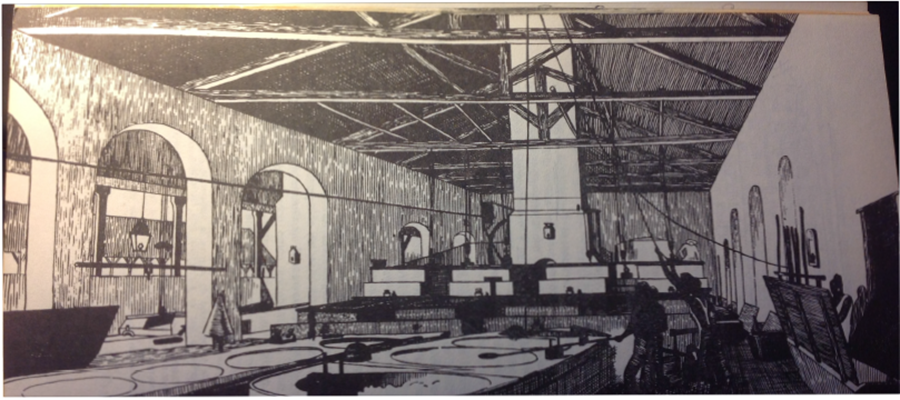
**Dan Rood, University of Georgia**

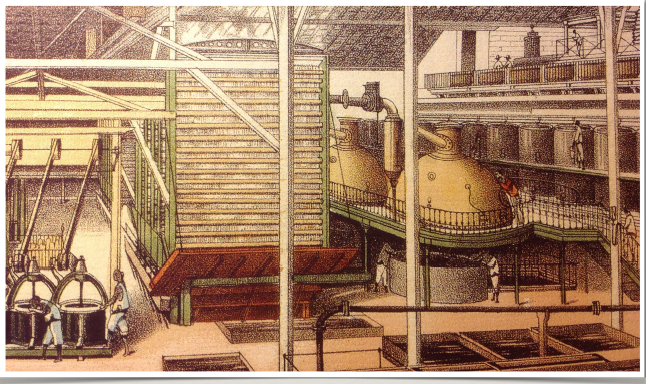
**“A Republic of Blueprints: the Creolization of the Industrial Revolution in the Cuban Sugar Mill, 1830-1860”**

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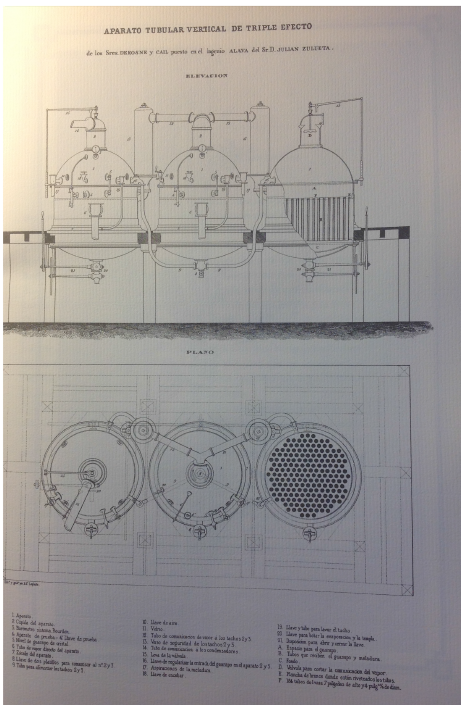
*Sugar-processing in English: "the Jamaica train,"ca. 1830 (single effect)*

*(From Manuel Moreno Fraginals, El Ingenio, vol 1, 219.)*

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*Derosne serpentine condenser, 1842. Installed at the Santa Rosa sugar mill,*

*Matanzas, Cuba. Justo Germán Cantero, Los Ingenios: colección de vistas de los principales ingenios de azúcar de la Isla de Cuba (Madrid: CSIC, 2005) orig 1857.*

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*The "triple effect condenser," installed at the Alava sugar mill, Cardenas, Cuba between 1853 and 1857.*

*From Cantero, Los Ingenios.*

**Introduction**

In the 1820s through the 1840s, Cuban society was marked by a cycle of slave rebellions raised in response to the ever-intensifying misery of the sugar plantation. The latest and largest insurrection, involving both the enslaved, as well as free people of color, was uncovered by the authorities, leading to bloody reprisals against both slaves and free Afro-Cubans throughout the year. In honor of the colonial state’s brutal affirmation of the racial status quo, 1844 was dubbed “the year of the lash.”[[1]](#endnote-1) The year that saw the execution of the radical mulatto poet Plácido, as well as the toture and execution of hundreds of black Cubans also saw the first “Derosne vacuum pan” apparatuses tried on the most advanced sugar plantations. Although one story swells with drama while the other sags under the weight of its own seeming ordinariness, the crushing of Afro-Cuban resistance and the revolutionizing of Cuba’s forces of sugar production were intimately related.

