The ORIGINS *of* SUGAR MANUFACTURE *in* AMERICA

I. A Sketch of the History of Raw Cane-sugar Production in America

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THE home of the sugar cane, as of many other cultivated plants, is India. The Greek soldiers of Alexander the Great found the cane growing in India at the time of their conquest of Asia in 327 B.C., and reports which they brought home are among the first historical accounts of the sugar cane that reached Europe. It is doubtful, however, whether sugar was manufactured from cane as early as this. The cane was first simply eaten; later its expressed juice was used as a beverage; still later this juice was boiled down to a sweet concoction for making preserves or sweetmeats and the crystallization, which took place in such concentrated juice, probably gave the people of India their first ideas of sugar making.

From its native home in India the sugar cane was carried eastward and westward. Its cultivation spread among the native tribes of all the East Indies, the Malayan archipelago, and the islands of the Pacific. None of these islanders, however, ever advanced far enough to manufacture sugar and for the development of this art we must turn to the western nations.

The first people to carry the sugar cane westward were the Persians who made some progress in sugar manufacture. They first made a hard sugar called *Kand* from which our word candy is derived. The original Indian or Sanskrit word for sugar, *sakkara*, became *shakar* in Persian and the same word, variously modified, appears in all the European languages.

It is to the Arabs that we owe the introduction of the sugar cane to the nations of Europe. The Mohammedans, in their conquests of Persia and India, came early in contact with the sugar cane and introduced it to Palestine, Egypt, Sicily, North Africa, Spain, and other Mediterranean countries. In this way the Spaniards and Portuguese became familiar with the cultivation of sugar cane and immediately after the discovery of America transplanted this crop to their colonies in the New World. Columbus in his second voyage, in 1493, carried sugar cane from the Canaries to San Domingo. The manufacture of sugar spread rapidly to Porto Rico, Cuba, the West Indies, Mexico, Brazil, and all the other tropical countries of America. In Louisiana which has a semi-tropical climate, several unsuccessful attempts were made to introduce cane-sugar manufacture but it was not until 1794 (three centuries after the first cane was brought over by Columbus) that the industry was established on a successful basis.

The processes of cane-sugar manufacture in the beginning were very primitive and wasteful, although the three essential stages of the process have continued unchanged through all the centuries. These stages are: first, the crushing of the stalks and expression of the juice; second, the evaporation of this juice; and third, the crystallization and separation of the sugar.

One of the earliest illustrations of cane-sugar manufacture which has come down to us is that of a factory

FIGURE 2.—CANE-SUGAR MANUFACTURE IN SICILY ABOUT 1570

From an old engraving by Filippo Galle of Harlem (1537–1612) reproducing a drawing by the painter Giovanni Stradano (Hans von der Straat) of Bruges (1536–1605).

in Sicily about the year 1570. The sugar cane from the fields was cut into small pieces and then ground up by a water mill; the fibrous pulp was then squeezed out in a press and the juice evaporated in open pans over the fire. The thick, sirupy residue was then poured into conical molds where it was allowed to crystallize. The loaves of raw sugar thus made were shipped to Venice where they were made into refined sugar.

The earliest mills for grinding the sugar cane consisted of a circular stone set upon its edge which was moved in a stone or concrete basin about a vertical axis by means of man or animal power. It is a type of mill still used in the Oriental and Mediterranean countries and was one of the first forms of cane mill to be used in tropical America during the period of colonization.

The old vertical mill stone began to be abandoned in the sixteenth century in the more progressive sugar factories for the roller mill. These first rollers were vertical, the horizontal rollers which are now employed not coming into general use until after the invention of the steam engine. The expressed juice was evaporated in open pans, the impurities which rose to the surface being removed by perforated skimmers as shown in Figure 5. The concentrated sirup, called the cooked mass, or *masse-cuite*, was poured into conical molds where it hardened into the loaves that were shipped to Europe for refining.

