Fortune

One Dollar a Copy

DECEMBER 1937

Ten Dollars a Year

SULFUR IS A BASIC MATERIAL OF CHEMICAL INDUSTRY

. . . along with salt, limestone, and coal. Here are uncounted tons of it, better than 99 per cent pure. It has been mined from beneath more than 500 feet of quicksand and rock on the Louisiana coast—which sounds difficult but has been extremely easy ever since Chemist Herman Frasch thought of the perfect way to do it forty-six years ago. Three concentric pipes pierce the quicksands to the underlying sulfur. One pipe carries hot water, which melts it; another carries compressed air to blow it out; the third carries the sulfur to the surface. Here you see it, as painted for FORTUNE by Eminent American Artist Charles Burchfield, standing in the great, glistening, yellow monuments that are left after the sulfur has cooled and hardened, and the wooden bins have been knocked away. The sulfur has been molded in these setback steps so that great man-crushing chunks will be less likely to break off. FORTUNE calls sulfur *sulfur* because the American Chemical Society has ruled that *sulphur* is an archaic spelling.

Chemical Industry: I

It is perhaps the most progressive industry alive. It lowers prices, but has few market wars. Bankers never heard of it until the World War, when it was a hundred and twenty-three years old. Three companies account for about two-thirds of its assets, although hundreds of companies make it up. It sells acids, alkalies, ammonia, and diphenylparaphenylenediamine—and if you don't see what you want, ask for it.

FROM his laboratory in Dayton, Ohio, Thomas Midgley Jr. one morning a few years ago telephoned to Detroit to talk to his intimate scientific and personal friend, Charles Franklin Kettering. They chatted for a moment about minor matters and then, according to the recollection that Mr. Midgley later had good reason to write down, Mr. Kettering said: "Midge, I was talking to Lester Keilholtz last night and we came to the conclusion that the refrigeration industry needs a new refrigerant if it ever expects to get anywhere. So I told Lester that I would call you and have you see him to talk it over. He is leaving for Dayton tonight."

Duly the next day Mr. Keilholtz arrived at Dayton, and he and Mr. Midgley sat down together. Mr. Keilholtz was then chief engineer of Frigidaire; Mr. Midgley was the brilliant chemist chiefly responsible for discovering why automobile engines knocked, and then developing a substance—tetraethyl lead—that would stop them from doing it. Now Mr. Keilholtz wanted Mr. Midgley to try his hand at creating another new substance: a liquid whose boiling point would be well below the freezing point of water—and which would therefore be a refrigerant—but which would be nontoxic and noninflammable.

Awkwardly enough, the refrigeration industry possessed no such thing. Its two best bets for use in its domestic refrigerators were sulfur dioxide and methyl chloride. Both substances were toxic; one was inflammable. Particularly with air conditioning just around the corner, the refrigeration industry stood in urgent need of a technological improvement.

Mr. Midgley listened and was dubious. He doubted that any one substance could be found that would be nontoxic and noninflammable, and still be obliging enough to boil between 0° and -40° Centigrade—the essential range. Nevertheless, he left Mr. Keilholtz and went to lunch with two laboratory associates. They discussed the possibilities, and after lunch the three of them went to work—not in the laboratory, as you might expect, but in the library. What volatile but stable (nondecomposing) organic compounds might they discover in the International Critical Tables—tabulations of melting and boiling points and other properties—that they could hope to synthesize without too much trouble?

The small size of chemical industry conceals its vast importance, whether in peace or in war. For its importance, definition, and characteristics see:

The most helpful thing that Midgley and his associates found in the International Critical Tables was a mistake. The tables listed carbon tetrafluoride as boiling at -15° Centigrade, and there were good reasons for thinking that this was wrong, as it later proved to be. But that started Midgley thinking about the organic compounds of fluorine, despite the fact that fluorine is a gas belonging in the same family with chlorine, and even more toxic than chlorine. Discarding the Critical Tables as too incomplete for his purposes, Midgley turned now to a table of elements arranged according to Nobel Prizeman Irving Langmuir's theories of atomic structure. Could volatility be related to this table in some way? It could indeed; the elements on the right-hand side of the table were the only ones known to make sufficiently volatile compounds. Of these dozen or more Midgley now ruled out every element that the Critical Tables told him made unstable compounds. He was left with eight possible elements—and it suddenly dawned upon him that all the refrigerants known so far were made from among those elements. But there was one element, and only one, that had never been so used. It was fluorine. He ran his finger up a column of elements, and noted that in general toxicity decreased from bottom to top. Then he ran his finger from left to right across a row, and observed that inflammability decreased. And where his lines met, there, once again, stood the element fluorine.

"It was" said Midgley himself, "an exciting deduction. Seemingly, no one had considered it possible that fluorine might be nontoxic in some of its compounds . . . If the problem before us were solvable by the use of a single compound, then that compound would certainly contain fluorine." Still working in the library, the Midgley team decided to synthesize a product containing fluorine, which was said to boil at -20° Centigrade, but whose other properties were entirely unknown. Its name was dichlorodifluoromethane.

Starting with antimony trifluoride, it wasn't hard to make. But the antimony trifluoride, being a specialty chemical in no demand whatever, was hard to come by. Midgley corralled five one-ounce bottles of it; so far as he knows, that was all the antimony trifluoride in the whole U.S. From one bottle they made a few grams of dichlorodifluoromethane—a water-clear liquid. They put a teaspoonful, furiously boiling at room temperature, under a bell jar with a guinea pig, while a physician watched earnestly for symptoms of the guinea pig's collapse. There were none. The guinea pig breathed dichlorodifluoromethane with equanimity and unconcern, and the predictions of the Midgley team were triumphantly fulfilled. The job had taken three days!

Big, bespectacled, jovial Chemist Midgley got the Perkin Medal this year—next to a Nobel prize, the most resounding acclaim a U.S. chemist can receive. Chemist Midgley has a sound instinct for the dramatic; and in the course of making his acceptance address he demonstrated the qualities of his new substance by personal experiment. He drew in a lungful of the

Paul Meltsner

FROM COAL: COKE, GAS, AMMONIA, FERTILIZERS, ALCOHOLS, DYES, MEDICINES BY THE UNCOUNTABLE THOUSANDS

warmed gas as casually as he draws in tobacco smoke, held his breath for a moment, and then blew it softly through a rubber hose into a beaker in which stood a lighted candle. The candle flame wavered and went out.

Nontoxic, noninflammable, dichlorodifluoromethane is, to all intents and purposes, something new in man's world. It existed before Midgley, but only because someone, somewhere, had once happened to synthesize it. Its use was unknown; its very existence obscure. Its utility to the refrigeration industry would never have become known were it not for the fact that, Anno Domini 1937, the chemist is in possession of something that has been tagged with the momentous phrase "a technique of discovery."

But there is another aspect to dichlorodifluoromethane. It represents an industry. This previously unknown material and its chemical cousins are now tonnage chemicals. Hundreds of thousands of refrigerators were supplied with them this year, and since each refrigerator requires from two to four pounds, hundreds of tons have rolled out in tank cars from the plant of Kinetic Chemicals, Inc. (a du Pont and General Motors jointly owned subsidiary) during 1937. Dichlorodifluoromethane manufacture has called for other chemicals like carbon tetrachloride and has provoked a new activity in the mining of fluor spar for its fluorine in Kentucky and Illinois.

WE MAY, then, take Mr. Midgley as a token of the strange industry with which this article is concerned. It is a small industry, made up of three dominant companies (du Pont, Allied Chemical & Dye, Union Carbide & Carbon), plus some fifty smaller companies listed on the Big Board or the Curb (Dow and Monsanto are typical among such companies), plus hundreds of still smaller ones. The total value of the products of all is, perhaps, $700,000,000 a year. As industries go, it is extremely new. It is as broad in its scope as it is difficult to define. For want of a better term, we may call it chemical industry. Its activities, obscure to the layman, can best be expressed by saying that it is engaged in making something into something else—not by altering shapes and sizes visible to the eye but by working with the unseen and unseeable building materials of the chemist: atoms and molecules. Working principally with its two great weapons of heat and pressure, it busies itself with making things that are new, things that are cheaper, things to make other things, things that the eye of the ultimate consumer seldom if ever falls upon. Chemical industry is not concerned with a great many things that the U.S. public and the U.S. Government think it is: chemical industry does not mean writing ink, fireworks, candles, or mucilage—although all of these things are essentially chemical products. If we are to define chemical industry, then, we had best go back for a moment to the man who in truth began it, although his aim was notably less.

The man who began it was the Frenchman Nicolas Leblanc—and the year of his achievement was 1791. Nicolas Leblanc was not trying to make history. He was just trying to make a little money. French glass factories, then as now preëminent, had been accustomed to get their essential supplies of alkali from Spain—where the Spaniards burned seaweed to get ashes and took barilla (the alkali, sodium carbonate) from them. But the British armies had cut France off from this supply, and it was primarily to aid the glassmakers that Leblanc began hunting for some means of making a cheap alkali, independent of Spain or the hindrance of the British.

To this activity he had been spurred by a prize of 12,000 francs offered by the French Academy for a process by which soda could be made from salt. By what prescience the Academy had decided that the one might conceivably be made from the other is unknown, for the element sodium, common to salt and soda, was yet to be discovered. But if the Academy stabbed in the dark it stabbed in precisely the right place, and Leblanc, starting to work in 1784, had the answer three years later. He treated salt with sulfuric acid, and thus made "salt cake," or sodium sulfate. He roasted the salt cake with charcoal and chalk. Thus he got "black ash," from which he could dissolve out and crystallize sodium carbonate. Once Leblanc had done it, it was as simple as that.

NOW between what Leblanc did and what other men had previously done with *chemical* materials, there should be made an immediate and sharp distinction. There were earlier and greater chemists than Leblanc. Lavoisier, founder of modern chemistry, was famous enough in 1794 to be guillotined; the great Henry Cavendish and the great Joseph Priestley were roughly Leblanc's contemporaries, and ten times more learned than Nicolas Leblanc. Moreover, the activities of the common man had involved chemical processes like leather tanning, dyeing, distilling, glassmaking, for so long that pedants can wander in Phoenicia or Egypt or China ("the Chinese invented gunpowder") to their hearts' content and find the beginnings of this sort of "industrial chemistry" wherever it pleases them.

But what Leblanc did was different from all this. For a practical end, with deliberate intention, and by scientific means as he knew them, he set out to make something into something else, with his eye not only on chemistry but on economics. He was the first person on record to do any such thing. Upon that, as a distinction, rests his unjustly faded and obscure historical fame—and upon that, as a definition, rests the entire structure of modern chemical industry. With endless improvements, refinements, ramifications, and complexities added, the chemical industry continues its deliberate and calculated course of making something into something else.

If Leblanc had not committed suicide because the French Revolution cost him his plant and process, he might have seen that course begin. A prime peculiarity of chemical industry is that you seldom accomplish one thing at a time; your accomplishments take place two, five, or seventeen at once. Leblanc produced his cheap alkali primarily for the benefit, so he thought, of French glass. But as a result there soon began to grow an entire new industry, which was now enabled by cheap alkali to find a wider and wider market for something that had been, in Leblanc's day, a product of luxurious scarcity. The product was soap, out of which was to flower a new society, a new domestic economy, a new conception in medicine—personal hygiene. Further, the large-scale manufacture of soda by Leblanc's process gave the rapidly mechanizing textile industry a new and cheaper means of whitening its great new output of cloth without sunshine. It was typical of chemical industry then and now that Leblanc's discovery upset the economics of perfume and incense making, and of any other business that prospered because of the lack of soap. It was even more typical that Leblanc's revolutionary process was, before long, flung on the rubbish pile and utterly forgotten; a new and better process for cheap alkali arose to take its place. Most typical of all, chemical industry is today working toward "soapless soaps," which require no alkali to make. The segment of chemical industry represented by this cycle of change is small, but it is extremely characteristic.