Technological improvements in sugar-making and increases in slave exploitation represented decisive moves on the part of a fractious elite of creole planters, peninsular merchants, and colonial officials, to overcome the privileged, protected position of British and US refiners and sugar producers. They were searching for ways to get their hand on the tiller of a worldwide capitalist division of labor, reaching out from the semiperiphery to safeguard the value-added final phases of refining for themselves.[[2]](#endnote-2) By combining the familiar (the management of a segmented, racialized, and coerced labor force) with the novel (new technologies of transport and new geographies of production), this group navigated seismic shifts in the Spanish empire, as well as the global economy, reclaiming Cuba’s place as the major player in world sugar production while powerfully reaffirming the place of slavery within that world.[[3]](#endnote-3)

While in 1827 Cuban mills produced 74,380 tons of sugar, by 1861 they boxed 477,660 tons. The productivity per mill also skyrocketed, from an average of 74.4 tons per year to 328.8 annual tons.[[4]](#endnote-4) Cuban plantations outpaced increasingly insistent competitors in the eastern Caribbean, Brazil, South Asia, and the Pacific islands: while in 1820, Cuba accounted for 13.64% of the total world production of 402,425 metric tons of sugar, by 1850, Cuban planters, merchants, and officials could claim over one-quarter of a total world production that had itself more than doubled in the thirty intervening years.[[5]](#endnote-5) The 1850s would see a yet more rapid expansion of export figures, which was premised partly on technological transformation, and partly on a profound reshaping of Cuba’s workforce.

Although Cuban slaves had been unique in the Caribbean for the diversity of their employments, they were swiftly and decisively re-concentrated in the sugar plantation sector during this time. US, Spanish, and Cuban merchants continued the illegal slave trade to meet sugar planters’ burgeoning demand for labor as railroads opened up new parts of the countryside to potential cultivation. While in 1827 there were 270,000 enslaved people on the island of Cuba, 370,000 slaves were counted in the 1862 census, and the proportion of total captives working on sugar plantations rose from 25% to 50% -- a massive reapportionment of resources.[[6]](#endnote-6) The rationalization of labor control accompanied increasing mechanization: as Dale Tomich puts it, “slave labor was no longer a question of the reciprocal duties of master and servant, but simply a quantity of labor to be applied in a given amount of time.” In the age of the mechanized *ingenio*, management priorities shifted “toward an instrumental concern with establishing the optimal social conditions for exacting the greatest amount of labor from the slave population and increasing the productivity of the plantation enterprise.”[[7]](#endnote-7) In other words, slavery continued to undergo a ‘creolization from above’ that had long characterized flexible forms of labor control in Caribbean slave societies.[[8]](#endnote-8) Instead of housing captives in individual family huts (bohios), for example, planters built gigantic *barracones*, which were essentially prisons housing a thousand or more captives overnight. Much less freedom of movement, autonomy, and control over family lives – often separated by gender and by race. Racial architectures of work.

The plantation was reshaped by the epistemological dictates imposed by mass production, and in direct response to new challenges that had arisen for the sugar export economy after about 1830.[[9]](#endnote-9) Between the 1830s and 1850s, Cuban planters found themselves buffeted by successive waves of competition and new challenges from several sides, not least in the form of slave rebellion. Filibustering expeditions from North America infringed upon colonial sovereignty, while British authorities sought to enforce anti-slave trade treaties signed by the Spanish (especially the Mixed Commission agreement of 1817), raising Creole Cuban fears of impending abolitionist invasion. In response, jumpy metropolitan authorities clamped more tightly onto their most valuable remaining colony, demanding more tax revenue from planters.

The Panic of 1837, which set off a decade-long recession throughout the Atlantic world, brought these disparate trends into focus, creating a time of financial difficulty for Cuba’s sugar elite. In an 1842 address, well-known planter Julian Alfonso gave voice to the general feelings among his cohort on the island: “Today the face of things has changed, gentlemen. Just as we used to see so much prosperity, wealth, and hope, now we see nothing but a sad future, because misery and discouragement are inseparable companions of our agricultural and commercial sectors, both in ruins today.”[[10]](#endnote-10) The ensuing two decades saw rapid change across the western half of the island, with railroads, port infrastructure, the extension of cane plantings, the growth and intensification of slavery, and finally, the technological transformation of the sugar mill.[[11]](#endnote-11)

In this chapter I trace the transformation of the mid-19th century Cuban sugar plantation into a place of experimentation, a laboratory subsidized by planters, merchants, financiers and the colonial government with the goal of making over the island’s slave-centered mode of production according to the priorities (quantity, efficiency, scale and speed) of the Industrial Revolution that had been transforming the ways and means of commodity production in other parts of the Atlantic world.[[12]](#endnote-12)