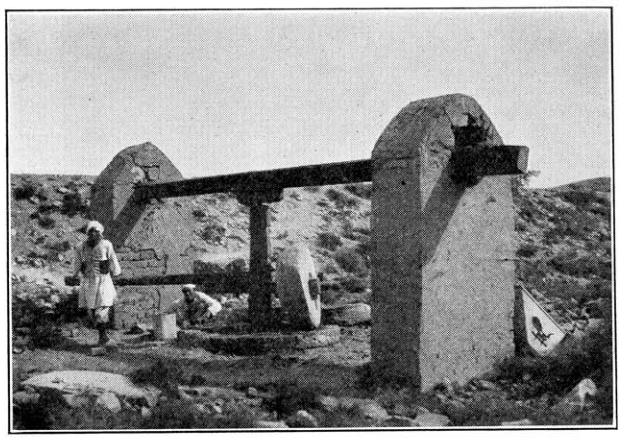


FIGURE 3.—STONE EDGE-RUNNER MILL NEAR LUXOR, EGYPT

This ancient type of mill is still used in the Mediterranean countries for crushing olives, fruit, and other agricultural products.

The early vertical-roll cane mills were cumbersome affairs. The cane had to be passed back and forth between the rollers by hand and at the very best not more than 60 per cent. of the cane juice was extracted, as compared with the modern cane mill which can remove as high as 99 per cent. of the total sugar in the cane. It happened occasionally that a slave lost a hand or arm by getting it caught in the rollers of these vertical mills. Notwithstanding their inefficiency they were a vast improvement over the old stone edge-runner mill.

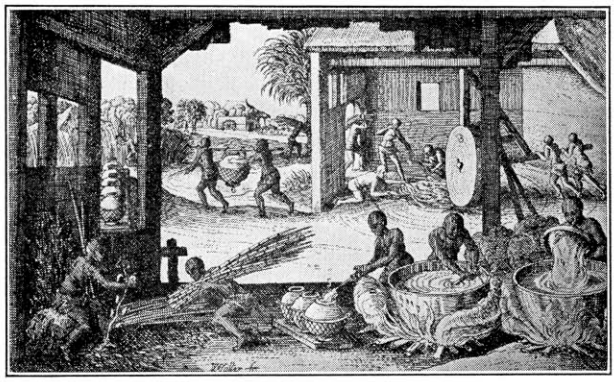


FIGURE 4.—CANE-SUGAR MANUFACTURE IN BRAZIL OF ABOUT 1630

The cane was crushed under the vertical stone grinder which is being rotated by slaves. The expressed juice was evaporated in kettles and the concentrated sirup poured into jars where it crystallized.

From an old Dutch engraving in the Bodel Nijenhuis Museum of Leyden, Holland.

In many countries of the American tropics windmills were used for operating the vertical cane rollers, and ruins of the stone towers of these mills can be found in nearly all the West Indian islands. These windmills are still used to some extent in Barbados for grinding sugar cane. The residue of cane fiber, called bagasse, after the juice was expressed, was spread out in the sun to dry, as seen in Figure 6, after which it was raked up into piles and used as a fuel for operating the factory. Bagasse still constitutes the bulk of the fuel used in tropical cane-sugar factories. In out-of-the-way places in the tropics the visitor may find primitive sugar factories such as this where the methods of manufacture have continued unchanged for three hundred years.

A great revolution in the manufacture of sugar resulted from the invention of the steam engine. The introduction of this great labor-saving invention was, however, very gradual for many difficulties had to be

overcome. It was only after 1800 that the steam engine began to be used in colonial cane-sugar manufacture. Its introduction into Louisiana dates from about 1820. These first engines were all of the vertical walking-beam type, the horizontal steam engine not coming into use in cane-sugar manufacture until about 1830. The old vertical engines, however, were most excellent machines and continued to be used for many years. Some of them are doing valuable service even at the present time.

The student of industrial chemistry will meet with many interesting historical observations upon visiting the abandoned cane-sugar factories of the American tropics. He can trace, as I have done, nearly the whole development of cane-sugar manufacture in the Western Hemisphere. There will be seen all types of cane mills, steam engines, and other mechanical equipment. Ruins of this character can be seen even in our own country as shown in the accompanying photograph (Figure 7) of a horizontal three-roller cane mill that was operated a hundred and more years ago at Port Orange, Florida. Although exposed to the weather for a hundred years the mill is still in excellent condition; the rust-resisting property of its iron rollers has long attracted the attention of chemists and engineers.

About fifty years ago a great revolution was introduced in the milling of sugar cane by increasing the extraction. This was accomplished; first, by subjecting the cane to a preliminary crushing or shredding so as to reduce it to a better mechanical condition before expression between the rollers; second, by increasing the pressure upon the mill rollers by hydraulic power; third, by letting the blanket of crushed cane pass through several sets of three-roller mills arranged in sequence; and fourth, by sprinkling the pressed blanket of bagasse from the first mill with water or dilute cane juice, the imbibed water being then squeezed out in the next mill and carrying with it more of the residual unextracted sugar. It was by this means that the extraction of sugar from the cane has been increased, from the first feeble efforts when 50 per cent. or less of the juice was pressed out, to the present time when over 99 per cent. of the total sugar in the cane can be expressed by the best modern mills. The blanket of bagasse which leaves the last mill contains from 40 to 50 per cent. of moisture and is conveyed directly to the boilers where by means of a special blast burner it furnishes the steam for operating the factory.

