude oil (bbl.).......	210,280
Daily cracking capacity (bbl.).......	96,300
Number gasoline plants April, 1941..	105
Rated capacity daily (bbl.)..........	1,912,050

conveniently located fuel supplies can provide all necessary electric energy in close proximity to new industrial plants, without further disrupting the transportation system of other sections of the country.

TRANSPORTATION

Oklahoma is served by four major trunk-line railroads, with connections to all parts of the United States. These are: Missouri-Kansas-Texas; Chicago, Rock Island and Pacific; Atchison, Topeka and Santa Fe; and St. Louis-San Francisco. These, together with a smaller group of connecting lines: Kansas, Oklahoma, and Gulf; Midland Valley; and Oklahoma City, Ada, and Atoka; as well as a branch of the Missouri Pacific, and a few short, local lines; reach into every county, and practically every county seat town.

The state has built and maintains an excellent system of highways. Except in the more remote, mountainous area, secondary roads give access to any locality in the state.

POSSIBILITIES

An investigation of each item—its frequency of use—its relative importance in the chemical processes—its relative cost—its cost where transportation is a factor—will indicate the advantageous position of chemical industries located in Oklahoma. Not on one or two items alone, but on a large percentage of the 15 most prominent items, Oklahoma is in a favorable position. This is worth considering because the interdependence of chemical industries among themselves is recognized. This inter-

dependence would indicate the advisability of centralization where the greatest number of the more essential raw materials and fuel are available, as in Oklahoma.

To all persons interested in chemical industry, Oklahoma cordially invites your consideration. It offers possibilities and inducements in far greater measure than is generally realized. The Oklahoma Geological Survey, at Norman, will furnish on request available information to anyone interested.

Basic Geologic Raw Materials for Industrial Chemicals, Availability in Oklahoma

Material	Frequency Index *	Availability Oklahoma Sources	Sources in Region
Water.............	99	Surface and underground supplies adequate in some areas.	
Coal...............	91	55 billion tons reserve. Bituminous and semi-bituminous. Shaft, slope and strip mining; 1 to 2 million tons annually.	
Sulphur............	88	None........................	Texas and Louisiana Gulf Coast.
Mineral salt.........	75	NaCl in salt springs and salt plains. Subsurface salt beds. Little or no development.	Kansas, Texas, Louisiana.
Limestone...........	63	Great abundance above 95% $CaCO_3$. Abundance 98 and 99 + % $CaCO_3$. Several quarries, many quarry sites.	
Sulphide ores.........	32	Leading producer of ZnS, important PbS production. Reserves of present-grade ores somewhat limited. Ores from other states brought in for smelting.	
Brines..............	24	Oil field brines in all oil-producing areas.	
Petroleum...........	23	Produced in 42 counties. Annual production 200 million barrels; third in nation.	All surrounding states.
Natural gas..........	16	Essentially same areas as petroleum, plus two important dry gas areas. Fourth in national production. Third in production of natural gasoline.	Large reserves in surrounding states, with trunk pipe lines.
Potassium salts.......	11	None known...................	Potash mines in eastern New Mexico.
Gypsum.............	10	Great abundance, easily obtainable. Considerable production.	Kansas and Texas.
Lead ores............	9	With zinc in northeastern part of state. Tri-State area. Reserves somewhat limited.	
Sand................	9	Various grades, including high-grade glass sand in abundance. Considerable production in Arbuckle Mountains.	
Aluminum minerals....	8	No high-alumina materials known.	Bauxite in Arkansas.
Iron ores............	6	Limonite in Arbuckle Mountains, titaniferous magnetite and low-grade hematite in Wichita Mountains.	Limonite in East Texas.
Phosphate rock.......	6	Low-grade deposits in several areas. Small supply of high-grade nodules. No production.	Northern Arkansas.
Copper ores..........	4	Small, very low-grade deposits. No production.	
Magnesium minerals...	3	Great abundance of high-grade dolomite. Moderate concentrations in some oil-field brines.	
Mercury ores.........	3	None definitely known..........	Produced in southwest Arkansas, adjacent to southeast corner of Oklahoma. Produced in Texas.
Zinc ores............	3	At present leading producer in nation. Tri-State area. Reserves somewhat limited. Some ore from other states smelted in Oklahoma because of abundant fuel.	
Antimony minerals.....	2	None known...................	Known in western Arkansas, adjacent to eastern Oklahoma line.
Barium minerals.......	2	High-grade barium sulphate in two areas. Quantity not known. Some prospecting in progress.	Arkansas and Missouri.
Manganese ores.......	2	Carbonate and oxide ores in Arbuckle Mountains; oxide ores in Ouachita Mountains. Quantity not large. Small amount mined.	
Titanium ores.........	1	Titaniferous magnetite ores in Wichita Mountains. Magnetite-ilmenite sands in streams of that area.	Rutile in Arkansas.

* Frequency index number is the number of times the particular mineral is used as raw material in the production of 150 important industrial chemicals, as found by Keller and Quirke. In general these numbers are an index of the relative importance of the various raw materials for making industrial chemicals.

TEXAS is abundantly endowed with cheap fuel and variety of minerals

ROBERT L. DABNEY *Director of Research Department, Houston Pipe Line Co.*

A STATE with an area of 265,895 sq.mi., or the combined size of New York, New Jersey, Delaware, Pennsylvania, Connecticut, Massachusetts, Rhode Island, Vermont, New Hampshire and Indiana, necessarily offers a great variety of topography and climate. Texas has these and, in addition, is abundantly endowed with mineral wealth. It now tops every other state in the Union in mineral production. It is producing approximately 15 percent of the total annual mineral value of the entire country. Petroleum contributes the bulk of this great production, nevertheless, it has a highly diversified mineral industry. Thirty classifications of minerals are produced on a commercial basis. The increase in the mineral production of Texas has been the most spectacular phase of the Texas economy since the beginning of the century. The enormous supplies of natural gas, petroleum and coal give the state the most economical fuel to be found anywhere. It has been said that Texas is at the cross-roads of North American geology.

Petroleum—Texas is estimated to have 53 percent of the known petroleum reserves of the country. And it is interesting to note that year after year authorities have made upward revisions of the state's underground reservoirs. The following tabulation gives the record of increase of production in the state.

Year	Production (bbl.)
1890	54
1900	836,039
1910	8,899,000
1920	96,868,000
1930	290,457,000
1940	493,000,000

Sixty-eight percent of this crude petroleum is refined in the state.

It is as a fuel that petroleum holds its greatest potentiality for the state's industrial future. Adaptable to use in steam and Diesel and other internal combustion engines, it is an all-round fuel that ranks second only to natural gas in convenience and adaptability to purpose. However, crude petroleum is the source of numerous products such as gasoline, medicinal oils, lubricants, candle wax, detergents, and recently has become the basis of an important synthetic organic chemical industry in the state.

Natural Gas—In 1939 (the last year for which a complete report is available) Texas produced 1,330,000,000,000 cu.ft. of natural gas, which was 40 percent of the production of the country. It was the opening of the great Texas gas fields and extension of long distance, high-pressure lines that brought about the transition of natural gas from a localized to a nationwide utility. Pipelines radiating from the gas fields carry the fuel at high rates of speed making it available to industry all over the state. Natural gas has been called the ideal fuel. Already it has been instrumental in bringing numerous industries to the state.

The principal industrial production into which gas enters as a raw material is the production of carbon black. The so-called "wet" gas of some fields is utilized for extraction of natural gasoline. In recent years there has been rapid progress in the manufacture of liquefied gas from natural gas. At present gas is coming into demand as a raw material for many synthetic organic chemicals such as butadiene for rubber production.

Coal and Lignite—There is in addition to oil and gas, a great fuel and power resource in deposits of coal and lignite. However, relatively little of these materials are mined in the state at the present time. These resources may be considered a dormant but potentially great industrial asset.

Sulphur—Approximately 1,300,000 tons of sulphur are produced annually in Texas. It comes primarily from three or four counties which are in a radius of 65 miles of Houston. It is now producing about three-quarters of the United States production of sulphur. Sulphur has tremendous potentiality as an influence in the future development of Texas because of its key position in chemical industries. In some form or other sulphur enters into a large percentage of chemical products.