THE processes of modern chemical industry are as many and varied as the products they produce. About the processes it is important to remember that the method made famous by the late Thomas Alva Edison—which consisted of trying everything

E. I. DU PONT DE NEMOURS & CO.

100 shares Dec. 31, '24 = $13,925 = 980 shares Dec. 31, '36 = $170,520 = $115,248 Oct. 19, '37

CHEMICALLY

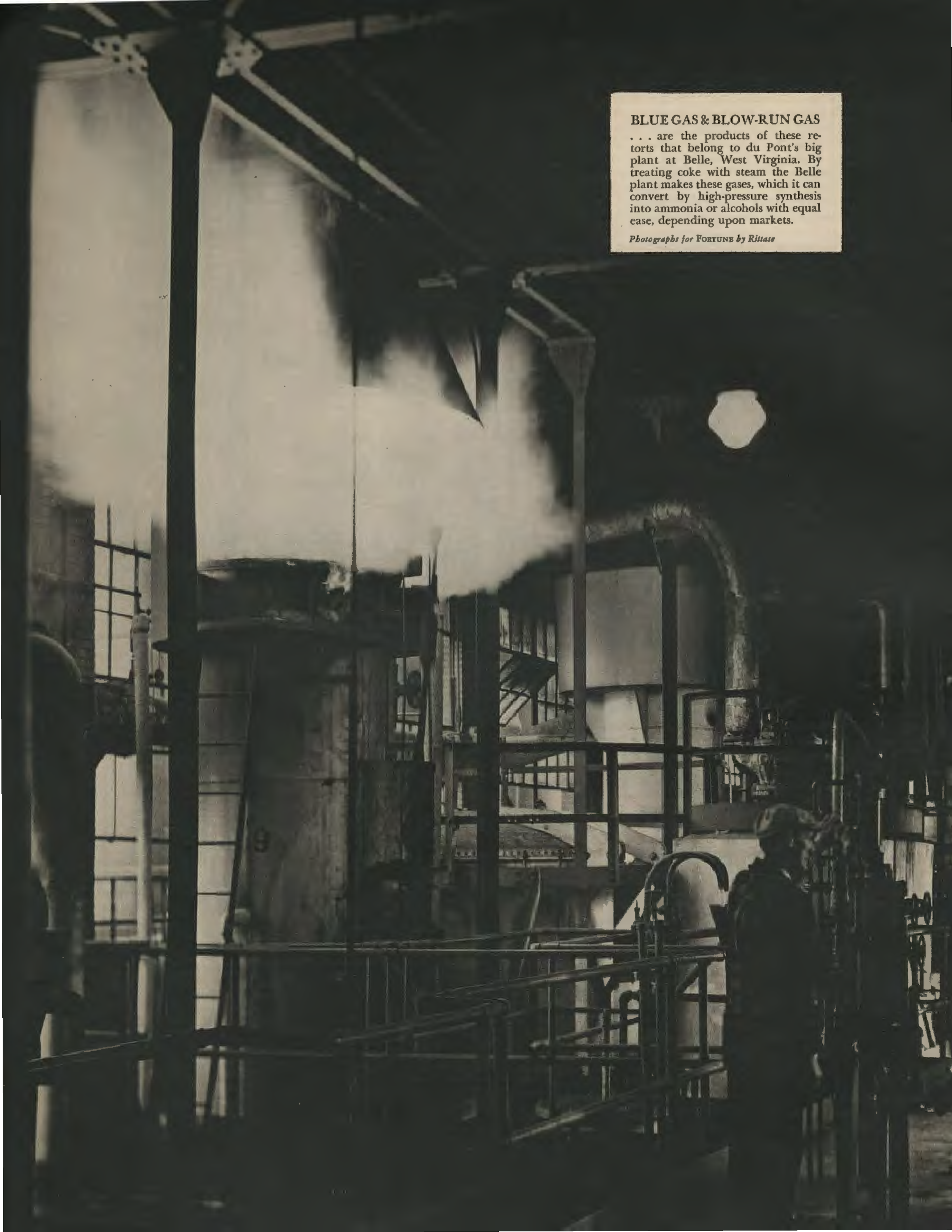
... biggest show in the U.S. Products ranked in order of importance to du Pont: *Fabrics and Finishes*—pyroxylin, paints, varnishes, coated fabrics; *Synthetic Organic Chemicals*—dyestuffs, tetraethyl lead, ethyl alcohol, etc.; *Rayon; Inorganic Heavy Chemicals*—acids, zinc and zinc products, insecticides; *Commercial Explosives; Cellophane*—cellulose film, caps and bands, sponges; so-called *Special Chemicals*—electrochemicals, chlorinated solvents, ceramic colors, specialties; *Plastics; Pigments; Ammonia*—products of, plus methanol, higher alcohols, urea; *Sporting and Military Powders*. If you're chemically wise that list is revealing, for du Pont ranks its *Ammonia* tenth in intracorporate importance whereas in the industry it is no lower than second and may be first. All this came from five generations of prolific du Ponts and a powder plant; shows clearly the conglomeration an imaginative chemist gets into. Research: preëminent, doubtless tops as to dollars spent; considered extravagant by some. Very wieldy regardless of size. Extremely aggressive. Many du Pont salesmen are chemists who tackle nearly any problem chemically, achieve some striking results, get and keep some potent accounts. *CUSTOMERS:* like other chemicals, du Pont sells to industries once or more times removed from the individual consumer, but unlike them du Pont gets some public recognition because of lavish institutional advertising. Munitions sales average only 1 per cent of total.

FINANCIALLY

... stronger than Gibraltar under present-day conditions. Du Pont, however, is no mere chemical even if it is biggest in U.S. Nearly half of its earnings since 1925 have come from a neat General Motors investment made in 1917 from War profits. G. M. holdings now total 10,000,000 (about nine-tenths G. M. share to one share du Pont common); carried at $18.45 each—market value October 19, 1937, 38¼; 1937 high = 70½. Which gives a rough idea of how du Pont values assets, reports its business. Big and strong, du Pont is on the frank side about finances: gross sales in 1936—$260,300,000, 18 per cent over 1935, 7 per cent above 1929. This year's first nine months show sales zooming, but profits crawling owing to $7,000,000 less from Motors. Management: one of the shrewdest in U.S. industry. Depression depth—1932, earnings $26,235,000, one-third of 1929's $78,000,000 plus. Biggest du Pont year: 1936; net profit: a hair under $90,000,000. In July the company sold 500,000 shares of $4.50 preferred through Morgan, Stanley for $48,750,000 to replace cash used in expansion—which never stops. That issue undoubtedly plumped into the lock-boxes of the shrewdest investors—with the more than a million $6 debenture shares that were one of the sweetest income propositions on any list but expensive now. Statistically du Pont is not exciting, it is breathtaking—as see below.

Earned since 1925	$627,174,000
Dividends since 1925	$555,224,000
Shares of common	11,065,762
$6 debenture shares	1,092,948
$4.50 preferred shares	500,000
Assets (net) June, 1937	$644,811,000
Common dividend, 1936	$6.10
1936 sales common, N. Y. S. E.	520,300
High 1937—180⅛; Low—113⅝ (Oct. 19)	
Net earnings, 1936	$89,884,000
Earned per share, 1936	$7.53
Undistributed-profits tax	$2,148,000
Return on av. inv. capital 1936	16.6%
Earned surplus June 30, 1937	$240,927,000
Property account (net) June 30, 1937	$237,894,000

For some reason du Pont states intangibles at $29,926,000, which, considering the job they have done, can be forgiven, believed, for if the Messrs. du Pont say intangibles are worth nearly $30,000,000—they *are* worth nearly thirty million dollars.



BLUE GAS & BLOW-RUN GAS

. . . are the products of these retorts that belong to du Pont's big plant at Belle, West Virginia. By treating coke with steam the Belle plant makes these gases, which it can convert by high-pressure synthesis into ammonia or alcohols with equal ease, depending upon markets.

Photographs for FORTUNE *by Rittase*

conceivable by the imagination—has been supplanted by the approach that we observed in watching Mr. Midgley: mathematical and deliberate. Of the product, you should remember that you seldom perceive it, of and by itself, with any of your senses (unless it is a drug), for it is either deeply concealed in something familiar, or it has died in giving birth to something else. The chances are against your awareness of diphenylparaphenylenediamine. Yet if you knew where, in your everyday life, to look for it, you would there also discover paraisopropoxydiphenylamine and perhaps also tetramethylthiuramdisulfide. All three of them may be in your automobile tires, as curing or accelerating or antioxidizing agents. You have already discovered the sizable amount of dichlorodifluoromethane that may be in your kitchen. If your wife has a wool garment of a lovely golden orange hue, it may have been helped to take its color by 4,4'-dimethylaminobenzophenonimid. But if you ever feel the need for 3,4-dihydroxyphenylmethylaminomethylenecarbinol hydrochloride you need only go to your neighborhood druggist and ask him. He would supply you with adrenalin.

But no matter how fantastic the names get—and they are practical, systematic descriptions, not abracadabra—it is important to remember that practically everything in chemical industry springs from four utterly simple raw materials: coal, sulfur, limestone, and salt—plus that relative newcomer, petroleum, and the celebrated "free goods" of the economist, air and water. From these raw materials the first products that chemical industry manufactures are "heavy" acids (sulfuric, nitric, hydrochloric); alkalies (soda ash, caustic soda); multitudes of products of coal tar; commercial gases (hydrogen, chlorine)—plus such basic materials as ammonia, industrial alcohols, and solvents. You could without trouble multiply this list by two or three, but among the so-called heavy chemicals these are the heaviest, the most basic, the most fundamental to the art of living in the world that the chemist has created.

AND chemical industry can best be defined as the highly imaginative and creative industry that makes these fundamentals, and a relatively few others like them, and then combines and recombines them into permutations and combinations of substances that are new and needed. It is an industry born of chemistry *and* economics. Its head may be in the stars but its feet are firmly set upon the practicalities of money-making business. To the practitioners of chemical industry, the world is still an extremely empty world. There are old needs, to be better met than by existing materials. There are new needs, which may be yet unsuspected but which will become urgent and vital if a new product comes into being to fulfill them. Unlike the economist, the banker, or the politician, the chemist knows where he is going. One of his aims is to synthesize better and cheaper products than the empirical "dump and mix" manufacturing of the past. But another is to synthesize better and cheaper products than the products of nature herself. If this is audacious, the chemist is quite able to reply that he is already doing just this thing with scores and scores of products.

Thus the industry that the synthetic chemist serves is not just a process industry, and our definition must rule such industries out of consideration in this article. They may be small, like candles and fireworks, or they may be huge, like the textile-processing industry, or the industries of pulp and paper, leather, glass, rubber, paint and varnish. But they are all alike in that chemistry and chemicals are to them not an end but only a means. Similarly the metallurgical industries, including iron and steel, fall outside our definition: like the process industries, they are not followers of Leblanc. For Leblanc was not trying to make glass or soap. But he did make cheaper glass and cheaper soap *possible*. With this criterion of chemical industry well in mind, we can now proceed to a check list of the industry's most outstanding characteristics.

FIRST characteristic of the industry is its extreme youth. Leblanc's discovery and the beginnings of the Industrial Revolution both occurred during the last half of the eighteenth century. That would seem to make the chemical industry no younger than any other sort of industry. But whereas the entrepreneurs of the eighteenth and nineteenth centuries instantly grasped the significance of the steam engine and the power loom, they did *not* grasp the significance of chemical industry. Consequently, chemical industry remained in a world apart. It grew, and it served other industries, without attracting either their notice or the notice of financiers. Calls for more and more of Leblanc's alkali led to calls for more and more sulfuric acid with which to make it. Then came an alkali process—the Solvay process—better than Leblanc's, but one that called for quantities of ammonia, instead of acid. From that grew the increasing importance of the byproduct coke oven that supplied the ammonia. By such means, chemical industry put on weight and stature throughout the nineteenth century—but so quietly that the outside world never knew it was there. A seventeen-year-old boy, who was to become the famous Sir William Perkin, in 1856 made the world's first synthetic dye, using coal tar that was the refuse of gasworks—and the entrepreneurs of mid-nineteenth-century England passed by the significance of what he had done with a total lack of comprehension. (Not so the Germans; Germany saw the vastness that lay in this new synthetic chemistry, and her early

ALLIED CHEMICAL & DYE CORP.

100 com. shares Dec. 31, '24 = $8,875 = 110¼ shares Dec. 31, '36 = $25,220 = $17,144 Oct. 19, '37

CHEMICALLY

. . . basic: largest factor in heavy chemicals. Probably produces better than one-third of domestic alkali requirements. Leading manufacturer of acids (especially sulfuric), ammonia, dyestuffs, and coal-tar distillates. Makes chlorine, and many another important chemical vital to the chemical process industries. Has $50,000,000 plant at Hopewell, Virginia, for the fixation of atmospheric nitrogen. Is said never to have been used to capacity. Hence Hopewell is potentially important—if it isn't a white elephant. Research: only fair compared to du Pont or Carbide. *CUSTOMERS:* Other manufacturers, particularly chemical processors. Glass, soap, textile, leather, fertilizer, and petroleum are heavy buyers; also motorcar, metal, paper and pulp, agricultural industries.

FINANCIALLY

. . . Allied was born big in 1920 via mergers. Stays big. Extremely secretive; President H. F. Atherton's 1936 letter to shareholders used 281 words including salutation, signature, and date, which might have seemed verbose to former Chairman (but still guiding light) Orlando F. Weber. A vigilant defender of the American chemical industry, and itself, against foreign invasion. Biggest Allied secret was financial, not chemical—the make-up of its marketable security account, which averaged (1929-34) $93,075,000. Today, owing to N. Y. S. E. and SEC clamorings, Allied has revealed holdings of U.S. Steel and Air Reduction stocks at a cost of $22,839,000—worth $38,532,000 December 31, 1936, $28,761,000 October 19, 1937. A "sundry" investment account of $28,800,000 is still needles and thread to outsiders. Management: extremely conservative, sound—stuffy to those who would know all. But Allied earns money monotonously—an average of $21,753,000 annually since 1925 (high $30,200,000 in 1929; low $11,400,000 in 1932)—pays whacking dividends (didn't cut during depression), prospers. Last year Allied retired its remaining preferred—about $47,300,000 including the premium—from its current position without batting an eye. Depreciation policy: ruthless. Last year's tonnage: record; dollar volume: under 1929 only; prices to customers on major products down about 25 per cent since 1929. But like most chemicals, Allied does not state its sales or cost of sales. Only a general depression hurts, and that not cruelly; it curtails, does not suspend profits.