This is not a story of metropolitan diffusion, rather a local and trans-Atlantic creole response to the failure of diffusion.[[13]](#endnote-13) The Cuban planters, scientists and government bureaucrats dedicated to this transformation reached out to Europe, North America, neighboring Caribbean islands and beyond for foreign expertise, capital and hardware. Instead of viewing technological advance as *either* a foreign import or an indigenous development, I show how the plantation became, among other things, a filter through which innovations both foreign and domestic could be assessed. The technological transformation of the grinding, boiling and draining aspects of sugar manufacture was a mix of local inventions and importations from Europe and elsewhere. Each of the most important innovations was subjected to extensive trials on tropical sugar plantations in Martinique, Guadeloupe, Louisiana, Borbon, and especially, Cuba. Marketability of new technologies was dependent upon their having endured the ordeal of a real sugar harvest. Engineers, capitalists, planters, chemists, and government officials circulated throughout these plantation islands, the U.S. and Western Europe. In their travels, they participated in experiments, wrote official and private reports, and corresponded with one another, collaborating in the refinement of the new hardware of sugar production, making it fit to bear a price tag and claim a place in the brochures of iron-working firms. In this way, both the vectors of invention and the modes of argumentation characteristic of the plantation laboratory make difficult the project of territorializing the sources of innovation, or the personnel involved as either metropolitan or colonial, *peninsular* or *criollo*, *yanqui* or *cubano*. Legitimacy to a certain extent depended on their ability to be both, or neither.[[14]](#endnote-14)

As Jonathan Curry-Machado points out in his exciting new research on British engineers in Cuba, traveling machinists were key agents of industrial technology transfer, since they had knowledge both of the point of machine production in England, and how best to adapt it to fit the local needs of the machine consumer in Cuba. Working class English and North American maquinistas often pioneered innovations while on the island, based upon what they learned there. The seasonal nature of the work allowed them to travel back to producer areas and fill orders that planters placed with them.[[15]](#endnote-15) The *maquinistas* were dispatched by the wealthy planters who employed them — however, back in Europe these men “did not function as simple messengers, but were able to exert quite considerable influence both over the details of the orders and with whom they should be placed.”[[16]](#endnote-16) Building upon their practical experience in the sugar mill during the rush of the harvest, many *maquinistas* actually contributed to technological development in their own right, inventing new mechanisms and filing patents for them in Cuba.[[17]](#endnote-17) Since Cuban planters and scientists collaborated actively with British engineers in the fine-tuning of sugar-refining apparatuses, these inventions themselves should be thought of as collectively authored, as the products of peregrination. Because artisans were undergoing a deskilling process in England, “these downwardly mobile but ambitious journeymen could change their fortunes, like many strivers before and after them, in the tropical colonies. Not only could they make much better money in Cuba, but they were given the opportunity both to become bosses, and to “become white.””

However, plenty of non-Anglos participated in the industrialization process, at different levels. Bridging scientific and technological concerns in a thoroughly transnational exchange of texts, technical drawings, and actual hardware, diverse networks of plantation experts formed what Leida Fernandez Prieto has called the “global tropical archipelago of sugar knowledge.” This global Republic of Blueprints shared elements both of a bourgeois republic of letters and an artisanal network of itinerant Atlantic craftsmen, as well as being rooted in assumptions about the particularity of the tropical sugar island.[[18]](#endnote-18)

The plantation laboratory was a new kind of space, for the crystallization of the new kinds of scientific identities. Nineteenth century ideas of climatic specificity and the differing racial makeup of worker populations profoundly shaped technological trajectories. Especially Cuban climate and what experts called “el principio sacarino” sharply delimited the applicability of European inventions to the Cuban setting. In the case of the “global archipelago of sugar knowledge,” knowledge and novel subject positions were produced by way of a rich dialectic, a complicated back-and-forth play between global literacy and local expertise, which emphasized the climatic and economic specificity of the Cuban sugar complex, as well as the botanical exigencies unique to sugarcane.

Since the levels of sucrose present in sugar cane decline quickly and steadily after cutting, continuous flow of production was a primary concern, a fundamental *chemical* necessity, not merely an economic goal, as it was in other kinds of production. In fact, scholars going back to CLR James have noted that, since sugar cane had to be processed within hours after it had been cut, the organization of labor and the flow of materials from the field through the factory that presaged the kinds of assembly-line speed-ups that would not be seen in Europe until the late 19th century. Knowledge production in this most important industry thus had to keep pace with and be rooted in, the intense rhythms of labor and technology in motion. Without mirroring the plantation’s tempo and without feeling its heat, creole scientists in the archipelago of sugar knowledge claimed, truth claims could not be trusted.

Cuban chemists and planters thus tapped into and transformed traditions of creole empiricism, in which credible knowledge about the colonial world could not be made from the comfort of an armchair or laboratory in Europe, but had to be rooted in everyday intimacy with an American nature at once fecund, degenerative, and dangerous – giving colonial whites an ambiguously privileged position within London- or Paris-centered scientific networks. While considerable work has been done examining this phenomenon of “creole empiricism” in 18th century natural history, plantation technocrats brought a sense of tropical authenticity into the factories of the tropics, challenging the universalist presumptions and apolitical self-image of European industrial sciences.[[19]](#endnote-19) The sugar-based Republic of Blueprints insisted instead that the Industrial Revolution would be creolized.

**“The Single-Effect”: Sugar-processing in English**

While many of the larger sugar mills had undergone considerable modification, installing state of the art, steam-heated “vacuum pans” to evaporate and refine sugar, a typical Cuban plantation of the early 1840s still processed sugar through a system known as the “Jamaica train.”[[20]](#endnote-20) Sugar plantations in the Greater Caribbean had long unified agricultural and manufacturing stages of sugar-making. Unlike contemporaneous movements for “scientific agriculture,” however, Cuban planters increased productivity through refined stratagems of labor coercion, and accessing untilled soils. Due to the ambition to make white sugar, far more resources were invested in transforming the mill than in reforming cultivation practices. Declining soil fertility in the fields was typically resolved by using railroads to expand the sugar frontier ever eastward across the island, burning old growth forest, and capitalizing on short-term fertility boosts from the resulting wood ash.