Cellulose—In 1936, the importance of East Texas pine forests were realized as a source of cellulose. It was during this period that a large mill

Texas tops every other state in the nation in mineral production

1- Barite
2- Gypsum
3- Lime
4- Limestone
5- Sulphur
6- Salt
7- Sodium compounds (natural)
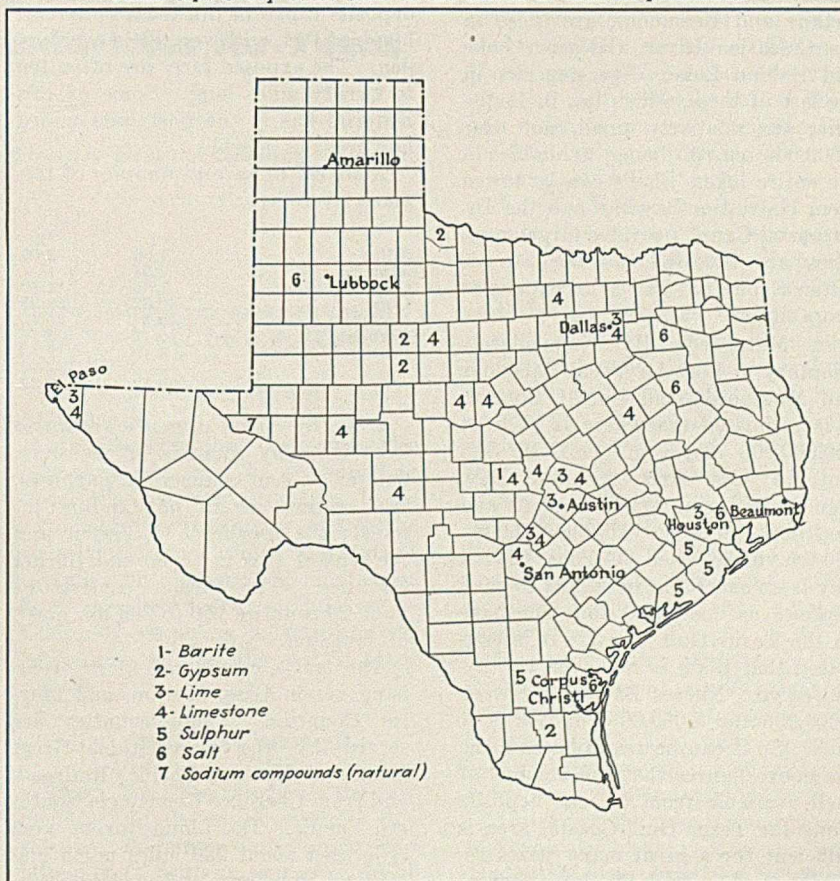
was established on the Houston Ship Channel to manufacture sulphate pulp and paper, and shortly thereafter the much discussed Herty process for making newsprint from southern pine was finally realized by the construction of a mill in East Texas. Two years later the first mill for making coated paper was built to utilize a portion of the sulphate pulp made on the Houston ship channel.

The Texas Gulf Coast each year produces large quantities of rice. Over 260,000 acres are planted to rice near Houston. After the harvest there is available annually 340,-000 tons of rice straw within a radius of 65 miles of Houston. This straw is now either burned or fed to cattle as roughage. It is possible to bale the straw and ship into the Houston area at a nominal figure.

Lime—The oyster shell deposits immediately tributary to Galveston, Texas City, Houston, and points along the Houston Ship Channel are those in Galveston Bay. From accurate data available it is safe to say that there is a minimum of 150,000,-000 cu.yd. of shell in Red Fish Reef alone, and that altogether in Galveston Bay there is at least 250,000,000 cu.yd. of shell that can be utilized for many purposes.

The shell deposits that are immediately tributary to Orange, Port Arthur and Beaumont, are those in the Calcasieu River, Calcasieu Lake and Sabine Lake. The deposits in the last of these, which lies in Louisiana, are relatively small, not over 2,000,000 cu.yd. being available in the entire lake. Shells can be towed from Galveston Bay through the Intracoastal Canal, provided large quantities are involved, as the tow is rather a long one and is an expensive proposition.

In Matagorda Bay immediately tributary to Port La Vaca, Palacious and Matagorda and Port O'Connor, it is estimated that there is at least 150,000,000 cu.yd. of shell. In San Antonio Bay and Aransas Bay, immediately tributary to Seadrift and Rockport, there is available 100,000,-000 cu.yd. of shell. Corpus Christi Bay is an exception in regard to shell deposits as compared to other bays on the Texas Gulf Coast. It is estimated that there is not over 10,000,-000 cu.yd. Nueces Bay has between 6,000,000 and 8,000,00 cubic yards of shell. So it can be readily seen from the above figures that the amount of shell available from various deposits along the Texas Gulf Coastal area is sufficient for a great many years regardless of increased consumption.

Clays—Bleaching clay has for several years been a large industry in Texas. Numerous deposits occur in a geological formation, outcropping at various points in an arch roughly paralleling the Gulf Coast shore line 150 miles inland. The first development of these clays was south of San Antonio, however, as better deposits were found, and as those deposits being worked became depleted, the industry has moved eastward. At the present time the largest producers of fuller's earth in Texas are located in the vicinity or just north of Houston. Several virgin deposits are known to exist in two of the most easterly counties. These deposits have been explored, surveyed and tested to ascertain their quality, ability to activation and amounts in place. Two of these deposits in particular contain in the neighborhood of 2,000,000 tons each. These deposits are well located as to railroads, water sources, and markets.

Dolomite—Large deposits of dolomitic limestone are found in Blanco, Gillispie, Llano, Mason, Burnet, McCulloch, San Saba, Lampasas, and Williamson Counties. These deposits have two railroads serving them—the Santa Fe and the Southern Pacific.

The material is a medium grain crystalline dolomitic marble with secondary dolomite infiltration. The deposits range in thickness to several hundred feet, with very little overburden. The exposed faces are often ten to twenty miles long. Some of this material has in the past been mined and used as marble.

Analyses of several samples of this material follow:

	1	2		3	4	5	6
Silica	5.00	3.00		3.33	4.30	3.32	0.62
Alumina	2.54			5.43	8.48	12.88	.74
Oxide of iron	1.96	1.80		3.18	.33	.25	Trace
Lime	30.32	28.98		29.38	27.03	28.62	33.00
Magnesia	15.14	20.40		14.32	14.99	10.81	18.56
Carbonic Acid	40.47	43.70		42.00	41.70	40.00	46.66
Loss on Ignition	4.49	2.46		3.00	3.60	2.58	.50
	99.92	100.34		100.64	100.43	93.66	99.58

Iron Ore—Iron ores are known to exist in many counties of the state, but for present commercial purposes, two centers are of outstanding interest; the northeastern region and the central area in Llano and Burnet Counties. The former consists of some 20 counties 150 to 200 mi. north of Houston.

The tracts considered most promising are in Cass, Marion, and Morris Counties. These counties are served by the International-Great Northern (Missouri Pacific) Railroad, and from Cherokee County via Southern Pacific. The Llano-Burney area is located about 230 miles north and west of Houston.

Salt—Salt is certainly a large contributing factor to Texas industrial development. There are limitless quantities of salt in the state. The best known deposits are the salt domes of the Gulf Coast region. They are intrusions from unknown depths that almost reach the surface in some instances. There are over 100 salt domes known to exist in Texas. This salt can either be mined by sinking a shaft into the salt mass, or by drilling wells into it and circulating water through the salt and producing the brine.

Vegetable Oils—The vegetable oils which Texas can and is producing are now receiving much interest throughout the nation. The stepped-up demand, coupled with the falling off of our imports has created a shortage of both edible and non-edible vegetable oils. The restrictions on the growing of cotton had already produced an apparent shortage of cottonseed oil, which left us with an insufficient supply on hand at the outset of hostilities. The reduced planting of cotton has incidentally produced a shortage of cotton linters, so important in the manufacture of nitro-cellulose or guncotton.

To offset the shortage of vegetable oil, the farmers have been asked to plant large acreages of peanuts for crushing purposes. The majority of the farmers are inherently cotton farmers; they have the tools to produce, gin, and bale the cotton. They will plant peanuts as the government has asked them; but will they have the tools to harvest and thrash them? It is the opinion of many in Texas that the increased planting of cotton would be a more satisfactory solution to the oil shortage that is before the nation.

Flaxseed—Numerous experiments have and are being carried on to determine which crops will best produce oils in the Texas climate. As far back as the fall of 1937 in the Taft Area, flaxseed were imported and planted on various test tracts. The results were so satisfactory that the planting spread year by year until at present it is generally being planted throughout the Southwest Coastal section.

The cotton seed crushers who had in no little way sponsored the intro-

duction of flax, were quick to see its possibilities, and several mills have been converted in order to crush flax-seed as well as cotton seed. Flax in Texas has assumed a position as a cash-winter crop and will help alleviate the acute shortage of drying oils in the paint and varnish industry.

