

hardened with any alloyed metal to make the pyrophoric alloy. When Baron Auer von Welsbach and his associates developed the pyrophoric alloy business, they did not form separate companies in each country, but centralized the manufacture of cerium and pyrophoric alloy in the Treibacher Chemische Gesellschaft of Treibach, Austria (a part of the rare earth cartel or trust). As stated above, they established branches of this Austrian company, namely, the Treibacher Chemische Gesellschaft in England, France, Russia, United States, etc., for the purpose of alloying the metal to meet local requirements and selling the alloy. It was not until some time after the first attack on France that a pound of cerium was made anywhere in the world outside of the Central Powers so far as I can learn, and then such cerium was made by the New Process Metals Company, which company operates under our basic patent on metallic cerium. Therefore, to reiterate somewhat for the sake of clearness, until the start of the European war the pyrophoric alloy business of the world was operated as follows:

The German and Austrian rare earth gas mantle cartel or trust turned over to the Treibacher Chemische Gesellschaft a large part of their cerium residues, which the Treibacher Company made into metallic cerium. This metallic cerium the Treibacher Company exported to its branches in France, England, United States, etc., which branches alloyed the metallic cerium with about 30 per cent of iron and other metals, and made the alloy into small pieces, selling these pieces of alloy to the manufacturers of pocket lighters, miners' lamps, gas lighters, etc. The business of marketing the small pieces of pyrophoric alloy was protected by the patent under discussion which has been contested, and, as stated, very broadly sustained in this country. The American branch of the Treibacher Chemische Gesellschaft was established about 1907, and handled all the pyrophoric alloy business in this country.

After August 1914, the efficiency of the British Navy made it impossible for the Treibacher Chemische Gesellschaft to deliver cerium metal to its agency in the United States. They tried by every means to secure cerium metal from Austria, even trying to import it by the submarine Deutschland, but were unsuccessful.

In 1915 the American agency of the Treibacher Chemische Gesellschaft got in touch with a chemical company in this country and tried to have this company produce metallic cerium for them. The company, after working several months, was wholly unable to do so. The president of this chemical company then learned that I had secured my degree from the University of Wisconsin as the result of experimental work on the electrolytic preparation of metallic cerium, and engaged my firm to work out a process for the commercial manufacture of this metal. With me in our joint laboratories were associated my brother and other assistants. After several months of intensive work in the laboratory, metallic cerium was commercially produced of satisfactory quality and in regular quantity, and thereafter the New Process Metals Company was formed which manufactured and sold this material. From that time until April 1917 the New Process Metals Company furnished metallic cerium to the American branch of the Treibacher Chemische Gesellschaft located in New York City.

In April 1917 the manager of the American branch of the Treibacher Chemische Gesellschaft formally notified the New Process Metals Company that he personally, doing business as the American Pyrophor Company, had purchased the business of the Treibacher Chemische Gesellschaft. From April until December 1917 the New Process Metals Company further furnished metallic cerium to this manager doing business as the American Pyrophor Company.

After war against Austria was declared, the property of the American Pyrophor Company, or the Treibacher Chemische Gesellschaft, which ever you choose to call it, was taken over by the Alien Property Custodian of the United States.

From the foregoing it is seen that the New Process Metals Company developed the cerium business in America. From shortly after the start of the war until the autumn of 1917 it was the only company in the world, outside of the Central Powers, making metallic cerium, and the pyrophoric alloy made from this product supplied the needs of the armies and civil populations of Russia, France, England, South America, United States, etc. In this connection, it is interesting to note that the cerium lighters have been extensively used in the trenches, first because of the great scarcity of matches in Europe, and second because of the effect of dampness on matches. We are glad to be able to say that for several years prior to 1918 we supplied the British and French armies with their requirements of pyrophoric alloy. Now this metal, we understand, is being made in France.

The future of the pyrophoric metal business in this country is an interesting field for speculation. We hope to be able to maintain this business to some degree at least. Frankly, it is our potential ability to market our alloy in the form of lighters upon which we rely for the maintenance of our company and it is our hope that our lighter facilities will become so economical as to enable us to successfully meet Austrian competition after the war.