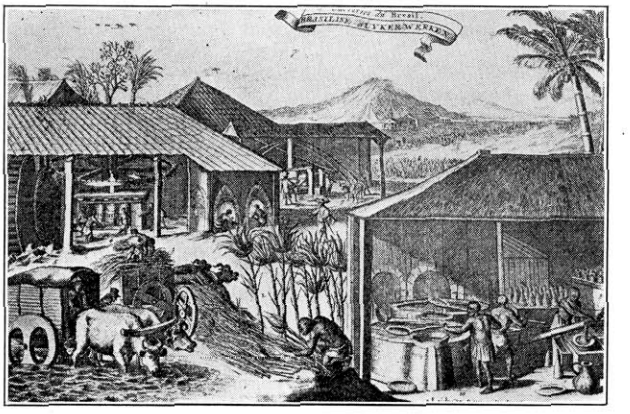
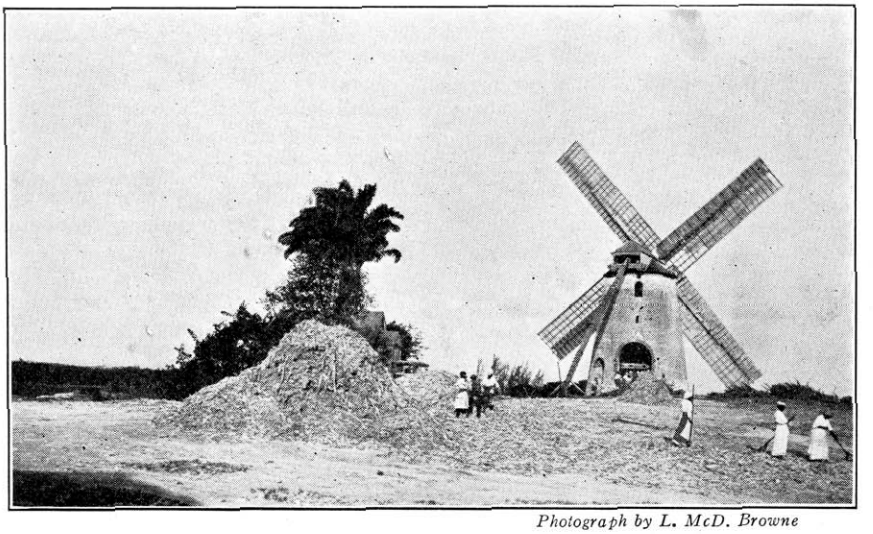


FIGURE 5.—CANE-SUGAR MANUFACTURE IN BRAZIL OF ABOUT 1647

Both water-power and horse-power were used to operate the vertical roller mills.

From an old Dutch engraving in the Bodel Nijenhuis Museum of Leyden, Holland.

It is thus seen that the development of the modern sugar-cane mill, the most expensive and most important part of the factory equipment, was of gradual growth. Many of the world's greatest inventors have been attracted to make improvements in the sugar-cane mill. One of these was the steam cane press (Figure 8) of Henry Bessemer, the inventor of the famous Bessemer steel process. A steam engine operated a large flywheel which moved a powerful pressure block back and forth in a longitudinal steel box with tapering ends. The stalks of sugar cane were fed through openings into the top of this box and were immediately reduced to pulp by the rapidly moving pressure block. The expressed juice escaped through openings in the sides and



Photograph by L. McD. Browne

FIGURE 6.—BARBADOS WINDMILL WITH VERTICAL ROLLERS FOR GRINDING SUGAR CANE

The crushed cane, or bagasse, is dried in the sun to supply fuel for evaporating the juice.