Immediately after extracting the juice by passing the canes through a roller mill (whose three iron wheels were turned either by oxen or, increasingly, by steam engines), workers transported the cane juice to the boiling house which held the Jamaica train: a row of open-lid cauldrons heated by one fire and a reverberatory furnace that conducted the heat underneath them. Each batch of cane juice passed through the cauldrons, which held hundreds of gallons on larger estates, in succession. First, the clarifying pan, in which the juice was heated and quicklime was poured in, which bonded with the byproducts and floated them to the top where slaves skimmed them off; then two evaporating pans to reduce the juice, and finally the “strike” pan, in which the transformation of the cane juice into granulated sugar occurred. The moist, brown, granulated sugar (*mascabado*) which resulted was then packed by workers into cone-shaped receptacles with a hole at the apex, and hung upside-down to drain off the molasses, typically leaving three grades of sugar in the cone: white at the top, yellow or “quebrado” in the middle, and wet brown stuff called “cucurucho” at the bottom. After two to three weeks of drainage, the artisan sugar master or another trusted operative in the mill broke open the mold and carefully sliced the loaf into those three grades. It was then ready to be broken up, packed into boxes and shipped. The two lower grades would be further refined in the receiving country, while the white, depending on its quality, might be sold directly to consumers as “unrefined white” sugar.

In the minds of plantation technocrats, the Jamaica train presented serious shortcomings. Planter Justo Germán Cantero got to the point: “Sugar-mills were established primarily with the goal of manufacturing purged white sugar” that would need not further refining in consuming countries. However, due to the worsening scarcity of labor and foreign countries’ favorable duties on “inferior classes” of sugar like muscovado or reconcentrated molasses, and “above all by the difficulty of obtaining in our jamaica trains white sugar that can compete with those using European refining procedures,” many mills had fallen back to making the lower-value byproducts.[[21]](#endnote-21) Of each cone of sugar made by Jamaica train technology, only about five percent of the mass was of the high-value sort, the vast majority consisting of cucurucho or even muscovado.[[22]](#endnote-22) This was because sucrose is a finicky molecule, breaking down into its constituent parts of fructose and glucose under the influence of excessive heat, exposure to air, and the action of micro-organisms. “Inverted” cane sugar, as this was called, was wet, brown, cheap, heavy for shipping, and difficult to extract the remaining sucrose from. While critics of the Jamaica train did not yet speak exactly in modern molecular terms, they were in the process of figuring out just how much of the sucrose present in fresh cane juice was inadvertently converted into molasses by the slow pace and temperature imprecision of the Jamaica train process.

Fuel efficiency was at least as important. The rapidly deforesting countryside of western Cuba, as well as the lack of local sources of coal on the island, had actually inspired the diffusion of the Jamaica train after 1800, complicating ideas that technical innovations should be understood primarily as “labor-saving devices.” In models that had preceded the Jamaica train, each cauldron had had its own furnace and fire. Using a single fire, and passing the heat under the row of pans by way of a reverberatory furnace, the Jamaica train welded a succession of individual processing units into a single, clumsy but fuel-efficient machine, fixed to the singular time frame characteristic of sugar-making. Although the governing concept of the Jamaica train was to economize on firewood, cooking in open air pans still wasted a lot of heat energy.

Not only did the fire-heated, open-air pans continue to consume regrettable amounts of fuel, but the system was also very slow, requiring long processing times. As sugar chemist José Luis Casaseca observed, one batch in the Jamaica train from the entrance of the guarapo into the first clarifying pan until its exit from the last pan in the form of dense syrup, “ready to give good grain with stirring and cooling, lasts four an a half to 5 hours.”[[23]](#endnote-23) All the while, quickly oxidizing cane piled up in front of the mill. Louisiana planter (and future Confederate Secretary of State Judah Benjamin) pointed out that the slow pace means the Jamaica train “consumes a large quantity of fuel, amounting on an average to 2 1/2 cords of wood per hogshead [of sugar].”[[24]](#endnote-24)

The long cook required by Jamaica train technology was not only costly in terms of fuel. It also accelerated inversion. This was the phenomenon the Spanish writer and famous observer of the sugar industry Ramón de la Sagra was referring to when he criticized the Jamaica train “for its absurd and pernicious concave pans, designed, it seems, with the intention of destroying the grain, burning the sugar, and converting it into syrups.”[[25]](#endnote-25) Inversion was a serious economic problem, Judah Benjamin informed his readers, “as molasses rarely sells for more than one third of the price of sugar per pound.”[[26]](#endnote-26) Find ways to lower the heat, and shorten the time of processing, and you'll reduce inversion, conserving more crystallizable sugar. And the less production of invert sugar (i.e. molasses or syrup that would cling to the sucrose crystals), Casaseca observed, “the better will be the color and quality of the sugar obtained.”[[27]](#endnote-27) Simple quantity also mattered. Improved processing equipment, which might squeeze more sugar out of every gallon of cane juice, could help offset declining agricultural yields, which consistently plagued soil-mining Cuban planters.