THE FERRO-ALLOYS

By J. W. RICHARDS, Professor of Metallurgy, Lehigh University

A large industry has grown up within the last 50 years, most of it within the last 25 years, which furnishes to steel makers alloys of iron with some of the rarer metals, in order to introduce these rare metals into steel. Such alloys are known as ferro-alloys, because they all contain iron (ferrum); some of them, however, contain more of the rare metal than iron. They were originally made in crucibles, cupolas, or blast furnaces, but are now being made principally in electric furnaces, and their manufacture is one of the principal electric furnace industries.

They are of great importance to the steel industry. The steel maker uses them for one of two purposes: (1) As reagents to take oxygen out of melted steel and thus ensure sound solid castings (ferromanganese, ferrosilicon, ferro-aluminum) or (2) to put into the steel a small or large percentage of the rare metal (ferromanganese, ferrochromium, ferrotungsten, ferromolybdenum, ferrovanadium, ferrotitanium, ferro-uranium, ferroboron).

Let us discuss these two uses. Melted steel, just before taking from the furnace, always contains some oxygen dissolved in it (like the dissolved gas in charged soda water). If this is not removed, the casting made is more or less unsound from cavities or blow-holes. The addition of a small amount of an element or metal with a high affinity for oxygen removes this oxygen and makes the casting sound. Manganese (1 per cent or less) is the cheapest and most generally used reagent for accomplishing this; silicon ($\frac{1}{2}$ per cent or less) is more powerful but also more expensive, and is often used to supplement the action of manganese; aluminum (0.1 per cent or less) is still more powerful and still more expensive, and is used in very small quantities as a final addition to complete the action of the manganese and silicon. All steel makers use one, two or all three of these reagents; manganese and silicon in the form of ferro-alloys, aluminum more often as the pure metal, but ferro-aluminum is sometimes used.

The second use is to make special steels, that is, steels containing such quantities of the rare metal as give to them properties different from plain carbon steels deoxidized by manganese, silicon, or aluminum. Thus we may make manganese steel by putting in 12 to 14 per cent of manganese, making a very tough, hard steel such as is used in mining and grinding machinery, burglar-proof vaults, etc.; chromium (2 to 4 per cent) makes a very hard tool steel; tungsten (15 to 25 per cent) makes high-speed tool steel, which cuts iron while red hot; molybdenum (6

to 10 per cent) has powers similar to tungsten, and is also used in steel for lining large guns. Vanadium ($1/10$ to $1/2$ per cent) makes a very strong steel which resists shock extremely well, as when used for automobile axles; titanium, uranium, and boron impart valuable properties not so easily described. Every one of these materials is used for producing some specific result which is not produced by any other; sometimes combinations of two, three, or four are used in one steel, producing a particular combination of special properties for some special purpose. Some of these materials cost \$5 per lb., and the special steels produced cost up to \$2.50 per lb., but their particularly valuable properties justify the expense. The value of these special steels to the industries, and particularly for military purposes, is very great, so great that the supply of ferro-alloys for their manufacture is an important factor in winning the war.

FERROMANGANESE

This is the oldest of the ferro-alloys. Its manufacture was begun about 50 years ago. It was first made in crucibles, had for a long time been made in blast furnaces, but is now being produced in many places in electric furnaces. It is made with 30 to 85 per cent manganese, 3 to 5 per cent carbon, a little silicon, and the rest iron. The rich grades, 75 to 85 per cent, are preferred by the steel maker, but they require rich manganese ores for their manufacture. The United States has very little rich manganese ore, but large quantities of low-grade ores; one of the present burdens of the steel maker is to use low-grade ferromanganese, in order that we may not have to use ships for importing the high-grade ores from Brazil.

The usual manufacture in blast furnaces is wasteful of both fuel and manganese; the furnace must be run hot and slowly, with very hot blast in order to reduce the manganese oxide ore as completely as possible and not waste manganese in the slag. Yet, in spite of all efforts, from 15 to 25 per cent of the manganese going into the furnace escapes reduction and is lost in the slag. This waste of fuel and manganese has led to the use of the electric furnace, in which fuel is required only as a chemical reagent and not to produce heat, thus saving about two-thirds of the fuel requirements of the blast furnace, while the higher temperature available causes the extraction of manganese to reach 90 per cent, *i. e.*, slag losses drop down to 10 per cent or less. Against these economies must be set the considerable expense for electric power and the smaller scale on which the furnaces run. At the present high prices of coke and manganese ore, and in view of the scarcity of manganese and the high price of ferromanganese, the electric ferromanganese industry is able to exist and make large profits. Whether it can do so when normal conditions return, after the war, is questionable; it is to be hoped that it will be able to do so, because of the economy which it undoubtedly possesses in regard to fuel and manganese.