Dividends since organization	$228,509,000
Earned since 1925	$261,032,000
Dividends since 1925	$182,978,000
Shares of common	2,401,288
Shares in treasury	187,189
Authorized (all no par)	3,143,455
Div. per share 1936	$6
1936 sales, N.Y.S.E.	259,500
High 1937—258½; Low—150 (Oct. 19)	
Net earnings, 1936	$25,324,000

Dividends, 1936	$13,285,000
Earned per share, 1936	$11.44
Undistributed-profits tax	$265,800
Return on av. inv. capital 1936	13.89%
Equity per share	$67.68
Surplus, end of 1936	$170,111,000
Property account (net) 1920	$86,858,000
Ditto, 1936	$76,609,372

SULFUR IS A NUISANCE

. . . as well as an essential to chemical industry. All this equipment is necessary in du Pont's plant at Belle to remove sulfur that would *contaminate the gases used as described on the* previous picture page. But this nuisance-sulfur is not wasted; du Pont resells it to one of its subsidiaries that makes sulfuric acid.

twentieth-century chemical preëminence was based upon it.)

In the U.S. the production and consumption of basic heavy chemicals went forward by slow increases—but chemical industry remained outside the haughty purview of the Empire Builders, the Robber Barons, the Merchant Princes. It remained in the hands of men who had started little plants to make products that industry needed, but that no one knew anything about. But with the World War the U.S. was suddenly thrust upon its own resources for the production of dyes and medicinal products that it had always imported from Germany. Only ignorance can say that munitions requirements were the means to chemical industry's growth, but it is nevertheless true that the War finally brought U.S. chemical industry to its maturity. And when Francis P. Garvan as Alien Property Custodian seized the German chemical patents in this country and turned them over to the Chemical Foundation, which had been created to receive them, the U.S. began for the first time an independent chemical life. Then, and thenafter, the bankers, the entrepreneur class, heard of chemical industry for the first time: in January, 1920, for example, such companies as du Pont, Union Carbide, Allied Chemical & Dye, Monsanto, Dow, etc., were yet to be listed upon the New York Stock Exchange. Previous to that chemists had not needed bankers. The expansion of chemical industry was slow enough to be financed out of earnings. And bankers had barely heard of chemists. *Chemically*, then, chemical industry dates from Leblanc and 1791; *industrially*, chemical industry was recognized only after the World War.

Its youth and its upbringing lend to chemical industry its second characteristic: it is as progressive an industry as it is possible to imagine. It is constantly questioning its own fundamentals. The industry's patriarchal chemical is sulfuric acid, which, one way or another, enters into product after product that the industry turns out. During the last few years, however, processes as different as petroleum refining and fertilizer production have been finding ways to get along with less and less sulfuric acid, and the all-time peak of its production has thus, perhaps, been passed forever. But the industry sheds no tears. After all, it makes its own acid; if it can do with less it has made an economy. The industry never holds on to an old product or an old process when it can find new ones; its orientation, in the nature of things, is entirely forward. Fortunately for it, its plants are flexible—an ammonia plant, for example, can be made into an alcohol plant almost overnight (page 170).

YOU might say that the industry is *bound* to be progressive: either it is progressive or it is nonexistent. With a similar urgency behind it, the chemical industry is efficient. To make a pound of soda, selling for one cent, the Solvay Process Co. must use two cents' worth of ammonia. Nevertheless, Solvay sells its soda at a good round profit. The answer of course is that practically every drop of ammonia must be recovered, saved, and recirculated, process without end. Written over the portals of the industry is the warning, "Save or die!"—and the chemical industry wastes so little that the packer's utilization of the pig is by comparison a prodigal's job.

But that is efficiency largely in terms of good engineering and good plant practice. The industry is efficient in other ways. It is, for example, entirely scientific in its approach, whether its approach is to chemistry or to marketing. Again and again, the chemical industry develops a new product, whose name is unknown, whose performance must be taken on faith, and must at the same time develop markets where none exist. Ethylene glycol was just ethylene glycol until Carbide developed it, *and a market for it*, as a radiator antifreeze called Prestone.

One reason for this efficiency and progressiveness is that the industry has, for its whole life, been interwoven, intermatted, interlinked with science. No other one industry has such a training ground as the chemical industry has in the laboratories and classrooms of this country's universities. Unlike the railroaders or the men in iron and steel, the men in chemical industry have been rigorously trained for their careers by the most intensive sort of scientific education. The habits and practices of the chemical industry put the word "research" into the spoken language. And it is not merely the technical staffs where the trained men are. J. G. Davidson, Vice President in charge of sales for Union Carbide's Carbide & Carbon Chemicals subsidiary, is a Ph.D. in organic chemistry. Elon Hooker, President of Hooker Electrochemical, is the holder of an earned doctor's degree. Since the 1880's young du Ponts have worn a deep path between Wilmington and Massachusetts Tech in Cambridge. And in a chemical plant, if you are not the holder of a college degree you are likely to be a janitor.

The efficiency of the chemical industry goes one step further and takes the form of a considerable economic enlightenment. The industry faces an unexampled obsolescence in plant and equipment. It meets this not only with a ruthless accountant's pencil but by a ruthless scrapping of equipment or process as soon as it begins to falter. But it is in questions of price policy and structure that the most interesting examples of economic policy in an industry make themselves felt.

UNION CARBIDE & CARBON CORP.

100 com. shares Dec. 31, '24 = $6,537 = 300 shares Dec. 31, '36 = $31,125 = $21,450 Oct. 19, '37

CHEMICALLY

. . . four general divisions: *Electrodes, Carbons, and Batteries; Calcium Carbide and Gases; Alloys and Metals; Synthetic Organic Chemicals.* In the 1936 report a list of products jammed fourteen pages of a dry brochure, compared to five pages of an equally dry one in 1929. Carbide's greatness is due primarily to the electric furnace, born of the carbon arc, with which it has a "partial skill monopoly." From the furnace comes calcium carbide; hence acetylene (Prest-O-Lite), once only an illuminant, now, with oxygen, a whole system of gas welding. From the furnace developed *Alloys and Metals:* chromium, tungsten, vanadium; also Haynes Stellite, a nonferrous metal alloy with nearly diamond hardness at red heat, used in tool steel, oil-well drills. From carbon come flashlight and radio batteries, millions of motor brushes, carbon electrodes, etc. New, with a great speculative kick, are *Synthetic Organics.* Carbide & Carbon Chemicals, Inc.—subsidiary—is a leader in high-pressure synthesis, from which it makes wood alcohol (methanol) that never saw wood. Also, Carbide makes commercial ethyl alcohol—"grain alcohol"—not from products like grain or molasses but by hydrating ethylene—a product of petroleum distillation. And countless other organics which can well change the natural state of the world as new uses appear. Plastics for Victrola records, toothbrushes, dentures, or what have you to replace? Antifreezes (Prestone, derived from same foundation as mustard gas), rust inhibitors, carbon dioxide for Dry Ice, Pyrofax gas, even gasoline (natural gas or casing-head gasoline), sold in bulk to oil companies, come from Carbide's Synthetic Division. Plants—164; sales offices—92; warehouse stocks—1,113; this in the U.S. and Canada; more abroad. Research: preëminent. *CUSTOMERS:* steel, petroleum, marine, motor-car, aeronautical, railroad, electrical, textile, lacquer, pharmaceutical, paper, photographic, explosives, and scores of subdivisions of these and other industries.

FINANCIALLY

. . . pure as Ivory Soap. Even 1917 merger was without stock fees for promotion or services, making Carbide lonely in merged company. Carbide is the result of internal growing pains, acquisition, and merger. And for that reason alone it is very unusual. Patents and good will: $1. Depreciation: all the traffic will bear. Expansion: good times and bad. 1925 property account: $158,000,000; in 1936 $250,000,000 after 1931's vicious write-down. Earnings: two hairs under du Pont without General Motors. Smart, young mentally, hard hitting, candid, racing—yet under control. Perfect dividend record. No preferred stock.

Dividends since 1917	$281,234,000
Earned since 1925	$288,918,000
Dividends since 1925	$198,996,000
Shares of common 1936	9,000,743
Shareholders 1936	55,705
1936 sales, N. Y. S. E.	896,000
High 1937—111; Low—67 (Oct. 19)	
Cash and equivalent to funded debt 1936	166.95%
Funded debt end of 1936	$21,125,000
Net earnings, 1936	$36,852,000
Dividends, 1936	$23,402,000
Times fixed charges earned 1936	43.4
Earned per share 1936	$4.09
Return on av. inv. cap. 1936	14.1%
Funded debt to inv. cap. 1936	7.9%
Equity per share 1936	$27.41

Since 1925 Carbide has paid $90,561,000 to surplus from net earnings, more than du Pont or Allied, the other two of the Big Three chemicals, less, percentagewise, than smart little Monsanto, American Cyanamid, or Dow. But enough. Has only funded debt of any size in Big Three—considering earnings it doesn't amount to much.

The chemical industry was born reaching out for lower prices: Leblanc was hunting for a *cheap* alkali. This is more than a symbol of chemical industry; it is an unalterable birthmark. The people of Leblanc's day needed more soda; they didn't know it, but they did. Therefore make it cheaper, and you could sell more of it—lots more of it. Looked at in this sense, every success of industrial chemistry is a success of economics as much as a success of test-tube science. Just as the man in the street did not know in 1784 that he needed soda, so the man in the street today is unaware of his need for iso-octane. Yet he may come to need it very badly, for it is already an internal-combustion engine fuel of a greater efficiency than the highest-grade gasolines—and is consequently a vivid new possibility facing aviation engineers. Moreover, chemical industry is itching to get prices down enough so that some day iso-octane can enter the automobile market.

The very necessity that the chemical industry is under of developing new products and new markets at the same time is at once its greatest challenge and greatest asset. The laboratory has always known how to make a new product months or years before the plant could make it; but before the plant could match the laboratory *and* create effective demand, it had to hammer its costs down to a point where the price made sense in a practical world. Aluminum's advantages of lightness, luster, electrical conductivity, and resistance to corrosion had been known for years before there came along a young man named Charles Martin Hall. But aluminum's attractions, before Hall devised an electrolytic process to win it from its ore, were only tantalizing—for aluminum cost $12 a pound. It now averages twenty-one and a half cents.

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AUTOMATIC CONTROL

. . . is the *sine qua non* of modern chemical industry. Pressures, temperatures, concentrations, rates of flow—all these are recorded on dials or traced on paper while junior engineers stand watch and scribble in their logbooks.

AMERICAN CYANAMID CO.

100 shares Dec. 31, '24 = $10,250 = 100 shares A, 400 B Dec. 31, '36 = $80,150 = $12,074 Oct. 19, '37

CHEMICALLY

. . . fourth largest; not a very good fourth, but heading the so-called little fellows. In 1909 Cyanamid was hot stuff with the only nitrogen-fixation process worth much. But it remained a simple fertilizer and mining chemical company. Principal product: calcium cyanamide, made by blowing nitrogen through white-hot calcium carbide. Crushed, it was fertilizer (75 per cent of Cyanamid's business); and the cyanamide could readily become cyanide (the rest of the business) used in modern metal refining processes. The Haber process of nitrogen fixation left Cyanamid on its heels, where it stayed until 1927. Then, by acquisition and merger, Cyanamid really got into chemicals. Fertilizer is now a slim 10 per cent, but important because of concentrated plant foods (ammonium potassium phosphate); mining chemicals about 15 per cent. Cyanamid has developed quite a stable: it makes beetleware and other plastics, dyestuffs, pharmaceuticals, explosives, gypsum, insecticides, rubber chemicals, alkalis, heavy acids. It owns big bauxite deposits from which comes sulfate of aluminum, no metal. Cyanamid even goes in for biological products. The company is more exciting chemically today than it has been for years—it has an up-boys-and-at-'em attitude (required in this industry) *and* a very keen interest in resins from phthalic anhydride that are currently bedeviling the older lacquers like Duco—which puts Cyanamid on the other side of the fence after all those years (1909-27) of tagging along. Cyanamid is unique not only in having made a chemical comeback, it is unique because its President, William B. Bell, is a lawyer.

FINANCIALLY

. . . after being for long like a gentleman who has honorably paid all his debts only to find himself seedy, American Cyanamid now has a new overcoat, hat, shoes; smokes fifty-cent cigars. Reason: the miscellany that came in with fertilizer starting with 1927 and then claimed it was a merged chemical when Wall Street specialized in fancy mergers or inverted pyramids, now seems to be running as a cohesive whole—to the surprise of the Street, American Cyanamid's shareholders. Those shareholders know what a beating is, also some of the hazards of chemical investments. (And there are hazards. Do not be fooled by those miracles the Big Three have wrought!) In the flush days Cyanamid sold some $39,000,000 in common stock to finance additions; waterlogged in 1931, the shareholders were asked to cut the par value of their shares in half; they did, wiped off virtually all of the new money. Management, therefore: realists. Shareholders: lambs. Then Cyanamid dug in, showed no red figures (minuscule black ones), whanged away at research, took the normal, violent depreciation charges, paid no dividends (1931-33), emerged in 1933 with a $2,500,000 profit for a change. In 1934 it paid a token dividend of twenty-five cents, got back to $1 in 1936, currently paid $1 extra. Today this stalwart old-new chemical is pretty pleased with itself and chemistry. Small funded debt.