FIGURE 7.—OLD SUGAR-CANE MILL AT PORT ORANGE, FLORIDA

The remains of the horizontal steam engine and ruins of the boiler house are at the right of the mill; the remains of the open-kettle evaporators are in the ruined building at the left of the road.

bottom of the steel box, while the fiber, compressed into narrower and narrower space by the tapering walls of the pressure chamber, was finally eliminated at the ends. Although this cane press was never used, being faulty in principle, it has been stated that Bessemer regarded it as his greatest invention. Mr. Hyatt, the inventor of celluloid, also patented a cane mill which he once stated was his greatest invention although it came into no greater use than the cane press of Bessemer. The history of industry and technology shows many examples of inventors who minimized the value of their greatest discoveries and magnified those of least account.

The greatest loss in early cane-sugar manufacture, next to that of incomplete extraction, was the destruction of sugar by inversion and caramelization, as a result of the high temperatures in the open-kettle evaporators. These evaporators, which were placed directly over a fire of burning bagasse, were usually arranged in a series of five kettles (Figure 9) of diminishing size. In the first or largest kettle the expressed cane juice

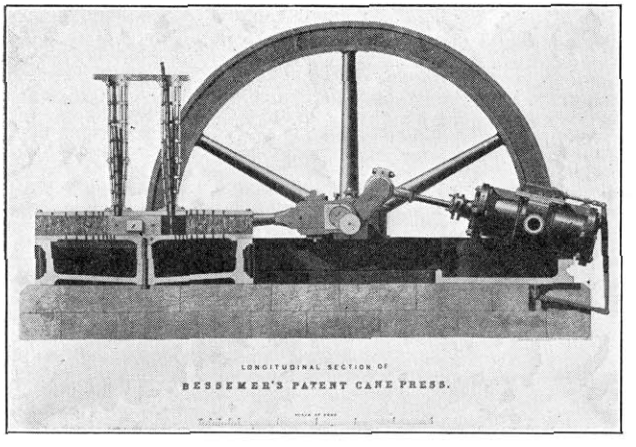


FIGURE 8.—BESSEMER'S SUGAR-CANE PRESS

was heated to boiling with the addition of a little lime water and the coagulated impurities which rose to the surface were removed by skimmers. The partially

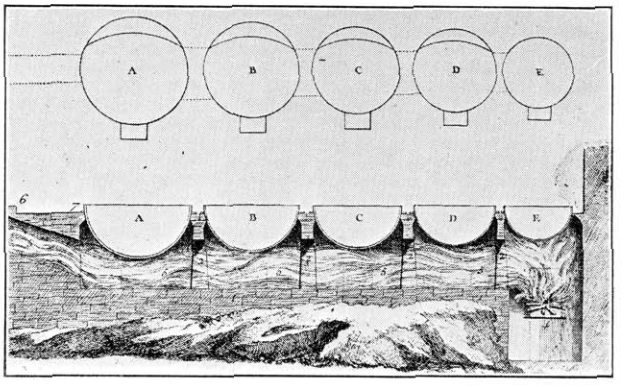


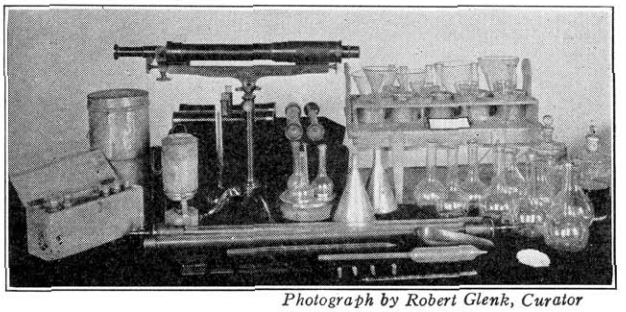
FIGURE 9.—TRAIN OF OPEN-KETTLE EVAPORATORS

The first or largest kettle was placed next to the chimney and the smallest kettle over the hottest part of the fire. In Louisiana these kettles were designated by their French names, A being *la grande*, B *le propre*, C *le flambeau*, D *le sirop*, and E *la batterie*.

clarified juice was then ladled into the next smaller kettle where the evaporation was continued, any further scum of impurities being removed as before. The process of ladling, skimming, and evaporating was continued in the other kettles, the final concentration being accomplished in the smallest kettle which was situated over the hottest part of the fire. The thick *masse-cuite* was then transferred from the last kettle to cooling vats where it was stirred with paddles to promote crystallization.