Steel producers use ferromanganese particularly for making the low-carbon or soft steels, because they can thus introduce the required manganese for deoxidation without putting in considerable carbon. For higher carbon steels spiegeleisen (15 to 20 per cent manganese), a cheap blast furnace alloy, can be used, and is being used at present wherever practicable, in order to save ferromanganese. The best practice with either spiegeleisen or ferromanganese is to melt them in a small electric furnace, and tap from it the required weight to be added to the heat of steel. The melted alloy mixes quicker with and reacts more actively upon the melted steel, while less of it is necessary because less is oxidized by the furnace gases. The saving in manganese by the use of the electrically melted ferro is alone sufficient to justify the expense of melting it in an electric furnace, while better and more homogeneous steel is produced.

FERROSILICON

This alloy may run 15 to 90 per cent silicon, but the most commonly used is the 50 per cent grade. It is made from ordinary silica (quartz or sand), reduced by carbon in the presence

of iron ore or scrap iron. The blast furnace is able to make only the lowest (15 per cent) grade, because silica (SiO_2) is exceptionally difficult to reduce, and under conditions which would reduce 99 per cent of the iron ore in a furnace, or 75 per cent of the manganese ore, only 15 to 20 per cent of the silica present can be reduced, and only a low-grade silicon alloy produced. The higher grades must all be produced in the electric furnace.

The raw materials are ordinary silica, the most abundant metallic oxide on the earth's surface, iron ore or scrap iron (iron or steel turnings or punchings), and coke. Electric furnaces up to 10,000 h. p. have been operated on ferrosilicon (50 per cent grade). At the high temperature required, a not inconsiderable proportion of the reduced silicon vaporizes, and burns outside the furnace to a white silica smoke. This can be largely prevented by skilful furnace supervision. In normal times, the 50 per cent alloy sells at \$45 to \$50 per ton, which is a low price for an alloy so difficult to produce.

Steel producers use ferrosilicon principally for the great activity with which the silicon removes dissolved oxygen from the steel. It is about four times as active as manganese in thus reducing blow-holes and producing sound castings. It is usual, however, to use manganese first to do the bulk of the deoxidation, and silicon afterwards, to finish up the reaction completely. It is particularly useful in making sound steel castings which are cast into their ultimate form and do not have to be worked into shape, because a slight excess of silicon may make the steel hard to forge or roll, whereas an excess of manganese does not have so bad an effect on the working qualities. A particular kind of steel called silicon steel carries 1 to 2 per cent of silicon and yet forges well; this would be classed as a special steel.

The ferrosilicon industry has attained large proportions in countries where electric power is cheap, particularly, therefore, in Switzerland, the French Alps, Norway, Canada, and parts of the United States. Under present conditions it is even profitably run where electric power is relatively dear, as at Anniston, Alabama, and Baltimore, Md. It is a large, interesting, and rapidly growing industry.

FERRO-ALUMINUM

This alloy, with 10 to 20 per cent of aluminum, was made in the electric furnace and used in considerable quantity in steel about 1885-88, but was displaced by pure aluminum as the latter became cheaper. Aluminum is about 7 times as powerful as silicon and 28 times as strong as manganese in acting upon the oxygen dissolved in steel; therefore only minute quantities are necessary, say 1 oz. or up to a maximum of 1 lb. of aluminum per ton of steel. Its use gives the finishing touch to the deoxidation of the steel.

About 1885 the Cowles Brothers, operating the first large electrical furnaces run in America, at Lockport, N. Y., made and sold considerable quantities of ferro-aluminum, selling the aluminum in it at the rate of about \$2.00 per lb., while the pure metal was then costing \$5.00. When, a few years later, pure aluminum sold for 50 cents per lb., the steel makers turned to using the pure metal instead of the ferro-aluminum, and at the present time aluminum is so used in practically every steel works in the world.