TEXAS CAN SUPPLY PROCESS INDUSTRIES WITH THESE RAW MATERIALS

Resources	Used to Make	Resources	Used to Make
Anhydrite	Salt cake (under research)	Helium	Diluting oxygen and air ships
Arsenopyrite	Arsenic for insecticides	Iodine	Medicine and chemical synthesis
Asbestos	Insulation	Iron ore	Iron, pigments and drilling mud
Asphalt rock	Floor tile and paving	Kaolin	Ceramics, paints and alum
Barite	Barium metal and drilling mud	Lead	Acid resisting linings and paints
Basalt	Insulation as rock wool	Lignite	Fuel oil and bleaching medium
Bentonite	Drilling mud and filler	Limestone	Lime, dry ice and as a flux
Bromine	Medicine, tetra-ethyl lead and others	Manganese ore	Steel alloys
Caliche	Insulation as rock wool	Mica	Electrical insulation and as a parting powder
Candelilla plant	Wax like bees-wax		
Castor bean	Insecticide, oil and fiber	Mineral waters	Iodine, bromine, salt cake, etc.
Cattle	Fertilizer, casein, hides and glue	Molybdenite	Steel alloys
Celestite	Fire works, signal flares and drilling mud	Natural gas	Fuel, carbon black, hydrogen, synthetic chemicals
Chromites	Chromium for plating		
Cinnabar	Mercury, calomel, etc.	Naval stores	Paint and plastics
Citrus fruits	Citric acid and oils	Oyster shell	Lime and dry ice
Clay	China, pottery, bricks, enamel and alum	Peanuts	Plastics, oil, etc.
Coal	Fuel and coal products	Petroleum	Plastics, asphalt, rubber, fuels and oils
Corn	Starch, oil and furfural	Potash	Fertilizers and source of potassium
Cotton linters	Rayon, explosives and plastics	Rice	Starch, alcohol, furfural and oil
Dolomite	Glass, enameling and magnesium	Rice Straw	Paper and paper board products
Feldspar	Glass, glazing and enameling	Salt	Chlorine, hydrogen and caustic soda
Fish	Meal, hides and oil	Salt cake	Paper making, etc.
Flax	Meal and oil	Sand	Glass, sodium silicate, abrasives, ceramics
Fluorspar	Glass, steel making and source of fluorine	Sea water	Bromine, iodine and magnesium
Forest products	Paper, wall board and paints	Silver ore	Silver and silver salts
Fuller's earth	Bleaching and as a filler	Sulphur	Sulphuric acid, sulphur dioxide, etc.
Gilsonite	Mastic tile, etc.	Sweet potatoes	Starch, syrup and stock food
Graphite	Dry lubricant and paint	Talc	Face powder, and treating rubber
Greensand	Water treatments	Water power	Industrial power
Gypsum	Plaster of Paris and plaster board	Zinc	Zinc plated steel and chemical synthesis

Chemical engineering developments that may mean new industries for Texas

E. P. SCHOCH and ASSOCIATES Bureau of Industrial Chemistry, University of Texas, Austin

IN 1914, the Bureau of Industrial Chemistry was established. Since 1937, its funds have been increased, and it now functions primarily as a research institution.

The three subjects being studied are those which were deemed to be most urgently in need of research. They are:

(1) New manufacturing processes for transforming natural gas at the wells into needed industrial products.

(2) New processes for changing the spinning properties of Texas cottons so as to make them more generally usable.

(3) Developing new Texas non-metallic minerals for fine ceramic wares.

In a larger way, these three divisions concern themselves with the following subjects respectively:

(1) Natural gas and petroleum;

(2) Products from the farm and ranch;

(3) Manufactures from non-metallic minerals.

It is believed that fundamentally new processes must be developed in order that the new industries to be established in Texas may add to the industrial life of the whole nation, —while the moving of industries from elsewhere to Texas or the establishing of competing industries might help Texas only at the cost of other regions.

NATURAL GAS PROBLEM

Texas furnishes nearly all the carbon black of the world—and for this purpose it burns daily about one billion cu.ft., with an average yield of 1.45 lb. per 1,000 cu. ft. feet. The price paid for much of this gas is about one-third cents per 1,000 cu.ft. Hence, this gas for carbon black may be said to be practically wasted. Other gas which is wasted outright raises the total daily gas waste to about one and one-half billion cu.ft.

Since 1929, there has been in progress in this bureau an investigation of the effect of electric discharges upon dry natural gas (methane)—and this project was made the exclusive work of this division since 1937. It is found that at atmospheric pressure acetylene is obtained from natural gas with quantities of electric energy equal to or somewhat less than that required for making the corresponding amount of calcium carbide. The operation can produce an end-gas varying in acetylene content from 5 percent to 20 percent. It also produces about one-fourth as much carbon black.

At present, this division is busy with the testing of a pilot plant operating the process. It is also working on the production of pure acetylene and the production of butadiene direct from the end-gas obtained.

An idea of the possible significance to Texas which this process may have can be obtained from the following:

If the gas now used for making carbon black is used in this process it will furnish enough acetylene to make twice the amount of rubber used in the United States during peace time, and leave enough residue gas to produce all the power needed for this process—and in addition produce 25 percent more carbon black than is now produced, and which is now the sole product obtained from this gas. Surely, such an economic result is worth striving for.

The cotton research program is to so modify the short staple cottons produced in Texas as to render them acceptable to the trade despite their staple lengths. We have, therefore, devoted our entire attention to the chemical modification of the surface of the cotton fiber, without destroying its fibrous properties, to the end of enhancing the property of frictional resistance.

Considerable success has been obtained with one treatment, and after cooperative experiments with cotton mills in various sections of the country a small pilot plant has been built for the production of the treated cotton and a complete cotton spinning and testing laboratory is being installed to develop the technology necessary to bring to a full fruition the newly developed property.

Several other projects being initiated are: (1) utilization of the cedar (*Juniperus mexicana*) covering hundreds of square miles of Texas in dense, readily accessible stands. Cedar is the source of cedar-wood oil, widely used in the drug and cosmetics industry, and it is a peculiar property of this species of *Juniperus* that the foliage contains an appreciable amount of camphor; (2) utilization of agricultural crops, either directly or as wastes, for the development of a fermentation industry. Texas is producing a tremendous quantity of fermentable crops, and could produce a much larger quantity, particularly of corn, sorghums, sweet potatoes, and wood waste; (3) development of a wool scouring industry in a state producing one-sixth of all the wool grown in the United States; (4) development of an essential oil and drug industry, utilizing crops either native to the state or readily cultivated, such as rose, gardenia, ephedrine, horsemint, wormwood, cassie, mint, sage, etc.

Research bearing on requirements of ceramic porcelain industries, dinnerware, hotel china, sanitary ware, electrical porcelain, and high-grade floor and wall tiles, has been carried on by the Bureau. First, adequate deposits of raw materials which such industries could use were located. The problem of proper processing of each deposit has been worked out, e.g., a feldspar of excellent whiteness and fusibility has been produced. Clays and related minerals have been given control treatments to produce plasticity without stickiness, strength with workability, and whiteness of extreme purity. In order to confirm results obtained in the laboratory, chinaware bodies composed of all Texas raw materials were submitted to representative manufacturers and made into ware by the regular factory processes. The results were highly successful.

It can now be stated that not only are all of the standard raw materials traditionally used by these industries found to be available in Texas, but also halloysite and white firing montmorillonite. The latter is now attracting much scientific attention. Therefore, any porcelain industry wishing to locate in the Texas market area can now have not only the ideal cheap fuel but the advantage of superior raw materials close at hand. At the present time the cost of transportation of these wares from distant points forms such a large item of cost to the consumer, that the principles of national economy call for porcelain production in the state.

Recent research has brought to light clays of unusual properties maturing at the same temperature as that required by the artist's glaze colorings. The occurrence of volcanic ash in this area has imparted these unusual qualities to certain clays and offers the artware manufacturer raw materials not available to most of the larger manufacturing establishments located elsewhere.

Hence, it may be said that not only are the usual raw materials for ceramic manufacture available in the Texas area, but many deposits have unusual properties which research in this Bureau is placing at the disposal of the manufacturer.