For Benjamin, “pure, crystallized sugar” is “natural,” while molasses, “far from being naturally an element of the juice, is in reality manufactured by our imperfect process.”[[28]](#endnote-28) For plantation technocrats, refining sugar did not de-nature food, as we might think of it today. On the contrary, processing progressively peeled off layers of excess, and a batch of dry, white sugar, simple carbohydrates with no other nutritional elements, was the true and natural essence of the sugar cane, an endpoint of its life cycle, rendered pure by modern methods. Pure whiteness was the core identity of the organism, and the judicious application of technology should liberate white crystals from the “colored” byproducts clinging to them. Their botanical reading mirrored fears of “Africanization” that followed the year of the lash. The Africanization scare, as it became known, was a panic about the demographic takeover of Cuban society by blacks and people of color. Encouraging white colonization from Europe, and even looking forward ambivalently to the end of the slave trade, the Africanization scare of the 1840s paralleled the anxious pursuit of whiteness in the sugar mill.[[29]](#endnote-29)

The Jamaica train, then, was marred by problems environmental and economic, violating precepts for profitable sugar production. These problems, so particular to the Caribbean setting, had led a large group of elite planters to import the latest technologies developed in Europe’s beet sugar refineries. Through a lengthy process of plantation experimentation, sharing of experience, and investigatory sojourns, however, they discovered that the same exceptional conditions that condemned the Jamaica train to obsolescence also made the haphazard, wholesale importation of European technology problematic. The Industrial Revolution in European sugar refining would need to be creolized, and by 1860, a mere thirty years after the Jamaica train had become popular across the island, the process was well advanced.

Casaseca thought he was kicking off attempts to supercede the Jamaica train when he toured European refineries in 1842, hoping to bring back the best technologies. In his zeal to redeem those he viewed as backwards Caribbean sugar planters, however, Casaseca overlooked experimental efforts already being conducted on the island. Cárdenas planter Wenceslao Villa-Urrutia, who already had a Derosne system operating on his estate, was one step ahead of the Havana-based chemist. “It strikes one as a strange, singular circumstance,” Villa-Urrutia reflected sourly, “that Mr. Casaseca, upon leaving for Europe, was unaware of the fact that the Derosne apparatus, which he had gone abroad to investigate, was already established here and had been in operation during the previous harvest as well.” The insulted planter found it “difficult to explain” how Casaseca had managed to remain ignorant of the fact that he had already used the Derosne apparatus for two successive seasons, and that Derosne himself had even been a guest on Villa-Urrutia’s plantation, “personally directing the experimental first run of his system.” Showcasing his own far-reaching connections within the global archipelago of sugar knowledge, Villa Urrutia also pointed out that “the selfsame Mr. Derosne who three months before was here in Havana,” overlapped with Casaseca in Paris. Inexplicably, the Cuban chemist had “failed to confer” with the well-known French manufacturer.[[30]](#endnote-30)

Villa Urrutia called for Casaseca to return to the island in order to “*study on the land* the real inconveniences or difficulties that the adoption of the Derosne trains may present.” Demanding experimentation on the Cuban plantation itself, Villa-Urrutia also seemed to suggest that witnessing a machine’s operation in a Parisian refinery, as Casaseca had recently done, missed the point. Villa Urrutia, however, protested too much: how would he have learned of the Derosne apparatus without looking abroad? In spite of the rhetorical points Urrutia was able to score on Casaseca, time would prove that they were both right: investigatory trips abroad would be coupled with sustained experimentation at home. Plantation technocrats drank in new ideas from the global archipelago of sugar knowledge, and worked out those ideas in daily practice, a process Sagra evoked with his throwaway line about the “thousand experiments” for which Cuba’s mid-century sugar-mills had been the setting. Cantero spoke of the “satisfaction” he felt when, being told that “in the Exposicion Universal of Paris, intellectuals were admiring the ingenious system of using escape heat for great fuel economy,” he could point out that “such a system had already been in use on the Island of three years.”[[31]](#endnote-31) Rejecting their peripheral role in an Atlantic division of knowledge, Creole elites like Villa-Urrutia and Cantero were simultaneously rejecting their peripheralization in a changing geographic division of labor in the world economy.

**The Sugar-Mill as Artificial Agro-Ecosystem**

A liquid boils when there is enough energy in the molecules in the body of the water to overcome the atmospheric pressure that holds them in place. The higher the atmospheric pressure, the more energy is required for the molecules to overcome it and escape into the air (this is why boiling temperatures decrease at high altitude). Thus, lowering the air pressure by creating a vacuum around the liquid lowered boiling temperatures substantially. Driven by a steam engine, new vacuum pumps designed in Europe sucked the air out of a closed chamber, allowing cane juice to reach boiling point at as low as 130°F, whereas in open air the juice would have to be raised to 235 or 240°, in order to bring a juice of 42 or 43° density to a boil. Under a vacuum, then, the watery constituents of the cane juice departed the mixture rapidly.[[32]](#endnote-32)

While use of vacuum power was largely a mode of temperature and pace control in European refineries, the pneumatic principle would take on additional significance in the global tropical archipelago of sugar knowledge, because heat, humidity, and the nature of the cane plant itself (cane juice, it was said, was denser than beet sugar juice at the same temperatures, requiring more energy to boil) made inversion all the more likely. Wealthy Cuban planters’ investment in vacuum pan technology was also ecologically motivated: the savings of fuel and water, especially when coupled with high efficiency steam boilers and mechanisms to reuse waste heat, were considerable. Since the pressures on planters were so different in the sugar islands, the machines imported from European refineries would require quite profound reimaginings to be made useful in the tropical plantation context. Fuel efficiency and complete enclosure would be accentuated, made almost the goal of the technology, with the Rillieux and Derosne triple-effect devices, invented in the archipelago.