There seems to me a distinct opportunity for makers of ferro-alloys to revive the manufacture and sale of ferro-aluminum. Such great advances have been made in the construction and operation of large electric furnaces since 1890, and so much experience has been had in reducing the difficult oxides to ferro-alloys, that the production of 50 per cent ferro-aluminum at say \$100 per ton may be a distinct electric furnace possibility. That would furnish the contained aluminum at about 10 cents per lb., as against 30 cents for the commercial aluminum now used. The alloy should be broken up small before using and thrown in the runner or on the bottom of the ladle, in order that the melted steel may quickly dissolve it as it runs into the ladle.

Such ferro-aluminum would require bauxite (aluminum ore) with iron ore or scrap iron for its manufacture, but there are large deposits of low-grade bauxite rich in iron in Southern France, which could be reduced directly to the alloy, without any additions, and thus furnish very cheap raw material for the operation.

In conclusion, ferro-aluminum is not now being made, but its electric furnace production is a real possibility.

FERROCHROMIUM

Ferrochromium is used for making what is familiarly (but erroneously) called "chrome steel." It makes steel exceedingly hard. Very hard cutting tools, and armor plates to keep out projectiles, are made of it. Only 2 to 4 per cent of chromium may be used.

Several grades are made in the electric furnace, depending on the per cent of chromium (25 to 75 per cent), and the content of carbon (2 to 8 per cent). This alloy takes up carbon so actively in the furnace that it has to be treated subsequently to remove the carbon, down to what can be endured by the steel into which it is introduced.

The raw material for its manufacture is a black ore known as chromite, an oxide of both chromium and iron. If this is mixed with carbon and smelted in the electric furnace, it reduces directly to ferrochromium alloy (often misnamed "ferrochrome"), and highly saturated with carbon (6 to 10 per cent). Steel makers want lower carbon than this, so the alloy is re-melted in another furnace, with more chromite, and the excess of carbon oxidized out. The low-carbon alloy sells for 2 to 3 times the price of the high-carbon crude material.

The cutting off of importations of high-grade chromite ore from Asia Minor has led to intense prospecting in the United States for chromite. Fair material has been found in many places, and at present our country is nearly independent of foreign sources of the ore.

FERROTUNGSTEN

Tungsten (also called "wolfram") imparts curious and valuable properties to steel. A small amount (2 to 5 per cent) has been used for half a century or more, to make the steel self-hardening; that is, a tool of this steel need only be allowed to cool in the air, and it becomes hard, without the ordinary quenching or chilling operation. Larger proportions (10 to 25 per cent) make a steel which stays hard even when red hot. A tool of this material can be run so fast on a lathe, for instance, that it gets red hot from the friction and work, yet keeps hard and keeps on cutting. It is called "high-speed tool steel," and its use alone has more than doubled the output capacity of the machine shops of the world.

The ore used is either wolframite, a black oxide of iron and tungsten, or scheelite, a white oxide of calcium and tungsten. It is found in considerable quantities in Colorado, and some other western states, and imports of this ore have not been necessary during the war. In this respect we are much more favorably situated than the European nations. A plentiful supply of tungsten ore may indeed be regarded as a large factor in the production of cannon and fire arms and all kinds of machinery, and therefore a considerable factor in winning the war.

FERROMOLYBDENUM

Molybdenum has only recently come into large use in steel. Its action being somewhat similar to tungsten, scarcity of the latter metal, particularly in Europe, has led to the manufacture of ferromolybdenum on a comparatively large scale.

The ores are widely distributed but not very plentiful. Molybdenum sulfide, the mineral molybdenite, looks almost exactly like shiny graphite, but it is a shade lighter in color and nearly twice as heavy. It occurs usually as flakes in granite rock, and might easily be mistaken for graphite. Lead molybdate, the mineral wulfenite, is a compound of lead and molybdenum ox-

ides, a yellow to red mineral very prettily crystallized in thin square plates. It occurs abundantly in a few lead mines in the West. It is usually first treated to extract its lead, and the residue then worked for molybdenum. The sulfide used to be roasted to molybdenum oxide, and this reduced by carbon in the presence of iron ore or scrap iron in an electric furnace. It is now smelted directly in the electric furnace with carbon and a large excess of lime along with iron ore or scrap iron. Ferro with 50 to 60 per cent of molybdenum is tapped from the furnace like other ferro-alloys, but with molybdenum up to 80 per cent the alloy has such a high melting point that it cannot be tapped out without freezing; it is necessary to make a furnace full of this alloy and then let the furnace cool down and take it apart, taking out a large mass of solidified alloy; the furnace is then rebuilt.