At atmospheric pressure, acetylene is obtained from natural gas with electric energy equal to or somewhat less than that required for making the corresponding amount of calcium carbide. Pilot plant for the production of pure acetylene, and the production of butadiene from the end-gas obtained
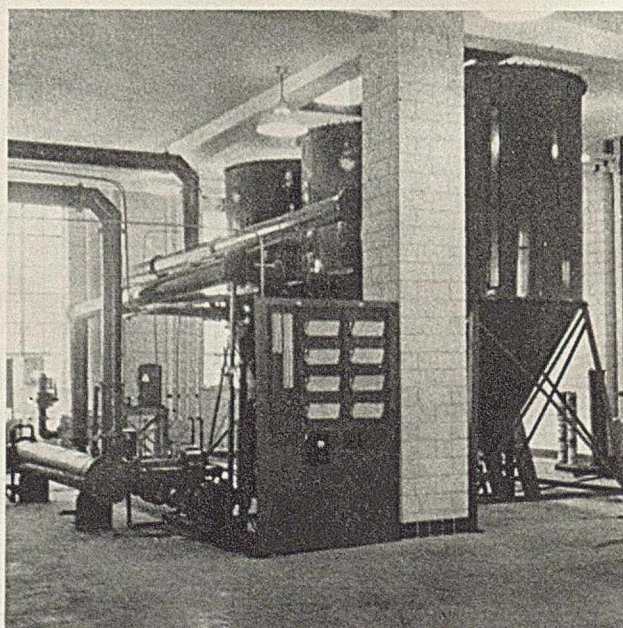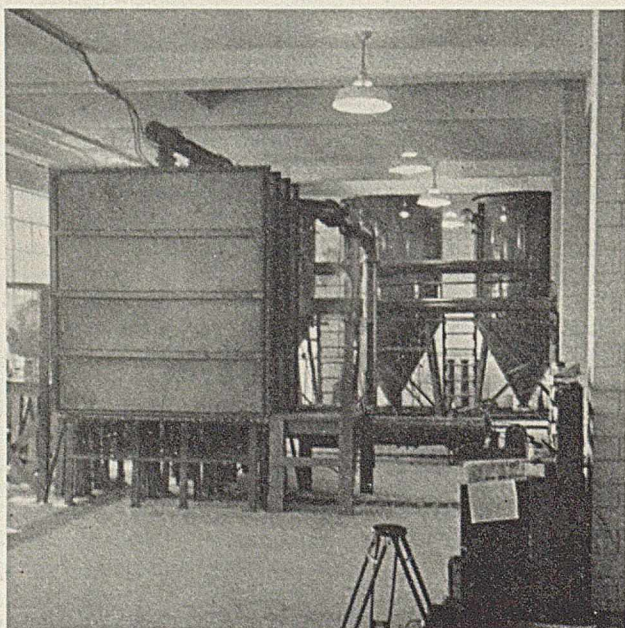
Machinery, Materials and Products

Asphalt Tile

DEVELOPMENT OF a new type of asphalt tile designed to prevent accumulation of static electricity has been announced by the Building Materials Division of the Armstrong Cork Co., Lancaster, Pa. The new material, which will be known as Armstrong's Conductive Asphalt Tile, provides a surface condition which results in less than 0.1 megohm resistance to static electricity under specific conditions. No open flames are required during installation or repair work. The material is especially suitable as a resilient flooring in arsenals, shell and bomb loading plants, powder plants, and in various other industries in which static electricity or open flames would present a safety hazard. Individual tile units can be quickly replaced if accidentally damaged, and since the tiles are laid on a fast-setting adhesive, the floor can be put into service immediately. The material is non-slip, non-dusting, non-sparking, moisture-resistant, odorless, and will withstand fast trucking. It is highly resistant to indentation. The asphalt tile is supplied in gauges of $\frac{1}{8}$ in., $\frac{3}{16}$ in., $\frac{1}{4}$ in. and $\frac{3}{8}$ in.

Extrusion Press

AN IMPROVED 125-ton extrusion press which permits simultaneous loading and extrusion, has been developed by the Watson-Stillman Co., Roselle, N. J. The first of these units, illustrated by an accompanying photograph, will extrude carbon mixtures, but the press is also suitable for extruding any plastic material. The press has two containers, mounted on a swinging arm. The operator starts the automatic extrusion cycle by push-button control, then devotes attention to loading the free container. The main ram is $12\frac{1}{2}$ in. in diameter and has a 12-in. stroke.
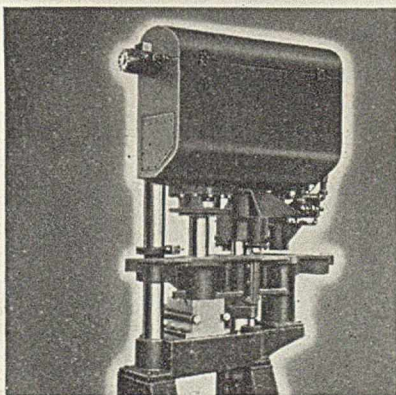
Advance speed is 54 in. per minute, pressing speed is 6.4 in. per minute at 2,000 lb. per sq.in. and return speed is 150 in. per min. Power is from 2 Vickers pumps driven by a 5 hp. motor. The complete unit is 10 ft. high and requires 4 ft. by 3 ft. floor space.

Insulating Varnish

A RECENTLY developed new insulating varnish, designated as S-110, has been announced by the Sterling Varnish Co., 116 Ohio River Blvd., Haysville, Pa., for application to electrical apparatus that must operate at abnormally high temperatures. Tests have indicated that S-110 will stand operating temperatures at 250 deg. C. or higher. When baked at 175-200 deg. C., it dries all the way through the deepest winding and does not resoften when exposed to high operating temperatures. The dried film is mechanically strong, adhesive and flexible, and retains these characteristics under adverse heat conditions.

One machine was wound with glass-covered wire and insulated with glass and mica, after which it was treated with two coats of S-110. The machine was then run to destruction. Upon investigation, the insulation varnish was found to be in excellent condition and the stator showed no signs whatever of breakdown even though the rotor bars had loosened, due to the brazing having melted away at 700-800 deg. C. The insulation test on the stator was perfect and when a new rotor was put into the machine and fresh grease in the bearings, the motor started up without any trouble.

Hard Rubber

A SUPERIOR TYPE of hard rubber made from Ameripol, the synthetic rubber produced by this concern, is announced by the B. F. Goodrich Co., Akron, Ohio. The new synthetic hard rubber will stand temperatures 100 deg. F. higher than the best hard rubber made from natural crude before it will soften. It has been pointed out that the new development will extend the field of hard rubber, since it overcomes many of the limitations which had restricted the service of this type of rubber under extremely severe conditions. The accompanying illustration shows molded and extruded types of hard rubber made from the concern's Ameripol synthetic rubber.

Low-Temperature Heaters

A NEW LINE of Series 4 "Lo-Temp" unit heaters is announced by the Air Conditioning Division of the Fedders Mfg. Co., Buffalo, N. Y. The units are designed to operate on steam pressures up to 150 lb., with emphasis on low final temperature, and are built in 12 capacities, ranging from 18,000-288,000 B.t.u. per hour, based on 2 lb. steam pressure at the unit and 60 deg. F. entering air temperature. Heating elements are designed to expand and contract freely within the cabinet and are anchored by telescoping mountings which maintain alignment and prevent stresses between elements and cabinets.

125-ton extrusion press

Hard rubber made from synthetic rubber

Low-temperature unit heater
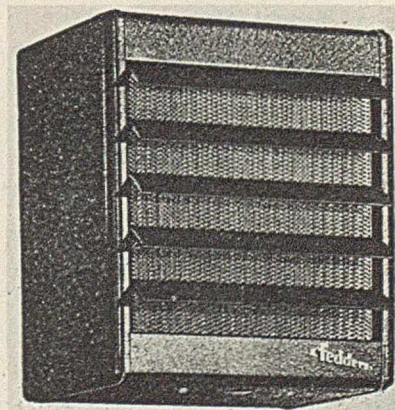
Toxic dust respirator

Tubes of 3 to 1 ratio provide stream-lined air flow over prime and secondary surface. Individual saddle fins allow each tube to give laterally, thus relieving differential expansion stresses between adjacent tubes. Fins saddled over the sides of tubes eliminate expansion stresses between fin and tube and between bonding points. One of the units is illustrated in an accompanying photograph.

Blueprint Letterer

A NEW TYPE of machine has been developed by the Ralph C. Coxhead Corp., 333 Sixth Ave., New York, N. Y., to speed the lettering of dimensions, bills of material, and notes on drawings and blueprints. The machine eliminates time-consuming hand-lettering of specifications, thereby saving valuable time for draftsmen. It is claimed that a hand-lettering job for specifications on a single sheet that formerly took 4 to 5 days of a draftsman's time is now done by a typist in half a day.

The new machine is an adaptation of the Vari-Typer, with changeable type faces and spaces. It uses a type font instead of letters and symbols on single type. Changing the type font permits use of a variety of styles and sizes of alphabets. The spacing arrangement is variable to permit use of alphabets with different width letters. The feature that makes the machine adaptable

Blueprint lettering machine

to sheets of great size is a basket-type carriage with open ends. The carriage and its supporting track have been extended to accommodate 20-ft. sheets. On the basis of a survey of 14 major companies producing war equipment, this concern has estimated that the new machine method of lettering drawings can effect a saving of 75 percent or more in draftsmen's time by elimination of hand-lettering. The machine is illustrated in an accompanying photograph.