Many planters chose a piecemeal, safety-first approach, instead of leaping fully into an unknown technological regime of steam and pneumatics. However, observations and experiments suggested that these hybrid set-ups were fatally compromised by not constituting complete systems. Since the Roth pan “only replaces the strike pans,” Casaseca noted, “this system does not constitute a complete manufacturing train.” One would still need clarifiers, evaporators, and concentrating pans. Early experimenters working with non-systematic strike pans like these put together a hybrid machine that carried out the first half of the process (clarifying and first concentration) in the Jamaican style, while finishing the concentration and striking with Derosne pan, in other words staying with the old-style until the meladura was already at 15° density and then “finishing” the batch with the new method. This didn’t help, critics pointed out, because the damage had already been done in the first two pans. No technology was wondrous enough to re-synthesize broken-down sucrose molecules. As we see in Villa Urrutia's statistics, a hybrid machine did even worse than the traditional Jamaica train.[[33]](#endnote-33) Major Cuban boiling houses would require, it turned out, a more cohesive, systematic structure of sugar processing– an innovative creolization of technology that kept the valuable product protected from the tropical elements.

Unlike the Howard and improved Roth apparatuses, “which have as their object purely and simply the cooking of the jarabes o meladuras,” the Derosne system “constitutes a complete system of fabrication.”[[34]](#endnote-34) As he transitioned from working as a chemist in the beet sugar industry to fabricating machines specially for cane sugar, Charles Derosne personally installed machinery in Cuba, Guadalupe, Martinique, and the east African island of Borbón. The apparatus was made by a pair of French manufacturers who gradually gained familiarity with “el principio sacarino” in extensive travels throughout the global archipelago of sugar knowledge. Unlike machines made specifically for European sugar beets, Casaseca promised, the Derosne system would be “applicable to our Ingenios,” both due the completeness of the system (no exposure to tropical air), and to ease of operation (race).[[35]](#endnote-35) Derosne and Cail’s brochure reassured planters that their modernized, mechanized boiling train only “seems complicated at first,” and tried to calm fears that planters had expressed about using their own workers in such a scheme. In fact, the French manufacturers pointed out, their design “facilitates operations, making them independent of the carelessness of the operatives; such that today the operative is subjected to the apparatus itself, which will keep him from the kind of errors that in the old system highlighted his incapacities.” The Derosne train promised to reinforce slaves’ subordination to the master with their subjection to the machine, harnessing the inchoate inevitability of the latter to a ‘rationalized’, and ‘modernized’ coercion practiced by the slave-holder.[[36]](#endnote-36)

The idea of cutting off operatives from direct interaction with fragile sucrose bled into other aspects of modern production as well. Derosne processing began with slaves dumping the cane from heavily loaded, oxen-pulled wagons onto “a conveyor belt” (“cadena sin fin”), which made it quicker for the cane loaders to drag their empty wagons back into the fields. At the Ingenio San Martin in Cárdenas, for example, the conveyor belt bringing the cane into the grinding mill was 80 feet long.[[37]](#endnote-37) The long feeding mechanism helped the individual canes lay in flat even rows, as opposed to entering the grinding wheels stacked one upon the other, which would obviously have had deleterious effects on the completeness of crushing.[[38]](#endnote-38) Creolizing technocrats honed in on continuous, regular, and proportioned distribution of materials through the system, as well as a neat disaggregation of slave and machine.

Moreover, the mechanism physically distanced labor from the machine (alienation). There was thus a double whitening going on in the factory. Chinese indentured workers known as “coolies,” tens of thousands of whom came to the island between 1834 and 1870, supposedly dominated “skilled” positions in the boiling house, were kept on a separate floor of the *barracón*, and were analogized to automated machinery, while African labor was ideologically tethered to the ground and what issued therefrom (nature).[[39]](#endnote-39) Sagra, for example, associated “intelligent labor” with Chinese operatives, but he analogized their mental attitude to “the constant regularity of industrial operations submitted to the incessant strike of the piston, or the pressure of steam, or to the fixed grade of the thermometer. One need only observe,” in one of Cuba’s large sugar mills, “a double file of Chinese, rapid in their movements like a driving belt, carrying out the filling of the molds, with the mathematical regularity of the pendulum.” For him, “los negros” clearly belonged in the fields.[[40]](#endnote-40)

The entire spatial organization of the plantation was continually reorganized, geared increasingly to the steady, unceasing flow of energy and matter. Particularly after the conspiracy of 1844, the movement of workers was more rigidly governed, centralized, and sometimes even automated (steam-powered oven for cooking in the barracon – the supermax of the 19th century). Racial hierarchies infused supposedly technocratic innovations, as planter-industrialists, chemists, and engineers refined biologically-ordered divisions of labor inherited from the Atlantic slave trade, and the plantation complex amid Europe’s global age of empire. Elizabeth Esch and David Roediger, have shown how “the management of labor in the US has roots in the particularities of a society that racialized its labor systems – slave and free — and this made racial knowledge essential to managerial knowledge.”[[41]](#endnote-41) We can also see this racialization of management – this management of race – intersecting with the architectural decisions in the transformation of the sugar-mill.