The first important step toward preventing the destruction of sugar by overheating in the open evaporating kettles was the invention of the vacuum pan by the English sugar refiner, Howard, in 1813. By boiling the sugar solution in a closed apparatus, from which

the air had been pumped, the temperature of evaporation was greatly reduced; losses from inversion and caramelization were prevented, and a much whiter sugar was obtained. The efficiency of the vacuum pan was afterward increased by the addition of the condensing column, which was invented by Davis in 1829. The condensing column consists simply of an upright pipe, some thirty-five feet or more in height. Cold water passing downward through the pipe condenses the vapors from the vacuum pan; this condensation, aided by the barometric weight of the water column produces a high degree of vacuum.



Photograph by Robert Glenk, Curator

FIGURE 10.—EARLY POLARISCOPE AND SUGAR-TESTING APPARATUS

Used by Valcour Aime of St. James Parish, Louisiana, before the Civil War, now belonging to the Louisiana State Museum of New Orleans.

Another great invention, of about that time, was the multiple effect, devised by a native of New Orleans, a mulatto named Norbert Rillieux. He conceived the idea of evaporating sugar juice not in one but in several vessels, and of so connecting these that the hot steam from the evaporating solution in the first effect boiled the solution in the second, and the steam from the second effect boiled the solution in the third, and so on. By increasing the vacuums in the effects as the heating power of the steam diminished, it was found possible to boil off the water in a number of vessels by the heat which was supplied to the first unit of the series. The original patent of Rillieux, No. 4879, December 10, 1846, gives the following description: "A series of vacuum or partial-vacuum pans so combined together as to make use of vapor from the evaporation of the juice in the first to heat the juice in the second, and the vapor from this to heat the juice in the third, which latter is in connection with a condenser, the pressure in each succeeding one being less." The original evaporator of Rillieux was a triple effect and this is now probably the most common form of multiple evaporator, although there are quadruple, quintuple, and even sextuple effects. Where more than three effects are joined, the juice in the first unit is usually boiled at, or slightly above, atmospheric pressure, in order to supply sufficient heat for carrying through to the last member of the series.

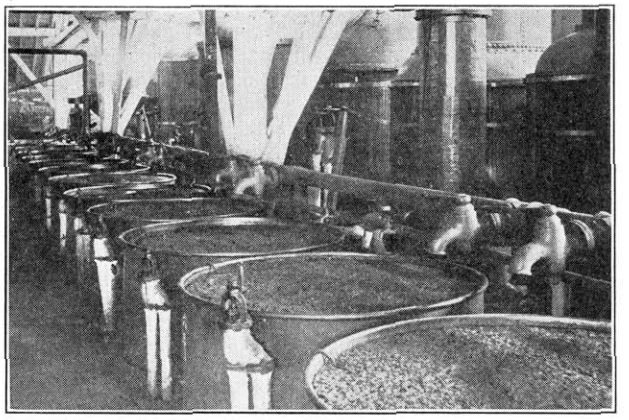


FIGURE 11.—CLARIFYING PANS OF A CANE-SUGAR FACTORY

Showing the scum of impurities upon the surface of the cane juice, after liming and heating.

Rillieux's invention of the multiple effect is one of America's greatest contributions to chemical technology. His invention has brought so many benefits to the various branches of industrial chemistry that the hundredth anniversary of its announcement deserves to be commemorated by the establishment of a suitable memorial.