Respirator

A NEW RESPIRATOR for protection against toxic dusts has been announced by the American Optical Co., Southbridge, Mass. Representing a new design in toxic dust respirators, this new American R9100-T protector is light in weight and gives full vision, as shown in the accompanying illustration. The filter has been approved by the U. S. Bureau of Mines for protection against the inhalation of toxic or poisonous dusts such as lead, cadmium, arsenic, chromium, manganese, selenium, vanadium and their compounds. The facepiece with its leak-sealing cantilever edges of pliable rubber gives comfort to the face, while the simple, non-reversing exhalation valve provides protection. The double headband of solid rubber holds the respirator, which weighs only $1\frac{1}{2}$ oz., in place without noticeable tension.

Industrial Humidifier

A NEW INDUSTRIAL humidifier just announced by the Carrier Corp., Syracuse, N. Y., provides low-cost humidification, yet is compact, easily installed and low in power consumption. The unit can be moved readily to accommodate equipment layout changes, and is suitable for use in single or in multiple. Available in two capacities, the two sizes will provide 4,800 or 6,150 cu. ft. of humidified air per minute, and evaporate up to 96 lb. of water per hour. The unit, built in two sections to facilitate handling and designated as the Carrier Type 43G, includes fan and motor, humidifier pack, heating coil, drip pan, dampers, lint catcher, and housing.

Condensate Sampler

A CONDENSATE sampler for electrical-conductivity check-up of steam or other condensate has been announced by Industrial Instruments, Inc., 156 Culver Ave., Jersey City, N. J. The device operates in conjunction with a suitable electrical instrument calibrated in direct-reading terms such as percentage of carry-over of soluble salts. The cell holder admits the condensate into the chamber provided with a baffle and a two-way drain cock. At the bottom of the chamber is the conductivity cell. The thermometer indicates the temperature of the condensate, and a sight

gage shows the presence of oil which can be drained off by turning the drain cock to the oil-drainage position, thereby safeguarding the conductivity cell against contamination. The cell holder is available alone for use with any type of condensate cooler or in combination with a new type of condensate cooler now available. The cell holder admits the condensate through its $\frac{1}{4}$-in. solderless pressure-connected copper pipe. An outlet pipe with a two-way control cock releases the condensate to the drain pipe. A neoprene baffle within the sampler chamber insures the proper circulation of the condensate past the conductivity cell screwed in at the bottom of the chamber.

Plastic Insulation

FOR THE cold insulation of pipes, walls, ceilings, tanks and other equipment, to prevent condensation and sweating, J. W. Mortell Co., Kankakee, Ill., has announced No-Drip, an improved plastic cork coating which does not require power spray equipment for its application. It may be applied with an ordinary paint brush, a trowel or a spray. This material is spread $\frac{1}{4}$ in. thick over metal, concrete, brick, plaster, tile, wood, composition or metal surfaces, and can be painted any color. It is said to act not only as an insulation, but as a protective coating for preventing rust.

Blower Units

PRODUCTION OF new motor blower units in a wide range of sizes is announced by the Niagara Blower Co., 6 E. 45th St., New York, N. Y. These are available in 16 models and are produced in 1, 2 and 3-fan assemblies to meet resistance up to 4 in. s.p. and in capacity from 880 to 42,600 cu.ft. per min. Fan speeds range from 300 to 1,750 r.p.m. The blowers may be secured with or without casings. They are belt-driven or direct-connected and are especially designed for simplified application to duct systems. Units are available in two series of fan designs. Series 1100 gives large volumes of air with quiet operation at low fan speeds for static pressures up to $1\frac{1}{2}$ in. Series 1200 meets the resistance of duct systems and special conditioning equipment, protecting motors from overload by a retarded horsepower curve, for static pressures up to 4 in.

Two-fan, belt driven blower
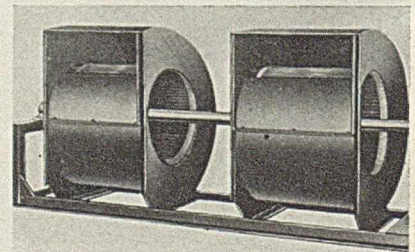
Equipment Briefs

A NEW MODEL of Mineralight ultra-violet ray black-light lamp, useful for identifying tungsten ores and other minerals which fluoresce under black light, is announced by Ultra-Violet Products, Inc., 5205 Santa Monica Blvd., Los Angeles, Calif. The new model operates with a cell in a built-in compartment and features a built-in regular flashlight in addition to the black light lamp. A double contact switch enables the operator to use either type of light, thus permitting him to look for likely indications with a regular light and to check at once with the black light. The unit weighs 7½ lb., including 2 six-volt lantern batteries. Small batteries will operate the lamp for 15-20 hours, which has an ultra-violet efficiency high enough to detect the mineral Scheelite as far away as 10 ft.

IN ORDER TO provide a method of indicating air raids and necessity for blackouts, the "Reco" motor-driven coding control has been developed by the Reynolds Electric Co., 2650 W. Congress St., Chicago, Ill. As its action is automatic, the danger of carelessness and error with manually operated sirens and alarms is avoided. The unit has two signals: one which gives a series of alarms in 15 cycles of raising and lowering tones during the period of two minutes, and the other which signals a steady "all clear" siren blast for two minutes. This control is supplied with automatic cut-off and push-button start, for 110 volts, 60 cycle current and can be furnished in weatherproof cabinets.

A NEW APPLICATION for its electrically conductive rubber and synthetic rubber compounds, in the form of a new sandblast hose, has been announced by the B. F. Goodrich Co., Akron, Ohio. The new hose replaces the company's previous anti-static sandblast hose which used an internal wire construction for dissipating static charges. The new hose contains no wire, the rubber compound itself carrying away the static electricity as fast as it forms. The company has also announced that its Type 400SS oil hose is now made entirely without natural rubber, its own synthetic rubber, Ameripol, being used.

PHOTOVOLT CORP., 95 Madison Ave., New York, N. Y., has announced the
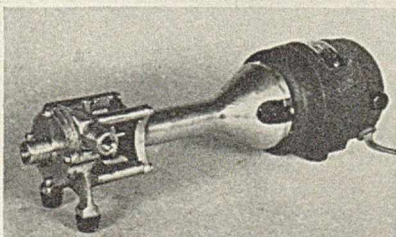
new Lumetron Model 400 portable photoelectric colorimeter which features portability, simplicity of operation and low price. The meter operates from any 110-volt outlet and is claimed to be exceedingly simple to use. Although in the price range of visual colorimeters, the new model offers the various advantages of photoelectric instruments, such as independence from the personal equation.

KNOWN as the Verd-A-Ray lamp, a new incandescent lamp said to reduce eye strain and fatigue and thus to conserve the body's vitamin A has been introduced by Save Electric Corp., Toledo, Ohio. The new bulb gives off less of the red and more of the green-yellow rays, casting a pastel green hue on white substances and making them glare-free, according to the manufacturer. The effect is said to be about the same as that of ordinary light or the so-called "eye-ease" green paper. The bulb is coated with a ceramic glass-on-glass filter, is said to consume the same amount of current as standard lamps of equal wattage, and is available in sizes from 40 to 1,500 watts.

TO CONSERVE NICKEL for the war effort, the American Manganese Steel Division of the American Brake Shoe & Foundry Co., Chicago Heights, Ill., has made available a new manganese steel welding rod known as "V-Mang." An alloy steel containing 12-14 percent manganese, molybdenum and other elements, this electrode will replace Amsco Nickel-Manganese steel electrodes, except in a few exceptional cases. Tests have shown that the new rod can be applied readily and that it has ductility and tensile strength equal to or better than nickel-manganese steel rod as applied. It can be used to repair fractures in manganese steel parts as well as for built-up work, depositing a uniform bead similar to that from nickel-manganese electrodes. It is available bare and coated in ⅛-in., 3/32-in., 3/16-in. and ¼-in. diameters and in 18-in. lengths. Standard containers, waterproof wooden boxes, contain 50 lb. of rods.