Dividends since 1926	$11,865,000
Earned since 1926	$25,783,000
A voting shares, 1936	65,943
B shares, 1936	2,454,425
Div. per share, 1936	$1
1936 sales, N. Y. C. E.	628,750
High (B) 1937—37; low—17⅝ (Oct. 19)	
Net earnings, 1936	$4,455,000

Earned per share '36 A and B	$1.77
Return on av. inv. cap.—1936	9.45%
Equity per share (A and B)	$15.66
Earned surplus, 1936	$12,497,000
Property account (net) 1925	$4,609,000
Ditto, 1930	$42,535,000
Ditto, 1936	$24,101,000

matters, which are necessary subjects of discussion and coöperative action. For one example, safety measures. The safety record of the industry is good, and doubly so since its everyday life consists of making and handling corrosive, toxic, or explosive materials. Last year it was eleventh on the lists of the National Safety Council; a little less safe than glass manufacturing, a little more safe than building automobiles. For another example, the association discusses container and shipping problems. An ammonia manufacturer will be not only willing but anxious to discuss tank-car design with a chlorine producer to the end that a tank-car builder may build them cars so lined and valved and protected that both can use them.

Despite its coöperativeness the industry does not importantly play the lawyer's game of patent pooling—prime means by which the radio business, for example, has grown. The Chemical Foundation was in its early days a patent pool, but it is now largely a pool through which Francis P. Garvan supplied money for such research purposes as he liked to encourage. The petroleum refiners have a sizable pool of chemical patents, but except for this the chemical industry disports itself much more in a pool of professional information than in any other way. For any chemist of any pretensions whatever is a member of the largest learned society in the world devoted to a single science—the body of scientists, 20,000 strong, who make up the membership of the American Chemical Society.

TWICE a year, once in spring, once in fall, the American Chemical Society holds a national convention. A quarter of the society's entire membership has been known to show up for these learned picnics, but a typical turnout is between 3,000 and 3,500 members—which is small only if you think in terms of the American Legion; 3,000 chemists are an awful lot of chemists.

For its fall meeting this year the society went to Rochester, New York. And on the evening of the first day, at cocktail hour, the bar of the Hotel Seneca filled up with chemists bound on conviviality and the gay life. Everybody ordered a drink, and the bartenders glowed with that sort of anticipation which only a convention can create. But then, as they looked on in shocked and almost tearful surprise, the Manhattans grew warm and sirupy, and the highballs turned pale as the ice melted, and the chemists sat on and on, talking endlessly about their business. By the end of the evening the glasses were still half full on the tables, and hardly anyone had thought of calling for a second round. It is not that chemists take vows of abstinence—it is just that a chemist would rather talk chemistry with another chemist than do anything else he can think of.

These semi-annual meetings usually last a week, and in the course of their morning, afternoon, and evening sessions, the chemists will read one another anything from 400 to 600 scientific papers. (There may be as many as eighteen different subject divisions, all meeting separately.) But despite the learned atmosphere of the convention, the authors of these papers are likely to address scanty audiences—for chemists go to conventions more for intimate interchanges of information with their friends in corridors, bedrooms, and bars than to listen to formal presentations. Two or three men with problems in common may sit up swapping information until four in the morning—and when you multiply this sort of inter-

Chemical Industry: I

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change a thousandfold and more you find the true basis upon which chemical industry goes forward.

In the chemical firmament thus displayed, there are always a dozen or more men who shine the brightest. One such is Thomas Midgley Jr., whom we met at the beginning of this article. He is a Vice President of the Ethyl Gasoline Corp., but the chemists know him better as this year's Perkin Medalist and as the eminent Chairman of the Board of the American Chemical Society. He is a particularly glaring exception to the rule of the Ph.D. in chemical industry—for although he is *Doctor* Midgley by virtue of an honorary degree from Wooster College, he had no formal training in chemistry, graduated instead as a mechanical engineer from Cornell. But, say his friends, "Midge would still be a chemist if he'd been taught horseshoeing." Brilliant and dramatic, he is one speaker who talks always to full audiences. Despite his intimate connection with the internal-combustion engine, the performance of which he helped to revolutionize, he refuses to ride in an airplane.

WITH none of Midgley's drama or dash, Chemist Irving Langmuir, General Electric's No. 1 research man, is an equal drawing card as a speaker. But whereas a Midgley audience listens with fascination, a Langmuir audience listens with awe. The most honored and the most illustrious of all U.S. chemists, Irving Langmuir is quiet, precise, learned, intellectual. He is another winner of the Perkin Medal; in fact, he has won practically every medal, every prize, every honor that U.S. science has to bestow. Five years ago he topped them all off by winning the Nobel prize for his researches in physical chemistry. The papers he presents are hard to grasp; they are remote, mathematical, abstruse. But Dr. Langmuir's abstruse speculations have led to a dozen practical improvements in everyday products. Tungsten lamps used to blacken, because the tungsten would boil away from the filament, then condense on the inside of the glass. The Langmuir remedy, now universally applied: bulbs filled with inert gas under pressure instead of vacuum-exhausted bulbs.

Still another Perkin Medalist (1936) and close to industry though not of it, is snorting, cheek-puffing Warren Kendall Lewis, professor at Massachusetts Tech, who is everywhere acclaimed among the country's leading chemical engineers. It was he who really codified chemical engineering; with the late William H. Walker he stated its basic principles in terms of the "unit operations" of evaporating, of drying, of distilling, and worked out mathematical approaches to them all. His retainers as consultant to companies in chemical industry probably far outrun his salary from Massachusetts Tech. Next year's President of the Society is Lewis's good friend, Professor Frank Clifford Whitmore, dean of chemistry and physics at Penn State, who is a top-flight organic chemist and, like Lewis, as good a businessman as a scientist.

Any roster of the great in U.S. chemical industry would have to include half a dozen Ph.D.'s-in-industry, all of whom are centers of interest and attention at chemists' conventions. There is Dr. George O. Curme Jr., Perkin Medalist in 1935, Vice President of a big Union Carbide subsidiary and largely responsible for its profitable excursion into organic chemistry. There is Dr. Robert Erastus Wilson, now President of Pan American Petroleum & Transport Co., but fifteen years ago the Director of Massachusetts Tech's Research Laboratory of Applied Chemistry, and still an active contributor to chemical journals. There is du Pont's Dr. Charles M. A. Stine, Vice President in charge of research, who conceals a brilliant chemical mind behind the façade of a suave Rotarian. There is his associate, Dr. Elmer Keiser Bolton, du Pont Chemical Director, who was the mainspring in the development of the chloroprene polymers that have become synthetic rubber under the names of Duprene and neoprene. There is that bubbling geyser of industrial research, Dr. Edward Ray Weidlein—Director of the Mellon Institute and this year's President of the Society. There is gruff, shaggy Dr. Milton C. Whitaker, Vice President of American Cyanamid; small, Swiss-born Gaston Dubois, no Ph.D. but able Vice President in charge of research of Monsanto. But any Chemical Society meeting will probably find that excellent chemist, Dr. Charles G. Tufts, conspicuously absent—for he is a Vice President of Allied Chemical & Dye, which maintains about itself a chemical secrecy as great as its corporate secrecy.

To these men, add four more. Add Dr. Arthur B. Lamb, editor of the erudite *Journal of the American Chemical Society;* bearded, handshaking Dr. Harrison Estell Howe, who edits the Society's more practically minded *Industrial and Engineering Chemistry;* precise, methodical Dr. Evan J. Crane, editor of its *Chemical Abstracts;* didactic, seventy-year-old Dr. Charles Lathrop Parsons, the Society's veteran secretary business manager.

ALL these names together will give you a good if incomplete *Who's Who* of the scientific brains that mold and motivate chemical industry. Search any other industry you like; you will not find in it any such aggregation of trained minds as these gentlemen personify or represent. For the chemical industry is one in which scientists and engineers are not just tolerated and not just employed; they are in the saddle; their ideas are the controlling ideas. They may not be the actual entrepreneurs, but an entrepreneur in the industry who could not speak the language would be helpless. Mr. Stuart Chase has for years been hunting an industry in which the engineer class was the dominating class. He could find no such situation in the public utilities, nor in textiles, nor in the construction industry. Had he looked at the basic chemical industry, he would have found it there.

THE necessity for high scientific training is, then, one of the most important characteristics of chemical industry. But although it must have brains, plus a considerable plant (on the average an investment of $11,250 is necessary per factory wage earner), plus generous supplies of fuel and power, the industry needs a minimum of labor. In 1935 it employed only 66,000 wage earners. Labor costs amounted to little more than 12 per cent of the value of its products.

The reason is simple: most chemical products are made by a continuous process (as opposed to a batch process). Consequently, they can be brought under automatic control—and the part of labor is therefore more to keep

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liberal arts. McKeon came out first as a visiting professor in history; later he was made a professor of Greek and Dean of the Division of the Humanities. A soft-spoken, genial person, he eventually got himself "home" as a member of the philosophy department by convincing them that he knew a lot and had no desire to force his opinions down their throats. Buchanan has recently departed for St. John's College in Annapolis, where, with Stringfellow Barr, another Hutchins man, he hopes to apply the educational program outlined in *The Higher Learning in America* to a small liberal-arts institution.

ALL this would be relatively unimportant if it were merely a matter of personalities. But the fight over Adler, McKeon, and Buchanan is not a personal fight; it goes, in fact, straight to the heart of the curriculum. On President Hutchins's office wall there is the original of a Thurber cartoon that pictures two women pointing derisively to a glum young man at a party. One of the women is saying: "He doesn't know anything except facts." The cartoon is symbolic: President Hutchins is pointing to U.S. education as a whole and saying: "It doesn't know anything except facts."

It is significant, however, that Hutchins has shifted his plan of battle since the early collisions over personalities. Realizing that a President's power is limited to persuasion in the academic democracy of Chicago, he has shown no disposition to force the hands of faculty or university Senate. His missionary work has been limited to private conversation and to books, articles, and speeches about the deplorable content of U.S. education. The students themselves, or those among them who are vocal, have been titillated by the philosophical squabbles at Chicago over Aristotle and Aquinas. But a sample test of student opinion at Yale, Columbia, Minnesota, and Chicago shows that undergraduates everywhere are still inclined to worship the factual approach to a subject. There are proportionately more students at Chicago who think Plato's *Republic* a better introduction to political science than the daily newspaper. President Hutchins has thus had his effect. But the differences here between Chicago and Yale, Columbia, and Minnesota do not constitute a sweeping victory for Hutchins's insistence that ideas are more important than facts. Moreover, the *Daily Maroon* opened its editorial year on October 1 with a demand for a "chastened president." The *Maroon* editor, for the first time in some years, seems to be unimpressed by the claims that wisdom resides with the ancients and medievals from Aristotle and Plato to Aquinas.

WHAT does the great battle at Chicago portend? Has Hutchins a legitimate case to make out against U.S. education? The answer is a qualified yes. Many educators are coming to think him at least partially right. They are willing to admit that universities and schools, in their haste to teach the facts that lie behind the headlines in the daily papers, have dropped most of the good books of the Western heritage from the curriculum. But many of Hutchins's critics think he has been staging a sham battle in his onslaught on the "fact gatherers." They point out that only the worst sociologists, for example, believe in amassing facts without some special purpose to guide them. They argue that all good scientists are agreed that theory, deduction, the formulation of hypotheses, are part of scientific

University of Chicago

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method; Darwin, for instance, had a hunch that his evolutionary theory was correct before he had piled up the facts to prove it. What Hutchins's critics fear is that, when he speaks of the "truth," he is referring not to the fruitful hunch that leads to scientific advance but to the "truths" of arbitrary philosophies or revealed religion. The neo-scholastic, so they tell us, is not interested in truth as a matter of verified hypothesis, but in truth as a matter of prior metaphysical assumption. To date, however, Hutchins has not proclaimed himself a neo-scholastic. As a matter of fact, he behaves very much like a liberal pragmatist. His appointments at Chicago have included representatives of all schools of thought; his defense of academic freedom has maintained freedom at Chicago for those who disagree with him. His enemy, Harry Gideonse, has written a book called *The Higher Learning in a Democracy* that is a ringing reply to Hutchins's own *Higher Learning in America,* and Gideonse has had the unmolested support of many like-minded members of the faculty, not to mention a lot of the students.

The root of the difficulty that many have encountered in analyzing Hutchins's position is his rhetorical tendency to blur the lines between science and ethics. For example, he has criticized modern political scientists for preoccupying themselves with a study of the phenomena of political power to the exclusion of a study of the proper ends of the state. But a study of the ends of the state is not science, it is ethics, morality, and philosophy. Hutchins by no means denies this; his argument is simply that philosophical assumptions are at the basis of all science. In the interests of common sense, he is merely asking that this be reckoned with. He is not doing this because he is a moralist; he is doing it because he is convinced that the moral and intellectual natures of man are inseparable and should be so studied in college. Otherwise, students will continue to be graduated knowing a lot about the *how* and the *when* of things, but nothing about the *why* or the *ought*. Or, if you insist, about the conflicting *oughts*.

In any case, the older men in the science departments at Chicago aren't worried that Hutchins will try to sneak over any authoritarian system of study on them. As one of them says, "Not that fellow; his metabolism couldn't stand it." If, as has commonly been said, metaphysics is battling against metabolism to make Hutchins aspire to the throne of educational dictator, it is a certain bet that metabolism will win.