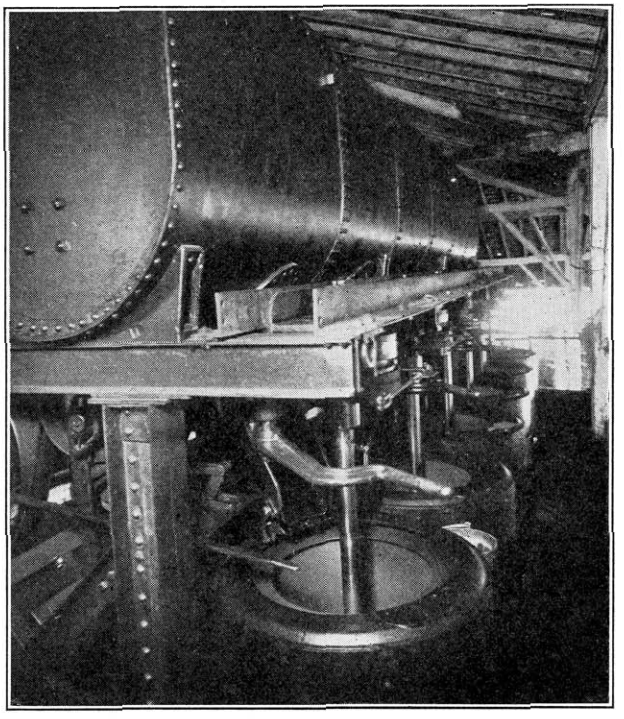


FIGURE 12.—BATTERY OF CENTRIFUGALS IN A MODERN CANE-SUGAR FACTORY

In 1835 the French physicist Biot invented the polariscope, and no single piece of laboratory apparatus has done so much to advance the science of sugar manufacture. It was possible, now, to determine sugar quickly and accurately and the foundation stone of chemical control in sugar manufacture was thus laid. The polariscope began to be used in the United States for sugar testing about 1842. The accompanying photograph (Figure 10) shows a polariscope and other early sugar-testing apparatus that were used at the sugar factory of Valcour Aime in Louisiana during the decade preceding the Civil War.

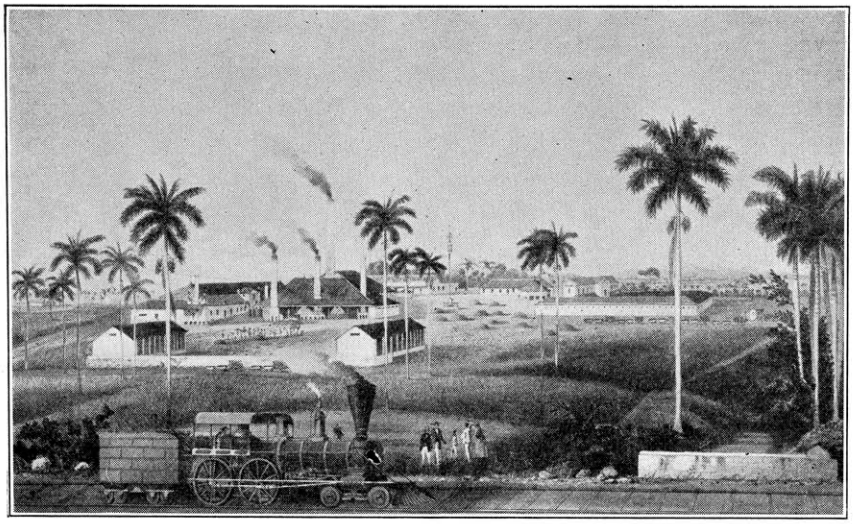


FIGURE 13.— EXTERIOR VIEW OF SUGAR FACTORY, "ACANA," CUBA, OF THE YEAR 1857

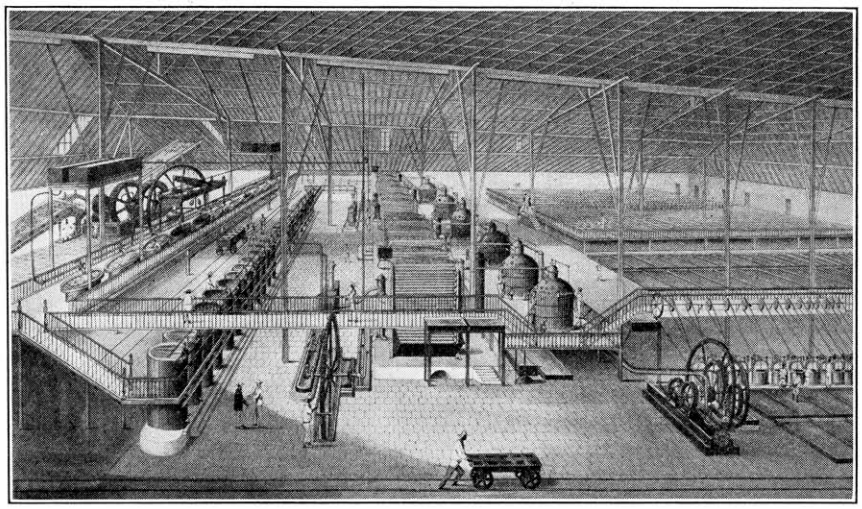
This apparatus can be seen in the Louisiana State Museum in New Orleans.

It was in the mid-century period between 1840 and 1860 that many important improvements were introduced into sugar manufacture. For the clarification of sugar-cane juices, lime and heat are the two agents which have been used from the early days of the industry. In the old method of clarification the insoluble impurities, that were thrown out upon boiling the limed juice, rose partly to the surface where they were removed by skimming and partly deposited where they were eliminated by settling. The accompanying photograph (Figure 11) of a series of clarifiers in a sugar factory shows the thick layer of scum upon the surface of the juice. The skimming and settling of the limed juices consumed much time and labor and these primitive methods were also accompanied by much loss of sugar. A great reform was, therefore, accomplished in 1853 when Needham invented the filter press, which made it possible for the first time to filter off the impurities of clarified juices with neatness and dispatch. There is not time to trace the evolution of this invention, which plays so important a part in modern chemical industry.