Midget Hot Liquid Pump

THE EASTERN Engineering Co., 45 Fox Street, New Haven, Conn., announces a newly designed midget hot liquid pump known as the Model EH, illustrated in an accompanying photograph. The design of the pump makes it suitable for handling hot liquids up to 500 deg. F. The unit is of the centrifugal type, weighs 7 lb., and is 12 in. long by 4 in. wide by 4½ in. high. The motor is of the 1/20 hp. universal fan-cooled type for use on 115 volts, a.c. or d.c. Both motor and pump are coupled through a 5-in. heat radiating tube and the shaft is supported by outboard ball bearings. The pump will deliver a maximum pressure of
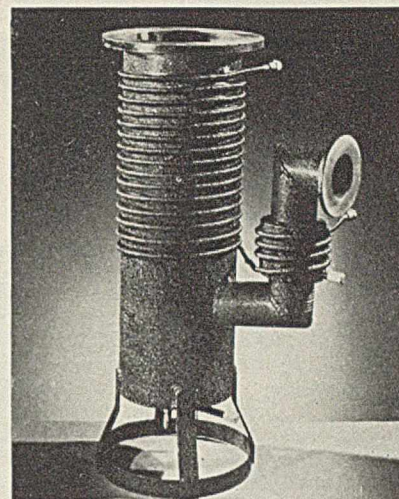
High capacity metal vacuum pump

21 lb. per sq.in. and a maximum volume of 7½ gal. per min. Materials of construction include stainless steel, Monel metal, chromium-plated bronze, Hastelloy "C" and other alloys.

Booster Pump

A NEW HIGH-CAPACITY metal vacuum pump, known as the Metal Booster Pump, Type MB-200, designed for use with forepumps having low volumetric efficiency at pressures below 1 mm. of Hg, has just been announced by Distillation Products, Inc., Rochester, N. Y. This 2-stage oil diffusion unit will boost the pumping speed to 200 L. per sec. and will carry the vacuum from 0.5 mm. to 5×10^{-5} mm. of Hg. The unit has a vertical casing 6x20 in. and is readily connected to large mechanical pumps by 1½ in. standard pipe fittings, or in the optional model, as shown in an accompanying illustration, by a 2-in. i.d., 4 in. o.d. flange.

Incandescent Luminaire

ADAPTED FOR extreme service locations, such as steel mills, foundries, chemical plants or wherever acid fumes, dust, smoke or excessive moisture is

Incandescent Millite luminaire

Hot liquid midget pump
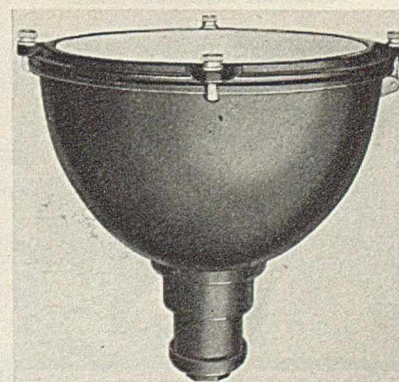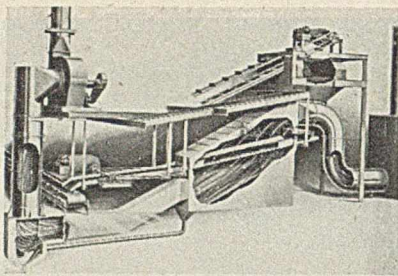
Unit for drying sized coal

present, a new vapor-tight Millite luminaire for incandescent or mercury lamps has been announced by the Westinghouse Lighting Division, Edgewater Park, Cleveland, Ohio. Because of its weatherproof construction, the unit can be used for outdoor applications. Consisting of three parts, a porcelain enameled steel reflector available in several sizes, a socket assembly, and a hinged glass cover, the unit is arranged for conduit mounting. Reflectors for 300 and 500-watt sizes are made from 19 gage iron sheet, and the 400,750, and 1,000-watt sizes are from 18 gage.

Vapor-tight sealing is obtained with a heavy, treated asbestos gasket between cover and housing. An impact-resisting glass lens 0.25 in. thick is designed to withstand sharp temperature changes and if broken, shatters to small dull fragments rather than splitting into large pieces. The unit is shown in an accompanying illustration.

Coordinator Device

A NEW COORDINATOR device, called the "Produc-Trol" and illustrated by the accompanying photograph, has been developed by Wassell Organization, Westport, Conn. Use of this device enables executives to see all facts concerning raw materials, parts, assemblies, machines and man hours. It is especially useful where multiple-shift production is maintained. The unit lists parts, assemblies, sub-assemblies, or individual operations on a part, at the left of the board. Movable tapes working from left to right on pulleys bring all pertinent facts into focus. Double rows of peg holes under the movable tapes and various colored pegs permit various arrangements of comparative data and control required for any operation.

Coordinator device and board
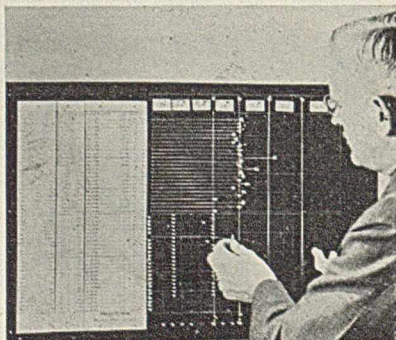
Units can be ordered in sizes to fit specific needs. Models are also available for individual and group incentive plans.

Coal Dryer

A NEW DRYER for the effective removal of surface moisture from sized coal has been tried out on actual installations and is now announced by the Link-Belt Co., 307 N. Michigan Ave., Chicago, Ill. The dryer, to be known as the Link-Belt "SS" dryer, combines mechanical dehydration with heat drying and is available for drying sized coal of 10 mesh and up. The unit comprises a drying chamber with perforated reciprocating-plate drying surface; coal inlet and outlet; hot air inlet from a coal-fired furnace; and an exhaust fan for drawing the hot air into the chamber, over and through the bed of coal, down through perforations and reciprocating plates to the exhaust stack. Operation of the moving element is analagous to that of the shaker screen except that the perforations are small and are intended only for passage of drying air. Inasmuch as the coal passes through the dryer in a thin bed at slow speed, it is uniformly dried with low temperature air and discharged relatively cool. Comparatively little power is required for operation of exhaust fan and reciprocating plate. The unit is illustrated by an accompanying figure.

Load-Center Unit Substation

NEW STANDARDIZED load-center unit substations are now available in sizes ranging from 100 to 2,000 kva., according to the Allis-Chalmers Mfg. Co., Milwaukee, Wis. These compact units can be installed anywhere in industrial plants or power distribution centers, saving valuable headroom, floor space and long secondary runs of heavy copper.

Extremely flexible, the standard unit substations offer a wide source of incoming- and outgoing-line arrangements. The substation consists of a metal-enclosed incoming-line section, a throat-connected transformer and a low-voltage heater section. On the high voltage side, potheads, disconnect switches, oil fuse cutouts, metal-clad switchgear or direct connection through terminal box can be supplied. On the low voltage side, stationary or drawout air breakers, electrically or manually operated, are furnished. Transformers can be oil-immersed, dry type or non-inflammable liquid filled.

Rotary Pump

A NEW VERTICALLY mounted rotary pump has just been put into production at the plant of the Blackmer Pump Co., in Grand Rapids, Mich. This unit has a capacity of 150 g.p.m. at a pressure of 100 lb. per sq.in. and is powered by a 15 hp. gearhead motor, 300 r.p.m. on the pump shaft. The same

type of pump and mounting is also furnished in capacities from 5–700 g.p.m. and in pressures up to 300 lb. per sq.in. This pump can handle a wide range of liquids. The pump is self-adjusting for wear, and there is practically no loss of volumetric efficiency during the life of the swinging vanes. When the buckets are worn out, the unit can soon be restored to its original efficiency.

Abraser Vacuum Pick-Up

THE TABER Instrument Corp., North Tonawanda, N. Y., has announced its improved Abraser Vacuum Pick-Up, Model HV-42, as accessory to the Taber Abraser method for measuring resistance to abrasion of surface finishes. The function of the vacuum pick-up is to prevent accumulation of abradings from interfering with the normal wear action of the Calibrase wheels. The unit has a nozzle mounted on the suction end of the housing so as to swing in and out of position. The nozzle-holder can also be adjusted vertically to the proper height above the specimen. The contaminated air is drawn through the nozzle and connecting tube into the high-speed centrifugal pump, then through a special filter bag, which can be quickly and conveniently removed for cleaning. The motor is the high-speed universal type designed for operation on any electrical circuit of 110-120 volts.

Panel Mounting

THE LITTLEFUSE indicator, or Panel Mounting No. 1414, which instantly reports a break in circuit by flashing on a light only when the circuit is broken, has been announced by Littelfuse Inc., 4757 Ravenswood Ave., Chicago, Ill. When installed at any convenient or desirable point in connection with remote motor control, it works instantly with a plainly visible signal to show "on" or "off." When the circuit breaker opens the light goes on. The unit can be had for 24 or 48 volt filament bulbs with which no resistor is used. Otherwise it uses a built-in, 200,000 ohm. protective resistor, in series with a neon lamp. The resistor prevents the lamp from blowing out on unexpected high voltages. The lamp glows on current as low as 100 micro-amperes. The indicator has a black Bakelite body and is made for panels up to $\frac{7}{8}$ in. thick and $\frac{1}{2}$ in. diameter mounting hole. Overall length is 2 in. below panel, $\frac{7}{8}$ in. above panel. The rating is 90 to 250 volts.