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To these generalities there are, of course, exceptions. That same Prestone which is Carbide's pride and achievement costs $2.95 a gallon largely because Carbide holds patents on its production. Someday that price will have to drop sharply—and it *will* drop when competition begins. When it ceases to be a protected price it will not, however, become a price-war price, if the past performance of chemical industry may be taken for a guide to its future.

FOR the next characteristic to be noted is that the chemical industry, despite its slowly lowering curve of real prices, is an "orderly" industry. It was practicing "coöperation" long before General Johnson invented it in 1933. It has seldom been bedeviled by overproduction, has had no private depressions of its own, and has not often involved itself in long or bloody price wars. The alcohol sector of the industry has frequently been guilty of disorderly conduct, and alkali made by the Solvay process has got into some nasty brawls with electrolytic alkali. But by and large the chemical industry has regulated itself in a manner that would please even a Soviet Commissar.

This characteristic is all the more surprising when you consider some of the situations that the industry faces. In the first place, technological competition operates at constant high pressure, and new processes displace old ones with some violent dislocations—like the dislocation that took place when synthetic methanol all but destroyed the manufacturers of methanol (which is wood alcohol) made from the distillation of wood. In the second place, the industry lacks the full coöperation of its second largest unit—Allied Chemical & Dye. This tight-lipped, secretive, and suspicious company gives nothing to the industry and asks nothing from it. It need ask nothing, for it is completely self contained—more so even than du Pont, which has no alkali subsidiary. Its technical men seldom go to the meetings of the American Chemical Society. It calls its own tunes.

Yet it has never for long called tunes too fast for the rest of the industry to dance to. The rest of the industry waltzes decorously, its Grand Marshal, du Pont, viewing it with a happy and beneficent eye. Its gentlemanly instincts are all against pushing and crowding. If, for example, you were to present du Pont with an idea that du Pont thought fitted better into the economic structure of Union Carbide, du Pont might well tell you, with grace but insistence, to take your idea to its competitor. The industry that believes in lowering prices does not believe in market wars. The industry that is in the public mind personified by the du Ponts is, in other and extremely non-Liberty League words, the practitioner of one definite sort of planned economy.

BASIC reason for this state of affairs is that to most of its important people, the industry is not just an industry: it is also a profession. The Manufacturing Chemists Association, to which most "proprietors" in the industry belong, is a quiet but active lobby, yet it is other things as well. It denies that it ever talks about prices—who can say that it does not discuss costs? But on its agenda it has other

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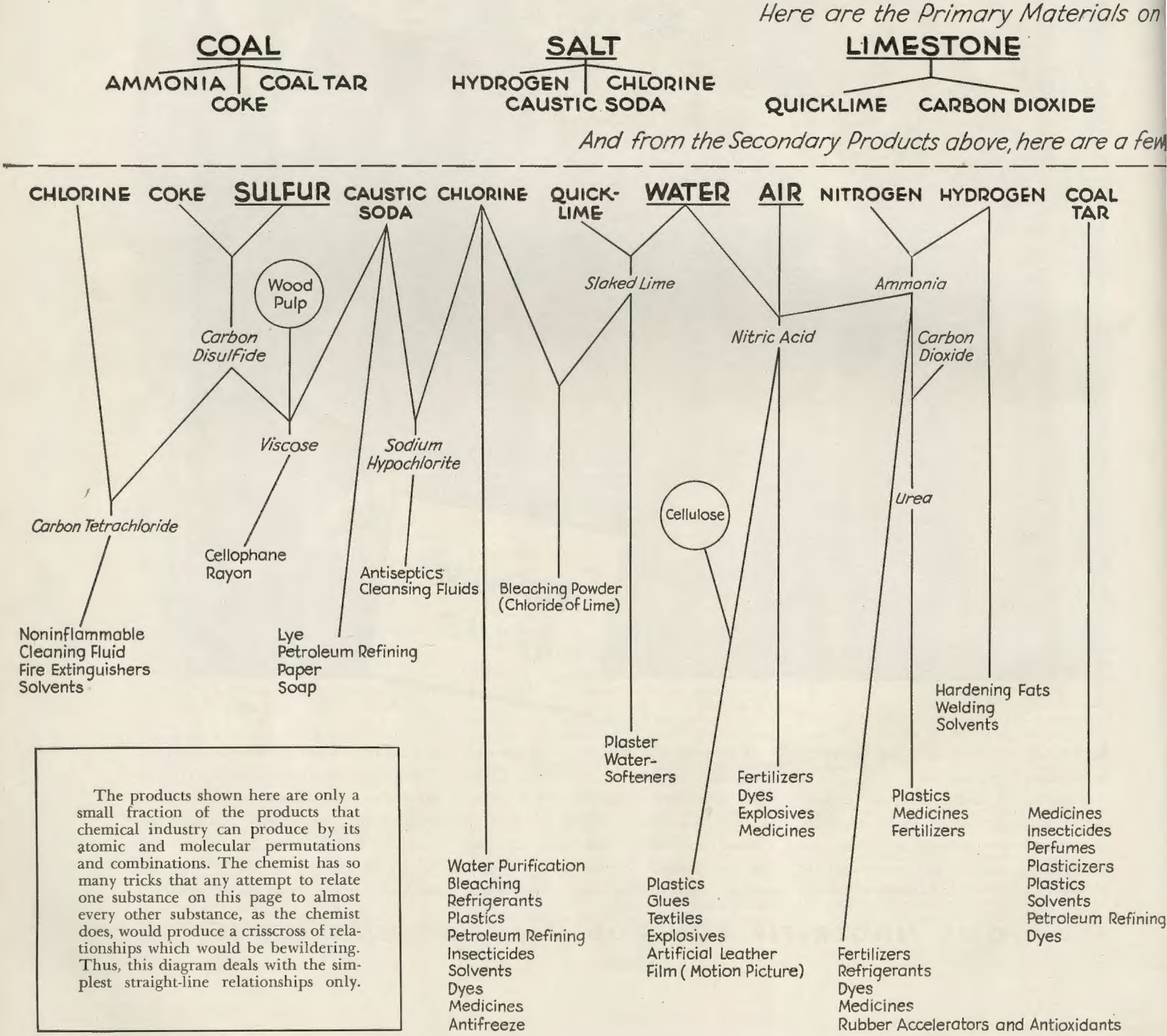
the plant clean, to turn a few valves, to weigh final products and dump them in sacks than to perform the feats of strength and skill and courage needed in a steel mill. A sulfuric-acid plant may be turning out dozens of tons of acid a day, yet the "crew" is apt to consist of one man, sitting in a glass cage and writing up a log of the day from the readings of automatic gauges. But because things can always go badly wrong in a chemical plant, the industry prefers intelligent labor, and its wages are relatively high. Last year they stood at 65.28 cents an hour and $26 a week compared to about 56 cents an hour and $23 a week in all factories—*and* most chemical employees work fifty-two weeks a year. The industry is at peace, has always been, and always expects to be. Settled usually in rural surroundings, it thinks it offers to John L. Lewis a minimum reason or opportunity for organization.

BUT the prime characteristic of chemical industry is the extraordinary proliferation of its products. Like so many of its characteristics, this one is largely inherent; it is all but impossible for one process to make only one thing. "It is," said the late Arthur D. Little, one of the country's greatest chemical engineers, "as though a cotton mill, to make thirty-five yards of cloth, was forced also to turn out forty shoes."

Thus the chemical industry is engaged in a perpetual economic and scientific juggling act. It no longer likes to use the word "byproduct" (although it still has to, occasionally), for the word is steadily losing its meaning. Suppose you are in the business of electrolyzing a salt solution to get caustic soda, as a "product," plus hydrogen and chlorine as "byproducts." Then the demand for caustic soda slacks off (as it has done) and the demand for chlorine

LAYMAN'S GUIDE TO



The products shown here are only a small fraction of the products that chemical industry can produce by its atomic and molecular permutations and combinations. The chemist has so many tricks that any attempt to relate one substance on this page to almost every other substance, as the chemist does, would produce a crisscross of relationships which would be bewildering. Thus, this diagram deals with the simplest straight-line relationships only.

goes sharply up (as it is now doing). What is your "byproduct" now? For such reasons the industry now defines a byproduct only as *something for which a full use has not been developed.* In the industry's world, such products are few, and becoming fewer.

A perfect example of the industry's juggling act lies in the relationship between two heavy organic chemical products, acetone and butyl alcohol. The best means of producing one also produces the other. During the War, acetone was a vital necessity for the high explosive, cordite. The British bought acetone in this country by the ton to treat their nitrocellulose; with the U.S. they set up here a company from which present Commercial Solvents Corp. grew. As it made more and more acetone, more and more butyl alcohol piled up in its plants as a useless, noxious byproduct. The company could not even dump it in the Wabash River; health authorities forbade. So it dug an expensive hole, and lined it with expensive concrete, and dumped the butyl alcohol in that—wondering how much it would have to pay someday to get rid of it, and how.

Instead, the War came to an end and everywhere vast stocks of nitrocellulose were left in various stages of treatment. And about that time Charles Franklin Kettering, whom we have met before at the beginning of this article, demanded on behalf of the automobile industry a better, faster-drying finish for car bodies than anything existing. The chemical industry found it for him—found it in treating nitrocellulose with solvents made from butyl alcohol, which turned out to be a perfect basis for the whole new lacquer industry which then and there began to arise. Today butyl alcohol is developing wider and wider uses as a solvent—and its makers now and again wonder vaguely what they are going to

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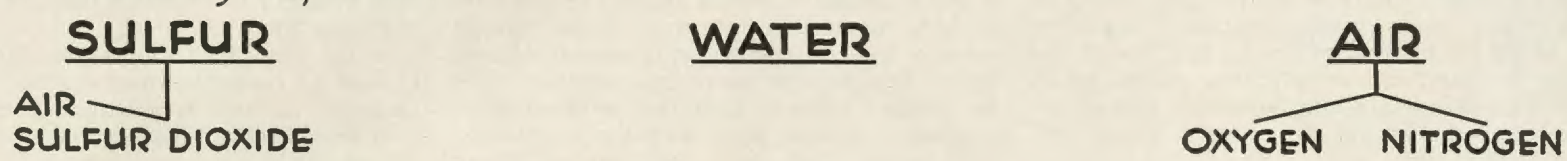
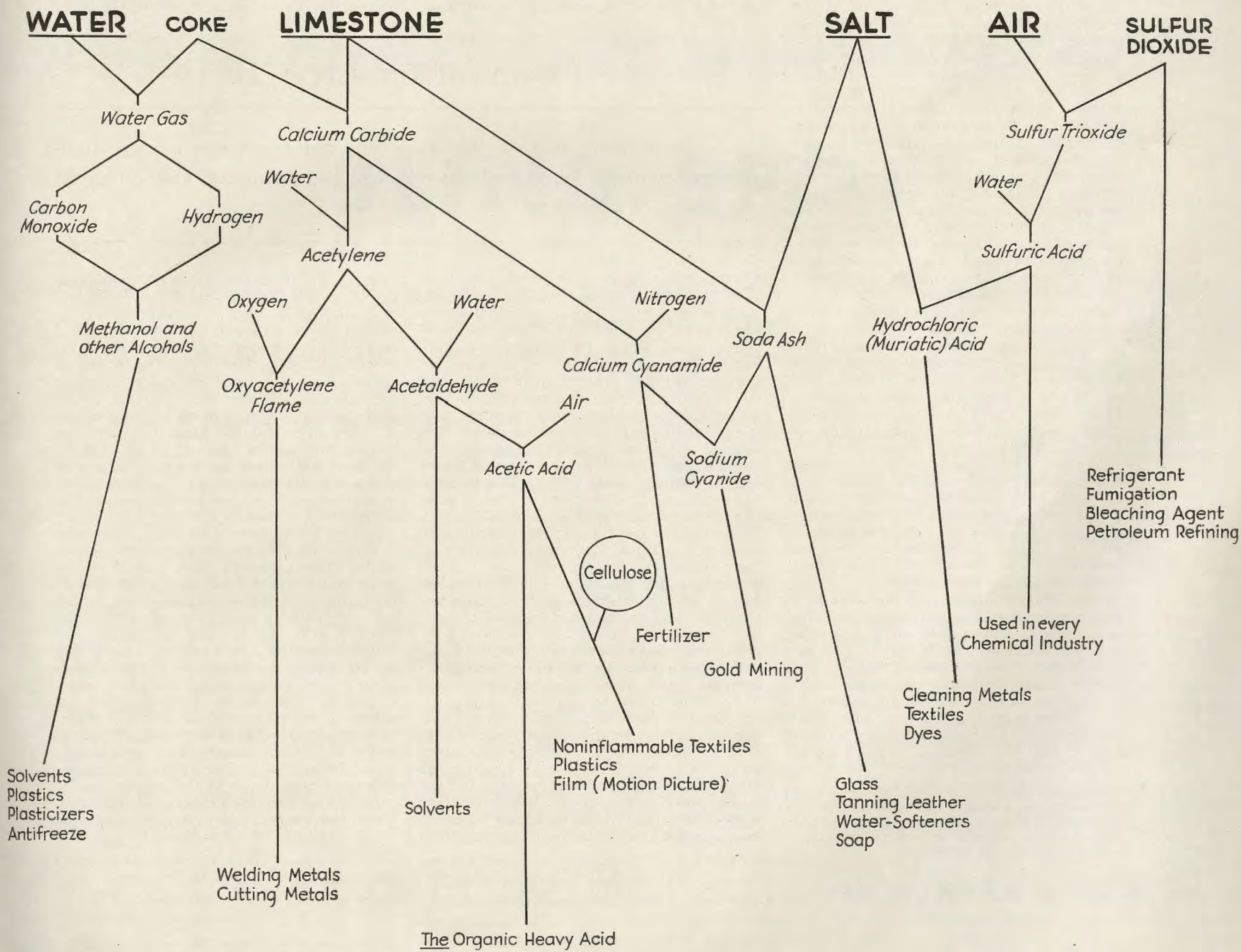
INDUSTRIAL CHEMISTRY

which Chemical Industry depends.



of the Chemists' Combinations and the results of them.