Another great improvement in sugar manufacture, introduced about this time, was the application of the centrifugal machine for removing the molasses or mother liquor from the magma of crystals after the sugar had grained. In the old days this was done by allowing the magma of crystals to drain in conical molds which had a small outlet at the point. The labor of handling these molds, the large amount of space which they occupied, and the long period of time required for the drainage of the molasses involved large expenditures of capital. All this began to be simplified in 1843 when Hardman first applied the centrifugal to the purging of sugar. The first centrifugal machines rotated in rigid bearings, but in 1850 Henry Bessemer (whom we have previously mentioned for his cane press) introduced a centrifugal which was suspended from a ball and socket joint—a great improvement that has been handed down to the present time.

It is thus seen that within the space of only a few years four great epoch-making inventions were intro-

FIGURE 14.— INTERIOR VIEW OF SUGAR FACTORY, "ST. MARTIN," CUBA, OF THE YEAR 1857



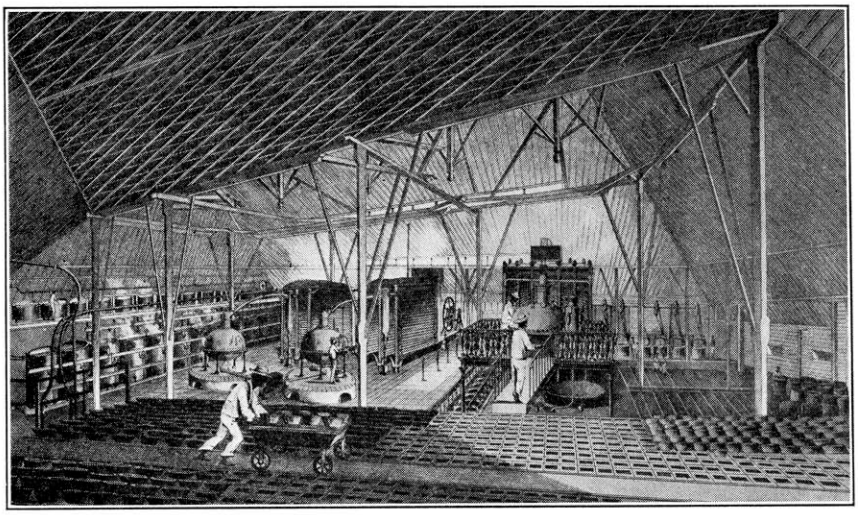


FIGURE 15.—

INTERIOR OF

SUGAR FACTORY,

"LA PONINA," CUBA,

OF THE

YEAR 1857

With "purging floor" in the foreground and clarifying, evaporating, and crystallizing equipment in the background.

duced into sugar manufacture: the multiple effect evaporator, the polariscope, the filter press, and the centrifugal. To trace the historical development of these and the other appliances which are used in the modern sugar factory from their first origin down to the present time is a most fascinating study, but time is lacking to pursue this branch of the subject further.

The processes of cane-sugar manufacture in the interesting decade between 1850 and 1860, when old methods were giving place to the new, are very well illustrated in the accompanying copies of four lithographs of Cuban factories published in 1857.

The first picture (Figure 13) shows an exterior view of a model sugar factory and plantation of this period, with an old-style locomotive in the foreground, cane fields, extensive factory buildings with their smoking chimneys, lines of cane carts drawn by oxen, slaves at work spreading out the wet bagasse which after drying in the sun was raked into piles for burning under the boilers, and the large quadrangular building which was the slaves' quarters.