Panel mounting

Beet Sugar Production

UGAR BEETS are grown in the district between Michigan and California and produce substantially 25 percent of the sugar (sucrose) normally consumed in the United States. Of the eighty-odd American beet processing factories, that of the Amalgamated Sugar Co., at Nyssa, Ore., is one of the most modern.

For processing, the beets are washed and "sliced" into long, narrow, thin v-shaped "cossettes". These are fed to a battery of vessels wherein the sugar and other soluble constituents are extracted by diffusion in a countercurrent manner. The resulting solution is treated, in first carbonation, with milk of lime (or sacchrate milk from the Steffen House) and carbon dioxide to precipitate impurities. The precipitate is separated from the purified solution by thickening and filtration and the clear solution is further treated with carbon dioxide to precipitate residual lime, and again the precipitate is separated from the solution by filtration. The resulting filtrate is concentrated in a quintuple effect evaporator to a point just short of saturation. The resulting solution is further concentrated in the "white" vacuum pan to produce sucrose crystals, and the resulting "massecuite" is separated in centrifuges to produce refined sugar and "green syrup." The refined sugar is then dried by passing through a rotary dryer and is, in the more modern factories, stored in bulk to be packaged for shipment as desired. The green syrup is further concentrated in vacuum pans to yield impure sugar crystals which are returned to the system for reworking.

Sugar is recovered from the molasses by adding pulverized quick lime to a dilute solution thereof (the Steffen Process) at temperatures below 20 deg. C. The resulting precipitate, tricalcium sacchrate, is separated by filtration and the filtrate is heated to produce a second sugar-containing precipitate which is separated by thickening and filtration. The two precipitates are mixed to form saccharate milk which is used in first carbonation.
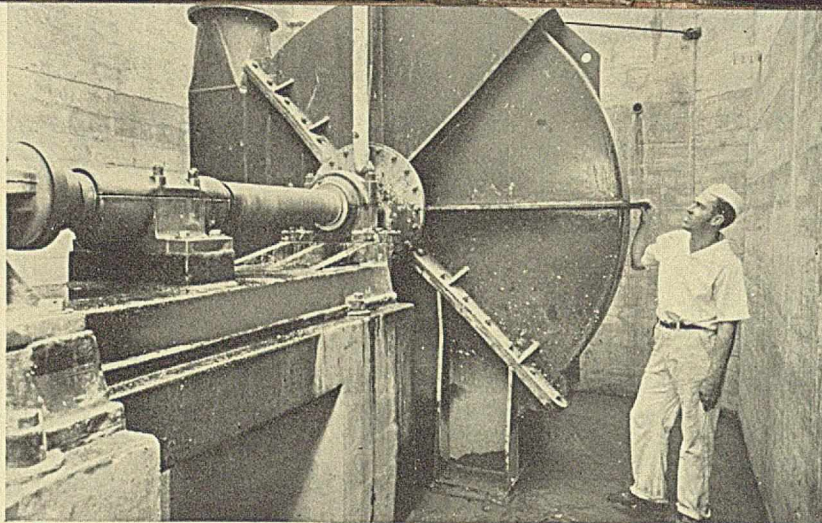
1 Centrifugal beet pump designed to transfer the whole beets from the unloading yard into the mill. Flume water and beets are lifted over 9 ft.