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do with all the byproduct acetone that they find on their hands.

As a final example of chemical industry at work, glance at the Dow Chemical Co., in Midland, Michigan. The Dow company has its being in Midland because it stands over a center of the great Michigan brine wells—wells inexhaustibly full of water from some subterranean ocean. In this water there is common salt—sodium chloride—plus sodium bromide, calcium chloride, and magnesium chloride. And by the electrolysis of this brine and subsequent chemical treatments, Dow was able last year to manufacture 304 different products. It needs large amounts of electric power, and it must purchase benzene in big quantities from outside producers. But that is almost all—and its brine is free for the pumping. And the products range from aspirin (of which Dow is the largest producer in the U.S., selling to virtually every pharmaceutical house) to phenol for plastics, aniline as the base of the dye industry, and metallic magnesium, which in some alloy form may someday give aluminum a run for its money as a lightweight structural metal.

LOOKED at from any vantage point, chemical industry presents a snug picture. The Big Three—du Pont, Carbide, and Allied—control some two-thirds of the business. Today the whole chemical picture has an air of financial stability that is unusual in so new an industry. There is no evidence of fighting among its companies for position: price structures are steady, affected more by chemical excellence than by old-fashioned price competition. This is the unique industry that knows its costs and refuses to sacrifice profits for the sake of volume. Competition is *chemical*—there you will find all the fighting you want—but the surface, the financial surface, is serene. And it will probably continue to be; new developments seek outlets through established chemical industrial channels, for there lie the talent and the money for development, one as vital as the other for any new process.

And the chemical industry is a rich industry. From 1925 through 1936 the six companies listed in the boxes that accompany this article* had a net income of around $1,240,000,000, paid $965,000,000 in dividends. Only one of those companies missed a dividend during the depression and none showed a loss. Their net income last year was $165,450,000; they paid $118,236,000 to shareholders.

As with these companies, so with the dozens of others that FORTUNE has not mentioned. By and large, their managements have been both shrewd and enlightened, their contributions of new goods to society both sound and spectacular, their return to stockholders extremely satisfactory. That would seem to be enough to demand of any industry.

The chemical industry, on the other hand, has its critics, just like any other. And these critics have a point to make which, in passing, it is interesting to note. It may be said in a broad sense that all industry owes a huge though intangible debt to the people—a debt that cannot be paid directly in dollars, but only indirectly, in lower prices, better qualities, moderate profits, and various forms of service. But U.S. chemical industry owes a peculiar debt in this respect: that it was *founded* by the people of the U.S. In 1918-20 the people's government set the industry up in business, as it practices business today. It was the government that wrote the tariffs that protected this truly "infant industry" in the twenties. And it has been the U.S. conception of education that has profited chemical industry most of all—for it is from the hundred-million-dollar scientific laboratories of the universities that the industry has drawn its priceless asset of trained men.

That the industry has paid back part of its debt in the form of endowments to the universities is unquestionable. That it has paid back part of its debt to the people in the form of lower prices and better services is also unquestionable. The question is, simply: *what* portion has it paid?

That question must be left open for the present time. It will not become pressing until a much greater question arises: the question of U.S. involvement in war. If war should come to the U.S. tomorrow, chemical industry would be ready. It has techniques that could be swung instantly into the production of explosives, poison gases, and dozens of other implements of international anarchy. There would be no waiting of the troops for their supplies; the waiting would be all the other way. This aspect of chemical industry—its ability at a word of command to turn from a benign Dr. Jekyll to a hideous Mr. Hyde—is widely misunderstood. Those who think of U.S. chemical industry as a threat to peace are reasoning with a sublime childishness. Pure self-interest, unmixed with an ounce of humanitarianism, alone would make chemical industry quake in its boots at the thought of another war. For with another war, the debt of chemical industry to the people would be instantly payable, and at a fixed price. The next war won't mean just the government operation of the railroads; the next war will mean the nationalization of all essential services of supply. Chemical industry would be No. 1 on the list of governmental confiscations —and whether it would ever again be able to emerge into the domain of private profits is a question that probably costs its present leaders some long, long thoughts. The next war, for chemical industry as perhaps for all of industrial democracy, would be one war too many.

Meanwhile, chemical industry pursues peaceful ways. Last month the Atlas Powder Co.—of all concerns—opened a big new plant designed to convert dextrose electrolytically into new softening agents, such as can be used for printers' rollers, etc. Hooker Electrochemical announced that it was building new capacity on the West Coast to hydrogenate fats. Membership in the Chemical Society increased by 500. Prices were firm and demand was brisk.

**On pages 85, 87, 89, 90, 164, and 166. The first four companies were chosen because they are the four largest in the industry; the last two—Dow and Monsanto—for their typicality of smaller companies.*

Chemical Industry: II

Sulfuric acid on the wane, and chlorine's star rising. High-pressure synthesis; methanol (wood alcohol), ammonia, and nitrogen; the future of hydrogen.

SOMEDAY a historian will pay to the nineteenth century the honor it deserves. In the midst of its mutton-chopped prigs and swooning ladies it produced almost every basic discovery upon which the twentieth century stands. If we are to see some of the more important chemical operations of the present day in their proper balances and relationships, we must first spend five minutes with the nineteenth century and in rapid succession view its most important chemical landmarks.

1. *The first synthetic dye is discovered.* By the age of seventeen, young William Henry Perkin was good enough to be an assistant to the great chemist A. W. von Hofmann, whom Victoria's Prince Consort had brought from Germany to teach at the Royal College of Chemistry in London. Working in 1856 with coal tar from gas retorts, for which no earthly use was known, Perkin produced aniline. That was no great trick; Perkin merely wanted the aniline because he had a theory that from it he could synthesize quinine, and thus break the Dutch monopoly. To his bitter disappointment he could achieve nothing even resembling the handsome white crystals of quinine; he found himself with only a tarry black solution. Into it he dropped a piece of silk. Why he did that, he was never in years afterward able to explain—but when he drew out his silk it was stained a deep purple, and the purple would not wash out. It was, in other words, a dye: the first dye ever made from any source except a root, a bark, or a berry. A firm of dyers, the Messrs. Pullar, of Perth, admired the color. They acknowledged the importance of having made a dye from such a source as coal tar, but they were afraid that its use would make dyed goods so expensive that they could not be sold. What Perkin's dye really did, of course, was by its new cheapness to make natural dye an obsolete product. Meanwhile, young Perkin went on to the synthesis of other dyes—and the great Hofmann, returning to Germany, there sowed the seed for the huge and hugely important chemistry of coal tar—from which dyes and medicinal products were shortly to come in what seemed like an unending profusion.

2. *The Solvay process for alkali supersedes Leblanc's.* In 1863 the Belgian Ernest Solvay all but blew Leblanc's alkali process off the earth by a newer and still cheaper method of producing soda. Whereas Leblanc had treated salt with sulfuric acid, charcoal, and chalk, Solvay dissolved salt in water, saturated it with ammonia, and let it trickle down a tower full of perforated partitions. Into the bottom of the tower he blew carbon dioxide, product of heating limestone to quicklime, and got sodium bicarbonate, which, heated strongly, left sodium carbonate or soda behind. Today, in the U.S., Allied Chemical & Dye, through its subsidiary, Solvay Process Co., is the most important practitioner of this process. Solvay soda, cheaper than the Leblanc soda before it, spread out into still wider uses: for more soap,

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Chemical Industry

[*Continued from page 162*]

for the manufacture of glass, and for the production of caustic soda, or sodium hydroxide, which, in its turn, was to become an essential in the textile industries, in the oncoming pulp and paper industries, and in petroleum refining. Most of these industries were nascent or rudimentary in 1863: the reason being that for their development they needed the cheap alkali with which the Solvay process was only then prepared to supply them. If there had been such a thing as the rayon industry, it, too, would have needed great quantities of caustic soda.

The Solvay process, in reaching out to find the ammonia it needed, set in motion still another new chemical engine, at first glance in no way related to it. This was the byproduct coke oven. The iron and steel industries, to which coke was a basic need, clung to the so-called beehive oven, which produced a hard coke that resisted crushing from the load it bore in blast furnaces. But the beehive oven wasted all the other products produced by coking coal. One of these products was ammonia—and because of the need of the Solvay process for ammonia it gradually came about that the byproduct oven supplanted the beehive and became, for a while, the most important source from which commercial ammonia could be produced. Thereafter the hitherto wasted products of coal distillation were saved as carefully as the coke itself. Perkin's discovery of a synthetic dye to be made from the coal-tar refuse of the coke oven was slow in making its significance felt—but when it did, the process of coke production lent it an all but inexhaustible source of raw material.

3. *Petroleum is distilled.* In 1850 lamps were still lighted by whale oil, supplied to the U.S. by New England's whaling fleets. It was getting steadily more expensive, and it stank. Five years and more before the great Drake well came in at Titusville, Pennsylvania (that was in 1859), people had been skimming a few barrels a day from surface oozings of petroleum near Titusville and Tarentum, because it had been discovered that petroleum, like whale oil, was a "'burning oil." But it was Professor Benjamin Silliman the younger who gave this piddling business a new reason for being when from crude petroleum he made the first careful and studied fractional distillations. Something called coal oil came from distilling petroleum—and it burned better than any oil had ever burned before. It was that which started the hunt for petroleum on the grand scale—for a source that would yield not just a few barrels a week, but hundreds upon hundreds of barrels a day. When the Drake well came in, Silliman's process of fractional distillation was ready for it—but the whole point of the process was to produce coal oil. There were lower and higher boiling fractions too, but they were nuisances. The higher boiling fractions were useless (the discovery of their usefulness as lubricants was still a decade away) and a lower boiling fraction, called gasoline, was worse than useless: it was a menace. It tended to make coal-oil lamps explode—one of the greatest household hazards of grandfather's day. And the greatest problem of the first distillers of oil was to throw away that gasoline without getting pinched by health or other civic authorities for maintaining a nuisance. For more than thirty years thereafter, the industrial chemist waited to find an outlet for this byproduct of the commercial production of coal oil.

4. *Electrolysis gains importance.* In 1800 Alessandro Volta made his momentous discovery of the electric battery, and in the same decade it was discovered that an electric current had a chemical effect. Connect electrodes to a battery, put the electrodes in water to which you have added a little acid, and under the influence of the current the water decomposes into its component hydrogen and oxygen. The principle established here was the principle of electrolysis. But it was a long while before that principle found any commercial uses. By 1880 chemists were pretty sure that electrolysis was going to be an exceedingly valuable weapon, but they weren't sure for what. Then Charles Martin Hall used an electrolytic process to produce cheap aluminum, and its uses began to dawn. By 1890 there was a small electrolytic plant at Niagara Falls for electrolyzing salt. Today electrolysis goes on wherever power is cheap—and electrolysis produces great quantities of those two vitally important chemicals, caustic soda and chlorine (page 168)—plus hydrogen, which is of a commercial importance now swiftly rising (page 170).

5. *Frasch mines sulfur.* Before Herman Frasch developed a new mining process, the

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THE DOW CHEMICAL CO.

100 shares Dec. 31, '24 = $6,200 = 907½ shares Dec. 31, '36 = $124,327 = $86,893 Oct. 19, '37

CHEMICALLY

. . . all products come from three kinds of brine: brine fields in Michigan, which can and do make any of the 304 Dow products; brine from oil wells, from which Dow makes nearly all of the U.S. supply of iodine; brine from the sea, for bromine to turn into ethylene dibromide. Practically, insofar as the layman is concerned, Dow makes *Medicinals, Industrial Chemicals, Dyes, Flavors.* Those are the big divisions. Then there is ferric chloride for photoengravers, phenol for resins like Bakelite, sodium sulphide for tanning, common epsom salts, which Dow is more pleased to sell by the ton than by the sack, aspirin (Dow is largest U.S. producer), and insecticides. One of the most important Dow products is Dowmetal—magnesium alloys. All products are sold to manufacturers, not to individuals. If you have an oil well that is no longer producing handsomely, Dow has chemicals that will acidify it, make it nearly as good as new. Dow makes carbon tetrachloride for dry cleaners, caustic soda for soapmakers, chlorine for bleaching and deodorants, salicylic acid for corn cures, bromide sedatives, even methyl salicylate, which is synthetic oil of wintergreen used in chewing gum. Magnesium also supplies the sparkle in sparklers on July Fourth and the metal foil for photographic flash bulbs. All this and more Dow makes by passing an electric current through its inexhaustible supply of brine, then combining and recombining the elements and the scores of compounds. One of the company's most important developments is the great plant at Wilmington, North Carolina, completed in 1933 to get bromine from sea water for the manufacture of ethylene dibromide, the scavenger that gets rid of lead on the cylinders of an engine, put there by antiknock gasoline containing tetraethyl lead. Dow buys some raw materials—benzene, basic to many of its syntheses, alcohol, and a very few others. *RESEARCH:* it would be difficult to find more intelligent; but it's all down one alley—what comes out of brine. The list grows and grows and grows: for instance—Dowtherms, mixtures of synthetics that smell like geraniums but have important and growing uses in the new so-called bi-fluid boilers (see page 170).