The large use of molybdenum in steel has been so recent that not much has been made public about it. Rumor says that the large German guns (the "Black Berthas"), which bombarded Liege, were lined with molybdenum steel (6 to 7 per cent) to increase their resistance to erosion. It seems certain that Germany drew considerable supplies of molybdenite from Norway to compensate for shortage of tungsten for high-speed tool steel. Parts of guns, gun carriages, motors, and automobiles have also been made of molybdenum steel of most excellent quality. Canada has been especially active in the manufacture of ferromolybdenum, most of which it exported to Europe. This alloy is therefore another preëminently valuable war material.

FERROVANADIUM

Without vanadium the modern automobile or auto truck would be a much weaker machine. When steel is desired to withstand the heaviest shocks and vibration, nothing is quite so effective as adding vanadium. This is another comparatively rare metal, found principally in the radium ores of Colorado and as a black sulfide on the highlands of Peru. The canary-yellow Colorado ore is treated for radium, and the residues for vanadium and uranium. The United States Government (Bureau of Mines) operates this process for the radium supply. The black ore of Peru is rich and unusual; it is a sulfide with some asphaltic matter, and it is roasted and gotten into the condition of iron-vanadium oxide before reduction. The oxides are best reduced by metallic aluminum. Vanadium oxide plus aluminum produces vanadium plus aluminum oxide slag. This is the well-known thermit (Goldschmidt) method of reduction. Electric furnace reduction by carbon is not advantageous because of the large amount of carbon taken up by the alloy; powdered silicon is therefore put into the charge as the reducing agent, together with iron, lime, and fluorspar, and then a 30 to 40 per cent vanadium alloy is obtained with seldom over 1 per cent of carbon, a very desirable composition (R. M. Keeney).

Only small amounts of vanadium are necessary in improving the steel; 0.1 to 0.4 per cent are the usual quantities. This is fortunate, because the vanadium costs \$5 per lb. and over. Metallurgists suspect that part of the improvement of the steel may be due to the vanadium combining with and removing nitrogen dissolved in the melted steel. This is probably true, yet some advantage undoubtedly must be ascribed to the final vanadium content in the steel; both avenues of improvement function. Steels thus treated are unusually resistant to shock and alternate stresses, making them very useful for axles, cranks, piston rods, and such severe service.

FERROTITANIUM

Titanium is an abundant element in nature. It occurs in immense amounts as a double oxide of titanium and iron, known as ilmenite, or titanite iron ore. This ore can be reduced directly by carbon, in electric furnaces, to ferrotitanium. The reduc-

tion proceeds more easily if some aluminum is put in as a reducing agent, but this is expensive and unnecessary. The alloy running 15 to 25 per cent titanium is sold for use in steel, as a refining agent to remove oxygen and nitrogen. Thousands of tons of steel for rails have been thus treated, the tests showing considerable improvement in the mechanical properties by the use of quite small amounts (0.10 to 0.20 per cent) of titanium. Only one firm in America makes this alloy, and its use in steel has not yet gained universal approval.

FERROBORON

This is another alloy whose valuable qualities have not yet been entirely determined. Boron is the metallic base of borax, which is a sodium boron oxide. Borax is very difficult to reduce to the metallic state. Another raw material, not so abundant, is colemanite, containing lime and boron oxide. Many attempts have been made, none very successfully, to reduce this with iron oxide to ferroboration. The American Borax Company offered a prize, for several years, for a process which would accomplish this. Boron oxide occurs rarely in nature, but it can be manufactured from borax and colemanite. When the oxide is obtained, this can be combined with iron oxide and the resultant boron-iron compound reduced by carbon in the electric furnace to ferroboration. Small quantities of this alloy have thus been manufactured.

Experiments on steel have shown that ferroboration acts somewhat similarly to ferrovanadium. Experiments in France showed remarkably strong and tough steels were thus made, using 0.5 to 2 per cent of boron. The results have not been properly followed up, partly on account of the difficulty in getting ferroboration; no one, as yet, has taken up its regular manufacture, and steel makers can hardly be blamed, in these stirring times, for not having as yet thoroughly explored its possibilities as an addition to steel.