A
Chem & Met
FLOW
SHEET

1
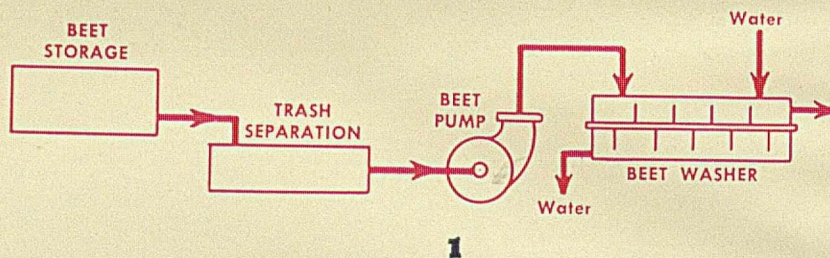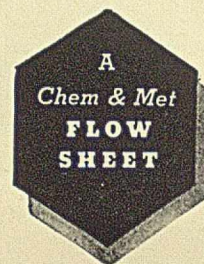
3 The cossettes are fed by conveyor to a battery of diffusion vessels where the sugar is extracted by counter current principle
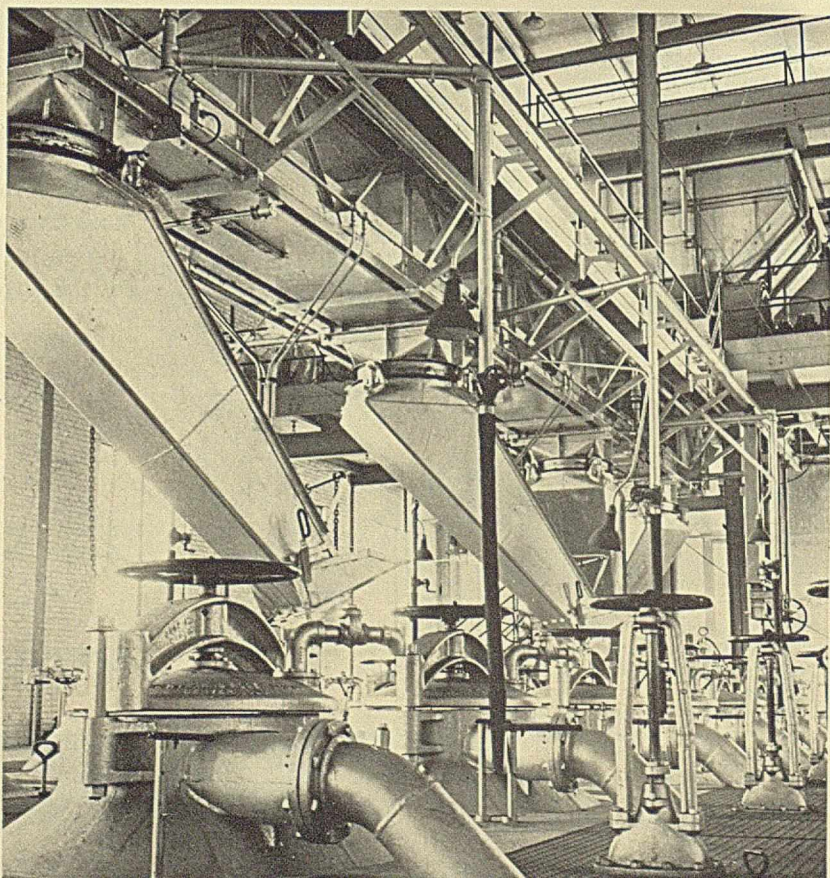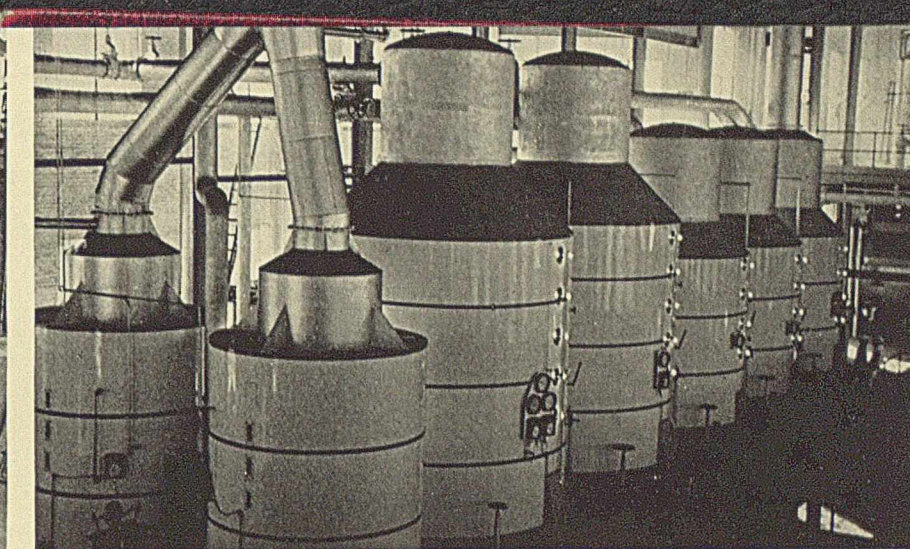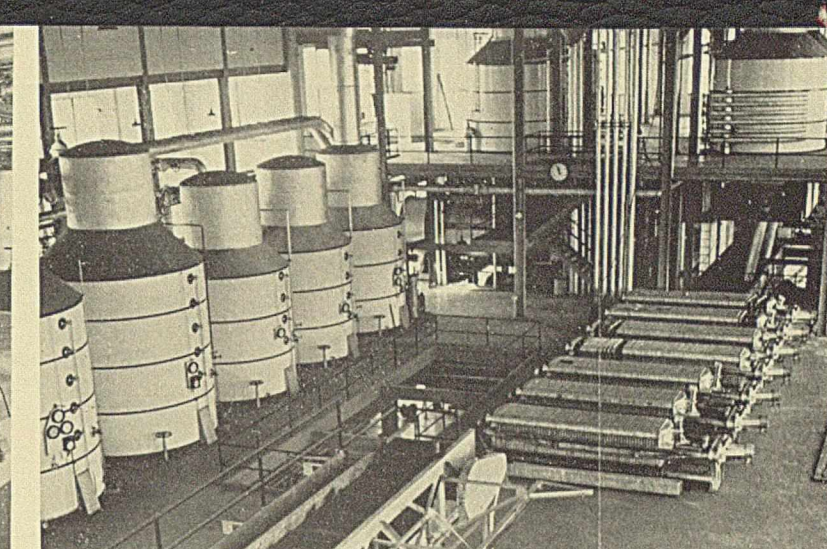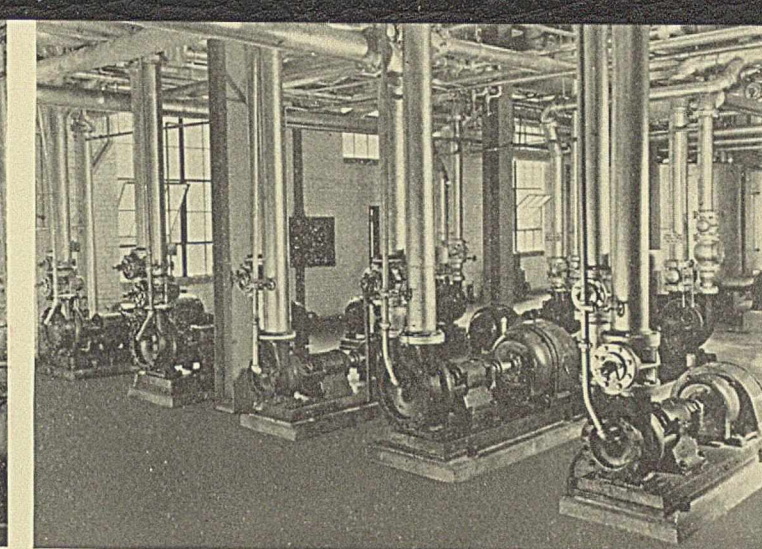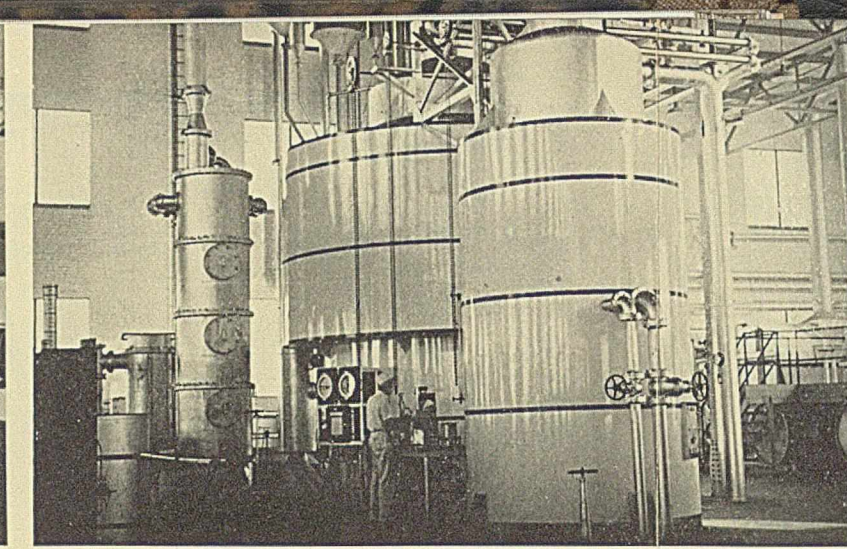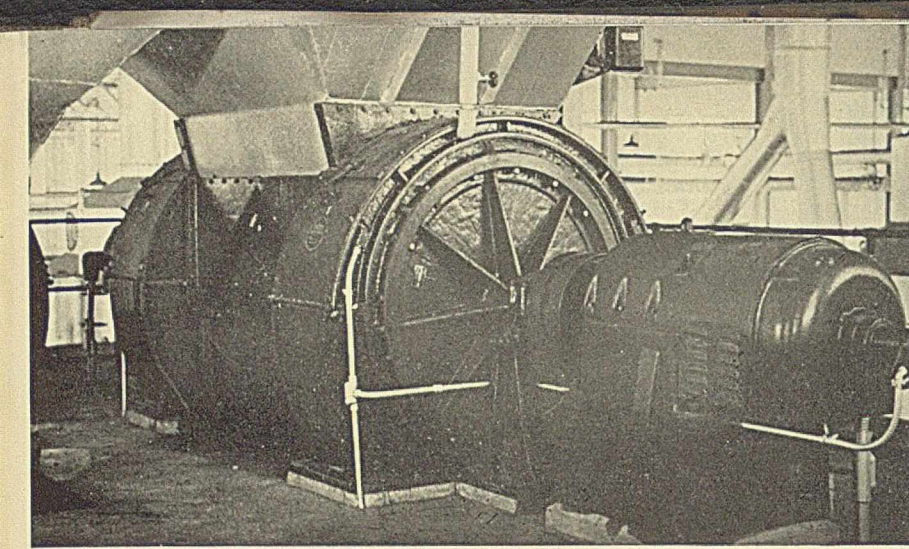
2 Beets are next washed to remove all dirt and trash, elevated to scales, dumped into cutters which reduce them to V-shaped slices known as "cossettes"

4 Sulphonation tower, and first and second carbonation tanks are shown. Sucrose solution is treated in the first tank with CO_2 and saccharate milk

6 Centrifugal juice pumps are of unique design in that they have what is known as an air or non-condensible gas removing fixture

7 General view showing evaporators (left), vacuum pans (rear), part of cossette conveyor (foreground), and one of the crystallizers (left rear)

8 After the final purification the sugar solution is pumped to the juice boilers and then to the quintuple-effect evaporators. Concentration is followed by graining

Diagram labels:

SCALE
2 CUTTERS
ELEVATOR
Water
BELT CONVEYOR
DIFFUSION BATTERY
3
Limestone and Coke
CO_2 (30%)
Saccharate Milk
CO_2 Gas (30%)
4 FIRST CARBONATION TANK
THICKENER
MUD PUMP
6 Clear Juice
SECOND CARBONATION TANK
SECOND CARBONATION FILTRATION
KELLY PRESS
SO_2
THIRD FILTRATION **7**
Exhaust Steam (15 lb.)
QUINTUPLE EFFECT EVAPORATORS **8**
CONDENSER
Solution
CONTINUOUS FILTER
Cake to Waste
HEATER PRECIPITATOR
Filtrate
MUD PUMP
THICKENER
To Sewer
LIME KILN
Lime
RAYMOND PULVERIZER
Lime (—200 mesh)
STORAGE BIN
Water
DILUTION TANK
Cold Water
Warm Water
COOLING TUBES
CONTINUOUS FILTER **5**
SACCHARATE PRECIPITATOR
Water
STORAGE AGITATOR
Molasses from "Raw Sugar" Centrifuges
STORAGE TANK

"WHITE" VACUUM SUPPLY PAN
ELEVATOR
WET BIN
"WHITE" PAN
DRYER
Warm Air
DRY BIN
FILLMASS STORAGE
BAG
SCALE
CENTRIFUGE **9**
Sugar
MELTER
INTERMEDIATE VACUUM PAN SUPPLY
RAW VACUUM PAN SUPPLY
INTERMEDIATE PAN
RAW PAN
FILLMASS STORAGE
CENTRIFUGE
CRYSTALLIZER **10**
FILLMASS STORAGE
CENTRIFUGE
Sugar
Molasses to Storage Tank

5 Impurities after the first carbonation treatment are removed on a continuous drum filter. The mud goes to waste and the filtrate returns to the first carbonation tank

9 Following the graining operation in the "white" vacuum pan, the fillmass passes to centrifugals where crystals are separated

10 Following a single calandria raw pan are two Lafeuille crystallizers. The recovered sugar goes to a melter and then returns to the white pan