Coordinating mechanisms like the cane conveyor became all the more important as each phase of the production process became larger and faster, and had to be linked together; seamlessness was the ideal. Water provisioning was of first importance. Much like Howard and Roth vacuum pans, the Derosne system was a thirsty machine. As Casaseca put it, “if we are speaking of a European refinery in a locality blessed with abundant water, the preference goes to the improved Roth apparatus.” The water usage, however, made it a bad fit for Cuba. The techno-economic landscape of Cuba called for greater celerity, and more efficacious use of resources than that required by French or Belgian refiners of beet sugar. Water had become so crucial in the new system largely because of efforts to exert more precise temperature control in sugar-making. Instead of enslaved firemen stuffing bagazo or firewood into the furnaces just underneath the evaporating pans (as in the Jamaica train), heating of the sugar was indirect: water, removed spatially from the sugar, was heated into steam, and the steam itself, traveling through pipes either underneath or within the body of the juice, heated the sugar. The fire (still maintained by slave firemen, of course) that created the steam in the boilers ran continuously through the grinding season, consuming as much as 200,000 gallons of water per day on some ingenios.[[42]](#endnote-42) Some of the estates had as many as eight boilers, exhausting natural water sources quickly. Thus, huge nearby deposits were needed. The reservoir of Ingenio Santa Susana, in Cienfuegos, for example, drawing water from several brooks and creeks, stretched for two miles.[[43]](#endnote-43)

Capturing, moving, and vaporizing such a quantity of water depended on the concerted application of coerced labor. Slaves built and maintained complicated systems of water supply (hydrostructure) on the major plantations. The hydrostructures, once laboriously carved out of the landscape, often mechanized. The steam engine which turned the mazas (the heavy iron cylinders waiting at the end of the conveyor belt to crush the cane), was in a sense the powerhouse for the whole cell of production. It was tasked not only with grinding cane, but with moving water. For example, the Fawcett-Preston steam engine, an English machine common on larger estates, was sometimes used to drive a water pump even while grinding sugarcane. This pump supplied the steam boilers, as well as the rest of the farm, with the water it needed.[[44]](#endnote-44) On Julian de Zulueta’s ingenio, one of the “best and biggest” masonry dams on the island held a large stock of water that could be pumped to various parts of his estate by the power of the mill’s steam engine.[[45]](#endnote-45) In other words, the steam engine fed itself (We will see this recursive logic taken to its ultimate conclusion in slave provision grounds and women’s reproductive labor in the criadero: self-reproducing value). The fuel savings that resulted from this cycle of reuse, however, depended upon sophisticated modes of energy transmission.

Planters wealthy enough to be located along navigable rivers used them as sources of power, sources of steam, and avenues of transport for their products to port, as well as, surely, drinking water for the hundreds of animals who also lived and worked on the estate. Owners of the Ingenio Güinia in Trinidad dammed a pond, and installed pipes leading up into the boiling house. This set-up “supplies water needed by the machinery, the draining house, and other dependencies.”[[46]](#endnote-46) Situated along a river that powered “a great number of rice and corn mills,” the property of well-known Güines planter Joaquin de Ayestarán had one of the island’s few water-powered mills. The breast wheel was fed by a long aqueduct made of stone.[[47]](#endnote-47) Ingenio Santa Rosa, belonging to planter and railroad magnate Domingo de Aldama, also had a large dam, which was connected to the boilers by an aqueduct about 600 feet long. On the Ingenio Trinidad in Matanzas, meanwhile, “an aqueduct brings potable water from a spring that is taken to a principal reservoir located at the highest point of the property, and from there it is distributed in various branches that supply all of the workshops and establishments of the farm with water.”[[48]](#endnote-48) The ingenio was being redesigned as a unified system of energy transmission to resolve the crisis of the 1840s and safeguard Cuba’s shaky position in the world economy.

This water was pumped into the steam boilers, which in the Derosne system were typically located outside of the sugar-boiling house. Fire tubes ran from end to end inside the boiler, quickly heating the hundreds of gallons of water each one held, and creating high pressure steam, the force of which quickly wore out the seams of these cast iron vessels. Then, a network of pipes and valves, so numerous that they shocked even the old hand Sagra, carried the steam to the engines as well as to the vacuum pans. The ingenio La Flor de Cuba, Sagra marvelled, possessed “the whole gamut of pumps necessary for the vacuum trains.”[[49]](#endnote-49) In addition to the two air pumps creating vacuums in the two vacuum pans, most Derosne systems had two water pumps moving condensed water that had been evaporated out of the guarapo back to the boilers for reuse. A fifth pump, powered by the mill engine like all the rest, “provides water to the diverse departments of the ingenio for all the necessities of sugar manufacture.”