FERRO-URANIUM

This is the latest of the ferro-alloys to enter the lists. Uranium is a very heavy and, chemically, very active element. It is found in small quantity as a black oxide, the mineral pitchblende, the mineral in which radium was first discovered. It is found more abundantly in the Colorado radium ore, a bright yellow oxide and silicate of vanadium, uranium, and lime. After extracting the radium and vanadium, the uranium remains in the residues as a by-product, usually as a soda-uranium compound. This is treated so that uranium oxide is obtained, and this can be reduced by carbon in an electric furnace in the presence of iron ore or scrap iron, to ferro-uranium (30 to 60 per cent). The recovery of uranium is not high (50 to 70 per cent), the rest being lost in the slag. Mr. R. M. Keeney has recently described these processes in detail, for the first time, in the August bulletin of the American Institute of Mining Engineers.

The results of tests showing the influence of uranium on steel are not yet completely known. Some firms have claimed for it wonderful strengthening power and resistance to shock. The subject is now receiving expert attention from steel makers and valuable results are confidently expected.

CONCLUSION

The ferro-alloys are exceedingly important materials to the steel maker, either in the making of ordinary steel or for producing special alloy steels. They are indispensable to the steel industry. They are important factors in producing both ordinary and fine steels, and therefore in winning the war. The country well supplied with them has a great advantage over the country in which they are scarce. They are deserving of all the expert attention which they are receiving from the War Industries Board, the steel makers, and the economists. The possession by the United States of large supplies and resources in the ferro-alloys line will be one of the important factors in determining the quick ending of the war.

SYMPOSIUM ON INDUSTRIAL ORGANIC CHEMISTRY

September 28, 1918

ADVANCES IN INDUSTRIAL ORGANIC CHEMISTRY SINCE THE BEGINNING OF THE WAR

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Many ordinarily intelligent people with no special acquaintance with scientific matters will confess to having had the belief that the United States had no established chemical industries at the outbreak of the present great world war, or if we had any, they did not cover the field of what is known as organic chemistry. Organic chemistry was to them the field of coal-tar dyes and synthetic medicines, and was not this the peculiar and exclusive domain of the German chemical manufacturer? We rather think that this expresses the actual knowledge on the subject on the part of our non-scientific newspaper and magazine writers at the outbreak of the war.

However, the elements which go to favor the establishing of a chemical industry are a wealth of raw materials and a market for the manufactured product, and with these the coöperation of intelligent chemical effort and capital. All four of these elements existed in the United States and the result of their coöperation had already been quite effective long before the beginning of the war in giving us flourishing chemical industries based upon organic raw materials and involving applications of organic chemistry. When we recall the great wealth of this country in petroleum and asphalt, in all varieties of coal, in vegetable and animal oils and fats, in cereals of all kinds, and in fibers of indispensable character, we would be surprised if flourishing chemical industries had not been established.

Let us briefly view some of these industrial organic developments as they existed prior to 1914.

The American petroleum industry easily ranked as the first in importance in supplying the world with the various products of mineral oil.

Of a total annual world's production in 1914 of over 400,000,000 bbls., the United States produced 265,762,000 bbls., or just about two-thirds, while Russia, the next in rank, produced 67,000,000 bbls., or 16.7 per cent of the total amount.

But it is not only the raw material production that is to be considered. By far the larger proportion of this crude oil was refined in the United States and from it were made gasoline, kerosene, lubricating oils in great variety, paraffin and paraffin candles, vaseline and similar products. These products were not alone for the American market but went all over the world.

We also had a great and well-developed industry in the extraction, refining, and working-up of vegetable and animal fats and oils. A peculiarly American industry was the cottonseed oil and cake industry. Hundreds of mills throughout our southern states were devoted to the crushing of the seed and the preparation of the cake, while the refining of the oil and the making of the finest edible products were carried out in large plants. The enormous production of lard and lard oil by our great packing companies and the preparation of oleo oil for foreign shipment was also an important and well established American industry. As a side product, the extraction and refining of glycerin had also become well established and the American soap industry was also well developed and a large export business already inaugurated.

The utilization of linseed oil for paint oils and in the manufacture of linoleum and oil cloth had also reached a high development at the hands of American technologists.

The great naval stores industries involving the production and utilization of American turpentine and rosin had also been well developed and many minor chemical industries based upon them. America was also one of the largest consumers in the world of rubber, and thanks to the manufacture of all classes of rubber and water-proofed goods and to the utilization for automobile tires, the working of rubber had been extensively developed