The next picture (Figure 14) gives a very extensive view of the interior of a large cane-sugar factory of eighty years ago, with its very orderly arrangement of equipment. At the left is the three-roller cane mill operated by a walking beam engine with enormous fly-wheel and cumbersome gear transmission. From this mill the juice was pumped into the adjacent battery of twelve clarifiers where lime was added, the juice heated, and the coagulated impurities removed by skimming and settling. The filter press does not appear in any of these pictures. The clear juice from the clarifiers (proceeding always toward the right of the picture) was next filtered through a battery of twenty-four bone-black filters which removed all the coloring matter. All the better equipped sugar factories of this period made white sugar for direct consumption and it is interesting to note that, after a long discontinuance of the practice, many tropical sugar factories are now returning to this procedure. The decolorized juice from the bone-char filters was next concentrated by letting it trickle down over the surface of the coils of twelve Cail evaporators which condensed the steam from the battery of six vacuum pans arranged along the middle of the sugar house. The Cail evaporator served a double function as condenser of steam from

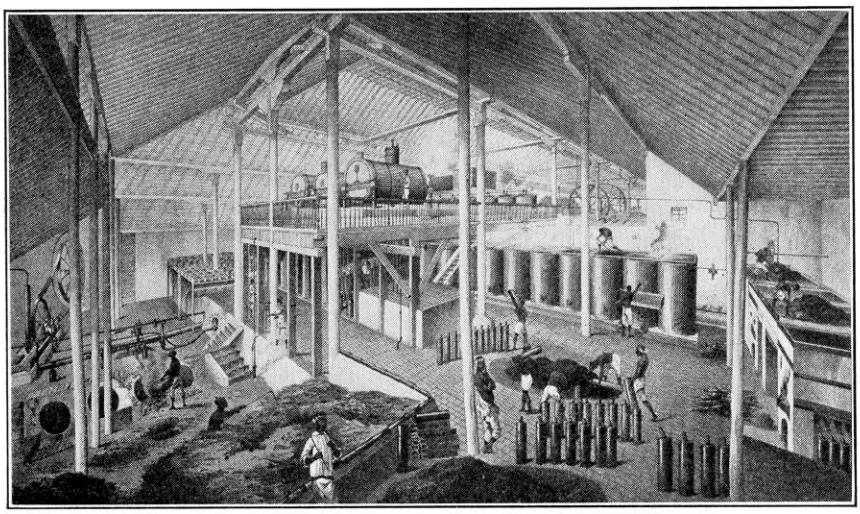


FIGURE 16.—

INTERIOR OF

SUGAR FACTORY,

"ASUNCION," CUBA,

OF THE

YEAR 1857

Showing early type of Rillieux triple effect on the gallery, bone-char filters in the rear, and kiln for revivifying bone char at right.

the vacuum pans and as evaporator of juice. It helped to conserve heat and although a great improvement over the old-style fire-heated open kettles could not approach in efficiency the Rillieux multiple effect by which it was soon superseded.

The sirupy juice from the open-coil evaporators was next concentrated in the vacuum pans to a thick stringy mass, called *masse-cuite*, which was run into large open coolers or trays (seen underneath the pan floor and at the right of the picture) where the sugar was allowed to crystallize. When crystallization was complete the magma of crystals and molasses was either spun out in centrifugals shown in the right foreground or else poured into molds which were placed on the "purging floor" which occupies the rear of the factory at the right. The molasses which drained away from the centrifugals and molds was usually fermented into rum.

The next picture (Figure 15) gives a nearer view of the "purging floor" of a Cuban sugar factory of this period. The molds after filling with the magma of sugar crystals from the cooling trays were wheeled by hand on a small truck to the "purging floor" and placed in small openings through which the adhering molasses trickled into tanks. The arrangement of the clarifiers, char-filters, Cail evaporators, vacuum pans, cooling floor, and centrifugals is similar to that of the previous picture.

The next picture (Figure 16) shows several very interesting features. At the left is the bagasse pit where the sun-dried bagasse was thrown by slaves from baskets into the fire-box underneath the boilers. On the gallery above is shown a new Rillieux triple-effect closed-coil vacuum evaporator which in this factory had replaced the open-coil evaporators shown in the previous pictures. Underneath this gallery at the rear is shown a battery of ten bone-char filters with a slave removing the spent bone black from one of the filters. At the right is a kiln for revivifying the spent bone black with two slaves filling the retorts. The receptacles in which the revivified bone black was delivered from the retorts, and where it was allowed to cool, are shown underneath the kilns and upon the floor of the factory.

These four rare lithographic prints give an accurate picture of the state of the cane-sugar industry as it existed eighty years ago. Although there were many improvements yet to come in the construction of mills, in burning bagasse, in clarifying, filtering, and evaporating juices and in graining, crystallizing, and curing sugar, sugar manufacture at this period had reached a high state of development, vastly superior in the best factories to some of the primitive places which can still be seen today and comparing not too unfavorably in some of its features with the best factories of the present time.

(*Part II will appear in the July issue.*)