FINANCIALLY

. . . time has been kind to Dow, exceedingly so to those few shareholders who bought in 1915, never sold. Dow has a solid record of dividends; has paid as much as $7.50 regular, $75 extra, and 60 per cent in preferred in one year (1915). 10 per cent stock bonuses were paid in 1925 and 1928; 400 per cent in 1929, another 50 per cent in 1934. 100 shares in 1915, plus exercise of rights when offered, would have cost $70,000, would have been worth $931,000 in May, 1936, would have paid dividends during the period of $127,514. Best word for Dow: unique. Dow, to an even greater degree than other chemicals, is important financially because it is so damned smart chemically; has in brine a better than "partial skill monopoly," a phrase loosely used in chemistry. Dow's North Carolina sea-water bromine plant (and *only* Dow succeeded in this process after bigger chemicals failed) fires the imagination. One square mile of sea water seventy-six feet deep contains chemicals and metals worth about $71,000,000—which isn't all idle dreaming as Dow *now* takes the bromine. The Wilmington plant, however, is jointly owned by Dow and Ethyl Gasoline Corp., in turn controlled by Standard of New Jersey and General Motors—the motorcar builder that at last has found a way to profit from building cars *and* running them. Dowell, Inc., is a Dow subsidiary, which acidifies oil wells on a royalty basis; is a mushroom. Big-little Dow must be appraised today on what it can do with what it has done, what it can do with what is left in its brine wells, in sea water. Almost alone in its field, protected by a blanket of patents, Dow has been less concerned with that gobbler of profits—obsolescence—than other chemicals.

Preferred shares	29,692
Common shares	945,000
Common shareholders, May '37	3,063
Common trading, N.Y.C.E., '36 (Now on N.Y.S.E.)	79,930
High 1937 (com.)—159½; Low—94 (Oct. 19)	
Div. on common—1936 (calendar year)	$2.20

Div. 1937 (calendar year)—through Aug. 16	$2.60
Net earnings, year ending May 31, 1937	$4,089,000
Earned per share May, 1937	$4.17
Funded debt	$5,720,000
Equity per share of common	$23.62
Total assets May 31, 1937	$35,683,000

[*Continued from page 164*]
essential ingredient for the most essential chemical in industry came almost entirely from Sicily. Sicilian sulfur was not too pure but it was the best there was. The sulfur producers of Sicily did not fail to appreciate their importance; the price of sulfur climbed so high that acid producers took to using pyrites, which is iron sulfide, instead of Sicilian sulfur in their burners. All this time, and well known to everyone, there lay in Louisiana immense beds of sulfur. Unhappily they lay buried beneath at least 500 feet of quicksand and rock, which completely balked ordinary mining methods. By 1890 Frasch had developed a process whereby this sulfur could with an almost ridiculous simplicity be melted underground, brought to the surface, and pumped into great bins to cool and harden. His simple process called for sinking three concentric pipes—one to carry hot water down to melt the sulfur, another blowing compressed air to force the sulfur out, and the third to carry the sulfur to the surface. It worked perfectly—and sulfuric-acid production, freed from the millstone of Sicilian sulfur and pyrites, bounded ahead, carrying all the rest of industrial chemistry with it on its broad and straining shoulders.

If Leblanc began industrial chemistry's history, these five further discoveries—from Perkin's dye to Frasch's sulfur—were the stepping stones by which industrial chemistry reached the twentieth century. Once arrived there, the chemical industry began an even swifter acceleration. And in 1913 it received one of the sharpest reorientations of its existence, for in that year the Haber process for the fixation of nitrogen was brought to commercial usefulness. The story of that revolution is told in its proper place on page 170. From here onward let us select, among the countless thousands of chemical industry's useful products, the four that are, today, the most commercially important. Let us remember, once again, that the industry's most basic ingredients are coal, salt, limestone, and sulfur—plus air and water, and that relative newcomer, petroleum. The sections that follow concern the secondary products that chemists produce from these raw materials.

Sulfuric acid

IF LEBLANC'S soda process was the Adam of industrial chemistry, sulfuric acid, made of its rib, was its Eve. Sulfuric acid, salt, limestone, and coal were Leblanc's raw materials and all but the first were ready to hand. Sulfuric acid had been known for centuries and had first been made in small lots as a kind of laboratory curiosity. Later, a few hardy souls built little plants to make the acid in sturdy lead chambers instead of fragile glass tubes and bottles. Fumes of burning sulfur supplied sulfur dioxide; when fumes from niter (mostly oxides of nitrogen) were added, the sulfur dioxide would combine with air and water to make the oily sulfuric acid. That was good enough for a business amounting to ounces or pounds, but the growing soda business needed tons and tons of acid. Thus the small lead chambers became bigger, and still bigger, and soon there were plants that took in fumes, steam, and air at one end, converted most of the mixture to acid, and left the niter fumes to blow out wasted at the other.

As volume increased and competition pushed prices down, this niter waste grew more and more serious; particularly so since niter was needed for wartime and mining explosives. (That was long before Chile's nitrate beds, later to save the Allies in the World War, had been exploited.) Happily, the acid makers soon found at least a partial escape from their trouble; somebody discovered that the brown fume coming out the end of the plant as a waste was precisely what was put in at the beginning. Well and good, said the acid makers, we shall catch it and make it work over again. So by washing the exit fumes with weak acid, they did catch it and were able to use it over and over again. The need for niter dropped to a tiny fraction of what it had been, acid was cheaper to make and actually purer.

This cheaper acid was finding wider and wider uses. The chemist Liebig made his great study of plant-food necessities; he put together his artificial manures, consisting of potash, phosphoric acid, and guano, and farmers began to be persuaded to use them. That called for sulfuric acid to produce phosphoric acid—first out of bones, later out of waste bone black from sugar refineries, still later out of phosphate rock from South Carolina, Tennessee, and Florida. The thriving new business of petroleum refining began to drink up tons of sulfuric acid to improve its products. Galvanizing and tin-plating of steel needed other tons for cleaning the raw metal so that the plating would stick. Gasworks were using acid to recover ammonia for the developing fertilizer market. Perkin had made his first dye, and the Germans were swiftly building a whole new industrial structure upon his discovery—all of which needed sulfuric acid. In Sweden, Nobel had given the explosives business a big push with his invention of dynamite: smokeless powder was being made of wood pulp or cotton by the action of sulfuric acid and nitric acid (made with sulfuric). But by that time Leblanc's cheap alkali process, which had started sulfuric acid on its careening course, was completely licked by the Solvay process—which needed no acid. The prime mover behind sulfuric's growth disappeared; and in the curious economics of chemistry that was all to the good, for an acute shortage of sulfuric acid might otherwise have developed. Other needs sprang up so swiftly that sulfuric-acid production never halted for a day.

These new consumers needed acid more concentrated than the lead-chamber process could produce. As the discontent with chamber acid grew, a chemical inquiry began as to why it was, year before, that an English vinegar maker had not been successful with a sulfuric-acid process on which he had a patent, and which had looked wonderful but hadn't worked. The vinegar maker, one Peregrine Phillips, had stumbled on the fact that when

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MONSANTO CHEMICAL CO.

100 com. shares Nov. 21, '27 = $3,875 = 786 shares Dec. 31, '36 = $76,831 = $62,976 Oct. 19, '37

CHEMICALLY

. . . Monsanto, one of the older U.S. chemicals, started life in 1901 as a maker of saccharin. Today, after many a tough year of cut-throat German competition, this St. Louis company is one of the best diversified of all, one of the smartest chemically. Products divide roughly into three broad groups: *Fine and Medicinal Chemicals, Heavy Chemicals, Intermediates.* The first group is most important; it consists of saccharin, vanillin, coumarin—flavors—aspirin, caffeine, phenolphthalein, salicylic acid, benzoates, etc. The *Heavy Group* refers, of course, to the acids, caustic soda, alum, chlorine. *Intermediates,* those essential in the production of other organic chemicals, are represented by paranitraniline, maleic acid, and scores of others. In addition, there are the highly important chemicals for the rubber industry. Monsanto products number well over 300; most important customer is the foodstuff industry, which took 15 per cent of domestic production last year. Products are used for bleaching flour, flavoring and sweetening for beverages, and flavoring for candy, as an ingredient in self-rising flour, baking powder, and animal foods. The butter, milk, cheese, and canning industries use Monsanto compounds as adjuncts. Pharmaceutical houses, next important customers, accounted for more than 11 per cent of last year's business. No other industry took more than 9 per cent. *RESEARCH:* constant and excellent—done by a subsidiary removed entirely from any manufacturing division. Plants—nine in the U.S., two in England.

FINANCIALLY

. . . this keen chemical earned $4,468,000 last year, a record; paid $3,235,000 in cash dividends, also a record (forced by undistributed profits tax). Monsanto made over half a million dollars more in 1933 than it did in 1929, which was the first million-dollar-profit year in its history. Its growth through depression years was phenomenal. But it wasn't always like that—Monsanto, started in 1901 with $5,000 capital, was once as scrubby a chemical as ever existed. It lost money the first three years; in 1904 got down to $204 worth of working capital. Today's working capital is a whopping $16,000,000. As smart financially as it is chemically, Monsanto, after a shrewd look at Mr. Roosevelt's tax on undistributed profits, promptly went into the money mart, offered $4.50 preferred at 101½ and accruals, gobbled up a cool $4,950,000 before October 19, 1937. Monsanto will probably continue to grow as it has before—by means of carefully made mergers, clever internal growth, and research. No funded debt.

Dividends since 1925	$10,790,000
Net income since 1925	$24,171,000
Shares $4.50 preferred	50,000
Shares of common	1,114,409
1936 sales, N.Y.S.E.	168,100
High 1937—107½; Low—79⅞	(Oct. 19)
1932 low—common	13⅜

Earned per share, 1936	$4.01
Paid per share, 1936	$3.00
Equity per com. share Sept. 30.	$27.91
Net sales, 1935	$24,705,000
Net sales, 1936	$28,848,000
Total assets, 1936	$44,947,000

sulfur dioxide and air were passed over hot platinum, they combined to form sulfur *tri*oxide, and that this need only be dissolved in water to make sulfuric acid direct, in any concentration. The platinum was left in the end just as it was in the beginning, its power to promote the combination of air and sulfur dioxide entirely unimpaired.* At least, that was what the patent said. But the process hadn't worked well for Phillips. His trouble turned out to be that impurities in his sulfur poisoned the platinum catalyst and made it refuse to function. But even when that was known and this new "contact process" for sulfuric acid was well under control, the process still accounted for very little production. The reason: sulfur pure enough for the contact process scarcely existed, and purification was too expensive. But that was before Herman Frasch brought sulfur, better than 99 per cent pure, up from under the quicksands of the Louisiana coast. Once this was accomplished, sulfuric acid, still cheaper, still more plentiful, entered its modern phase of use.

Of all the things made by chemical industry and consumed without going through the formality of a sale, sulfuric acid is probably the best example. In the peak year 1929 a quarter of the total production probably never saw the market. Each consumer—and every chemical plant is one—takes a careful look into the matter to decide whether he will buy his acid, or make it. Reasons for this principally involve freight charges. So much air and water combine with sulfur to make sulfuric acid that the acid that goes out of the plant weighs some three times as much as the sulfur that comes in. And the dangerously corrosive and burning acid is tough to handle compared to the innocuous sulfur from which it is made. Obviously then, there is good reason for building sulfuric-acid plants as close as possible to consuming markets and keeping them scattered and little, without caring very much how they relate geographically to the sulfur supply.

Sulfuric acid has been the pig iron of chemical industry. In 1929 its sales reached an all-time peak of 5,800,000 tons, worth $45,600,000—and this was only some 70-odd per cent of the total production. It has never returned to that peak (although chemical industry in general has) and there are those who think that it never will. Nothing is more characteristic of the chemical industry than the way it outgrows the products and conceptions of its youth—and there are some signs that the industry is beginning to outgrow its previous dependence on sulfuric acid. The new petroleum industry can no longer afford to treat its products as roughly as it used to. Therefore in this industry new refining agents —solvents and synthetic compounds—are replacing sulfuric acid. The fertilizer manufacturers are beginning to find new ways to make plant food from phosphate rock without sulfuric acid. Pickling steel for galvanizing and tin-plating is being done without sulfuric acid—hydrochloric acid is taking its place. And whereas hydrochloric acid used to be made almost entirely from sulfuric acid's action on salt, it is now being made from the chlorination of hydrocarbons—once wastes of petroleum distillation. Chlorine, indeed, is taking an industrial importance that increases almost daily—and to it we should look next.

**That is what chemists know as a catalyst, but an explanation of how it works has filled volume after volume with words that explain really nothing at all of how or why a catalyst works.*

Chemical Industry

[*Continued from page 166*]

Chlorine

As LEBLANC'S soda process fostered sulfuric acid manufacture to supply one of its raw materials, so one of its byproducts set another chemical wheel spinning by leading to the commercial production of chlorine. To make soda you treated salt with sulfuric acid to form sodium sulfate, which you wanted, and hydrogen chloride, which you did not. As long as soda makers made only a little soda, the winds blew this acrid gas harmlessly away. But as soda production grew the air about soda plants became more and more noxious. In England, where Leblanc's process was put to real work, it was only a little while before laws were clamped down to force the soda plants to stop this gaseous nuisance. And stop it they did by dissolving the offending gas in water, thus making hydrochloric acid (also called muriatic). But that only kept it out of the *air*. What was to be done with the tons of acid that accumulated when nobody wanted more than ounces or at most pounds of it? One early answer was to put it in casks, carry it out to sea and dump it.

But at length it developed that the rapidly growing textile industry needed something to help bleach and whiten its products. Whereas yards of cottage-made linens could be spread in the sun to bleach, acres of factory-made goods would need more landscape than England had. And sunlight was practically the only bleaching agent used—although it had been known since 1785 that chlorine, a vile, yellow-green, choking, poisonous gas that had been made in the laboratory, had bleaching properties. Ah, said the much beset alkali makers, we shall make bleaches from our muriatic acid and solve two problems at once.

And they did. A molecule of hydrochloric acid is made up of an atom of hydrogen and an atom of chlorine and it is easy to split them apart—oxygen from the air plus a catalyst will do it. The bleach makers—they were not just soda makers now—recombined the chlorine with slaked lime to produce the substance that still goes by the names of bleaching powder or chloride of lime. And from that successful attempt to get rid of a noxious waste product many important consequences began to grow. Chlorine is valuable because it is extremely active; a chlorine molecule delights to combine with wide varieties of other molecules—and in the combination it effects some radical changes. Also, chlorine is a killer. A few lungfuls of the pure gas will kill any animal. But chlorine is also a germ killer. It has helped eliminate the fear of typhoid-fever epidemics by destroying contamination in water supplies. It is the source of the active ingredient in the so-called Carrel-Dakin solution for application to wounds, which is made as is bleaching powder, but with caustic soda replacing lime. But its industrial uses far outrank its medicinal ones.

Chlorine continues to be the most important bleaching agent, not only for cloth but for paper. So long as it remained fairly expensive its use was largely limited to this. But when Niagara Falls began to supply the U.S. with its first really abundant electrical energy a new kind of alkali industry began to thrive, and along with it came more and cheaper chlorine.

We have seen that salt, in an electrolytic cell, produces caustic soda, hydrogen, and chlorine. Chlorine from this process is pure and ready to sell with only the formalities of compressing and cooling it until it liquefies. Then it can be bottled up in tank cars, which can trundle chlorine around the country with no excess weight of lime (as in bleaching powder) to burden the freight bill.

Soon chlorine began to come from wherever power could be cheaply installed and salt was plentiful—which, to Niagara, slowly added the Pacific Northwest, the salt belts of Michigan, and the Kanawha valley in West Virginia. The electrolytic process had this further advantage: if the demand for chlorine dropped, while the demand for caustic soda held steady, the unmarketable excess of chlorine could be combined with the hydrogen directly to make the highest grade of hydrochloric acid.

What has happened more recently, however, is that chlorine demand has outrun caustic demand. Cheaper and cheaper chlorine began to interest the solvent makers. You could make the valuable but highly inflammable material carbon disulfide (essential in viscose rayon manufacture) out of coke and sulfur in the electric furnace, and by treating it with chlorine produce the flame-smothering solvent called carbon tetrachloride, familiar to everyone in Pyrene for fire extinguishers, and in Carbona, the dry-cleaning agent. Chlorine plus acetone produces chloroform—seldom used now as an anesthetic but still a valuable solvent for oils and alkaloids. The making of the new, noninflammable, nontoxic refrigerants like dichlorodifluoromethane and the new flameproof dry cleaners' solvents called for chlorine and still more chlorine.

Therefore, as with sulfuric acid, so with chlorine: for a time it looked as if chlorine demand were going to outrun supply. So, also as with sulfuric acid, there were immediate attempts to produce commercial chlorine in other ways—ways not depending on electrolysis. Chlorine as a byproduct of caustic soda is all right as long as the soda sells; but, reasoned the chemical manufacturers, why could we not make chlorine a byproduct of sodium *nitrate*—valuable fertilizer for the cotton growers? The reaction is simple enough: dump nitric acid on salt instead of soda ash, and get the same old sodium nitrate, but get chlorine instead of carbon dioxide. Allied Chemical started out with that process at Hopewell, Virginia, getting its nitric acid by the oxidizing of synthetic ammonia (page 170). Tight-lipped Allied will not admit it, but the process has been giving it a great deal of practical trouble —and chlorine has only recently been produced at Hopewell in quantities sufficient to be felt in the market.

Notice now how the rise of chlorine has accompanied, and in some ways caused, the decline in sulfuric acid uses. When you use chlorine in making organic compounds and solvents, you frequently produce hydrochloric acid at the same time. The increasing use of hydrochloric acid is crowding sulfuric out of metal pickling. The chlorine-born synthetics include the petroleum-refining solvents, which have also intruded on sulfuric acid. And phenol, for plastic manufacture, and hosts of other intra-industry products were once wholly children of sulfuric acid, are now also children of chlorine. There are men in the chemical industry who are willing to say that

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the chemical industry is leaving a sulfuric-acid phase and entering a chlorine one.

Ammonia and nitrogen

THE layman knows ammonia only as something on the kitchen shelf—and this is not ammonia at all but a weak solution of ammonia in water. When the chemist speaks of ammonia he means *anhydrous* ammonia (without water), which is a gas and becomes a liquid only when subjected to sufficient pressure. The molecule of ammonia consists of one atom of nitrogen and three atoms of hydrogen—and the production of ammonia from the nitrogen of the air is a triumph that some sober historians of chemistry have ranked in importance to the race with the discovery of fire.

Inert and useless, 1,650 pounds of nitrogen press down upon every square foot of the earth's surface. Sir William Crookes in 1898 predicted the imminent end of civilization upon the presumption that the *combined* nitrogen that is an essential ingredient of every form of animal and plant life would be exhausted. Nitrogen from the air could be "fixed"—that is to say, could be combined with other elements into useful and nourishing forms—only by certain peculiar bacteria living on the roots of leguminous plants. The bodily wastes of animals are rich in useful nitrogen, and the farmer nourishing his plants with manure was doing his work of restoring nitrogen to the life cycle. But the enormous dissipation of nitrogen after a single use was helping to throw the entire cycle off its proper balance. Moreover, nitrogen in the form of nitrates was vital to the explosives industry—and the principal source of world supply was the great nitrate deposits of Chile.

The virtual world monopoly of Chile in nitrates was a matter of primary world concern when a methodical German, Fritz Haber, found the essential clue to the whole riddle of nitrogen fixation in 1908.* Using extremely high pressures and temperatures he was able, with the aid of a catalyst made mostly from iron, to cause nitrogen from the air to combine with hydrogen in the ratio of one to three, producing ammonia. The process, experimentally successful in 1908, was working at full plant scale by 1913—and the first wide use of this incalculably useful discovery, which solved the worst problem in the whole agenda of modern chemistry, came in the flaming outbreak of the World War. Without self-sufficiency in fixed nitrogen for explosives Germany could not have waged that war. But if the first result of the Haber process was calamitous, a more permanent result lay in the fact that the air, which had hitherto been useful in the support of life only by making the combustion of the body possible, could now be made not merely to support life but to contribute toward its nourishment and growth.

Before the Haber process, chemists had turned all sorts of complicated handsprings to make the nitrogen of the air combine usefully with other elements. The cyanamide process was one of these handsprings. If you fused lime and coke in the electric furnace, thus using great quantities of electric power, you got calcium carbide, which nitrogen would join to make calcium cyanamide. That could be used as a fertilizer or as a source of ammonia and other nitrogen compounds. In Norway other handsprings were being turned. Vast amounts of hydro-electric power were used to make nitric acid by the so-called arc process: in the presence of a vast, fan-shaped electric arc small amounts of nitrogen would combine with oxygen, both in the air, the end product being nitric acid. Lime treated with this is an excellent fertilizer.

**Peace-loving Fritz Haber lived until 1934. But at his death he was living in Switzerland as a voluntary exile from Nazi Germany.*

Simple as the processes were and plentiful as were the raw materials, the power requirements of these processes were huge. But the power requirements of the Haber process are much less and it can be used anywhere that coal and water can be economically brought together. The process begins when coke is burned in air, changing the air's oxygen to carbon dioxide, which is easily removed, leaving more or less pure nitrogen behind. Then more hot coke is treated with steam; the products are hydrogen and carbon monoxide. When you separate the carbon monoxide from the hydrogen you now have the two essential gases ready for their reaction, and need only compressors, catalysts, and heat to make ammonia. The ammonia may immediately be used for the production of fertilizers, or it may be oxidized to nitric acid for explosives or the production of nitrates for use as fertilizers. Or it can be turned into urea—for which the principal uses today are in the production of fertilizers and urea-formaldehyde plastics.

The Haber process was the first example of a practical chemistry of a new kind—the chemistry of high-pressure synthesis. It is a technique that can be used for more than one end. For example, remember that incandescent coke plus steam produce a mixture of hydrogen and carbon monoxide; upon that combination there hangs another vital industrial development. If a hydrogen and carbon-monoxide mixture is put into the compressors of the same apparatus that makes ammonia, out comes methanol—still known as wood alcohol from the days in which it was produced entirely by the distillation of wood. A change of catalyst is necessary, but otherwise the same plant can be set to work producing an entirely different product. Indeed, Commercial Solvents Corp. a decade ago made this very shift. After building an ammonia plant to consume hydrogen made as a byproduct of its fermentation processes, Commercial Solvents decided that too many other people were going into ammonia making. Then and there it changed its plans and overnight it made a methanol plant bloom from the seed of synthetic-ammonia apparatus. And synthetic methanol has all but ruined the business of the wood distillers.

Hydrogen

IF THE sulfuric-acid phase of chemical industry is an old phase and the chlorine phase a current one, perhaps a future phase is the phase of hydrogen. This lightest of all gases and simplest of all chemical molecules was the gas whose explosion destroyed the airship *Hindenburg* this year. Obviously, hydrogen will never again be willingly used as a buoyant gas in aeronautics; but hydrogen's commercial uses are growing and growing fast. We have seen hydrogen as the product of electrolysis, but electrolytic cells are impracticable to supply large-scale industrial needs. Prime reaction for the production of commercial hydrogen is the one we looked at just above: the interaction of steam and incandescent coke to yield hydrogen and carbon monoxide. You may make ammonia or methanol from this combination just as you wish. But by far the most interesting use of commercial hydrogen is for the process known as hydrogenation.

The hydrogenation of vegetable oils is an old story. If you pass hydrogen over vegetable oils like coconut or cottonseed or peanut, in the presence of a catalyst (usually finely divided nickel), you produce a solid substance useful in cookery. Crisco is such a product: a cooking fat from cottonseed oil, notably cheaper than lard. Large quantities of fish and vegetable oils are hydrogenated for the soap industry.

But other oils and other substances are also happily susceptible to hydrogenation. Petroleum can be made to yield better products (lubricants, gasoline) and to yield them more abundantly when subjected (as in the plants of the Standard of New Jersey and the Standard of Louisiana) to hydrogen under great pressure. Further, the "soapless soaps" in which du Pont and Procter & Gamble are interested are made from the acid parts of fats by another high-pressure treatment with hydrogen. The result yields a material that acts like soap in hard or soft water and leaves no dirty scum on the hair, the dishes, or the bathtub. These soapless soaps need no alkali for their manufacture, unlike the commoner soda soaps, and hence threaten another dislocation in the chemical economic balance.

BUT the most spectacular use for commercial hydrogen lies in the future. That is the hydrogenation of coal to produce liquid hydrocarbons. Because U.S. petroleum resources are still ample there is yet very little heard here about the possible hydrogenation of coal; yet in Germany, England, and Japan the process has already begun.

Its possibility in this country leads the chemist to think that such engineering conceptions as Bonneville and Grand Coulee are already museum pieces. Hydroelectric power has an appeal for the mind largely because no fuel need be paid for to develop power. But the fixed charges saddled upon such a plant are enormous, and the power any electrical plant produces cannot be efficiently transmitted more than a few hundred miles. Meanwhile, says the chemist, no one has been noticing the great increases in efficiency of fuel-burning plants. They come from an increased understanding of the characteristics of high-pressure steam—and also from new synthetic organic compounds like diphenyl oxide, which are in use in so-called bi-fluid boilers—boilers in which a fluid of higher boiling point than water is first heated and made to do work; then, in cooling, heats water above its boiling point, makes it work too.

Therefore the chemist's conception of the future of power does not lie in hydroelectricity. But neither does it lie in plants that are fired by coal that has perhaps jounced 400 miles in coal cars across country to be delivered from mine to point of consumption. Since the hydrogenation of coal produces liquid hydrocarbons, the chemist wants to know why these hydrocarbons should not be processed at the mine mouth with hydrogen made from coal and steam and then pumped in pipe lines, silently and efficiently, for 500 miles or more to the centers of power consumption, there to be burned as fuel for steam engines or in the cylinders of Diesels. And this conception is all the more challenging because the lowest grades of coal or even lignite—too poor in fuel value to warrant mining today—are the very substances that can be best hydrogenated into liquids.