Diversity reigned in the world of thoughput mechanisms aimed at energy economy in the Cuban sugar complex. Just outside the boiling house of the Ingenio Asuncion in Mariel, for example, there was a cooling tower over fifty feet tall and forty-four feet wide, that lowered the temperature of recently-condensed water so that it could be piped back into the vacuum pans and used to condense vapor and create stronger vacuums. The hot water was pumped to the top of the tower, where it was pushed through a number of perforated copper tubes. As the now atomized water fell “in the manner of a fine drizzle” to the deposit below, an auxiliary steam engine spun the blades of a large fan aimed at the water. Much like the fan located in front of the radiator core on an automobile, which cools the antifreeze that has just passed through the hot engine and prepares it for another trip through the engine block, the ventilator cooled the water so that it could then be used anew in the vacuum pans. “By the time it arrives at the deposit,” Cantero boasted, the water “is 3° below room temperature.”[[50]](#endnote-50)

Designers made sure that fire was kept out of the way of the boiling house, diminishing the risk of conflagration. There is no flame in the boiling house itself, only steam, just as there were no longer boxes of sugar in the streets of Havana, a city increasingly “made out of sugar.”[[51]](#endnote-51) While scholars have been entranced by how even the most basic approaches to sugar processing appeared to have an assembly line quality, the “immense ductwork that crossed the space in all directions,” as Sagra put it, presented a very different appearance than what had come before.[[52]](#endnote-52) The enclosure and segregation of the Derosne system’s various elements required throughput mechanisms that became more and more the subject of technocrats’ attention, since they enabled the new spatial order of the plantation crucial to commodity making. The technological path from the Jamaica train to the Derosne system was really one of reorganizing production spatially: segregation, enclosure, and linkage, *not* labor-saving or quantity-enhancing innovations, motivated plantation experts.

For example, to transfer the juice upwards to the clarifying pans, each Derosne system was equipped with a “sube-guarapo,” or automated juice lifter, which was also dependent upon the steam issuing from the boilers. The Jamaica layout had been on one level, but the Derosne system was vertically oriented. So, instead of the juice dripping into the first pan by the force of gravity, or being scooped from pan to pan by slaves using gigantic ladles, an operative opened a valve which admitted pressurized steam from the boilers into the guarapo receptacle underneath the mazas. The Derosne train was basically a system of very high and very low air pressures – the countervailing forces which created the motion in the system, and enabled the spatial distribution of the workforce.

New boiling house layouts had clearly segregated the generation of heat energy from its deployment, one of many innovations that had also been spatially reorganized, enabling and enabled by a novel racial hierarchy within the sugar-mill. Each level of a carefully segmented racial hierarchy of labor was belted to a given station on the spatially distended assembly lines of 9,000 acre sugar plantation. Anglo machinists, white creole overseers and sugar masters, Chinese skilled laborers, and an internally divided population of enslaved workers, with Cuban-born operatives often placed in skilled positions, and African-born *bozales* left to cut the cane. Dependence on skilled slaves show the slippage and internal contradictions within the sugar-mill’s overarching racial order. I don’t think this racially segmented workforce was part of some instrumentalist effort to stymy the unity of the working class (although this was certainly one consequence). I simply think planters took ideas about the differential endowments of the races quite seriously. This was also a recursive process: as they segregated and reordered workforces, they *made* race, elaborating upon and fixing spatially the raw materials of racial knowledge picked up from across the Atlantic world.

**Sugar-processing in French, or the double effect: The Derosne Serpentine Condenser**

The automated, recursive loops of water, sugar, steam, and coal, while taking much from European engineering firms, took on new urgency when the use of natural resources was so finite, and also internal to the firm. Scarcities were not exportable, but always immediately pressing, giving rise to demand from planters and managers for increasing tight loops of reuse, or the use of “every atom of steam,” as Cantero wrote. The mutual impact of medium and commodity was perhaps made most clear in the last evaporating phase of the manufacturing process: the serpentine condenser. The cane juice left the filters at about 8° density, and was carried by another pump to the top of the serpentine condenser, where it was pushed through a pipe with a multitude of perforations, which sprayed the juice in small particles down onto the parallel rows of copper condensing pipes. Just before this operation commenced, operatives opened another valve which brought the water vapor evaporated out of the guarapo from the previous vacuum pan into the serpentine tubes.[[53]](#endnote-53) The juice, being in small particles spread over the surface of the steam-heated tubes, took on the latent heat of the steam, thus losing its water content very quickly to evaporation. It dripped down to a receptacle, one step closer to complete processing. The steam inside the pipes, passing its own heat to the cane juice, condensed into liquid form. A water pump, powered by the mill engine itself, then carried the water back to the boilers for reuse in the production of steam for the engine.

The serpentine design thus used the cane juice’s original water content to evaporate its remaining water content, thereby halving the fuel needed to create granulated sugar. Essentially, the Derosne condenser used the eventual final product (sugar) as a fuel-saving processing material. The serpentine apparatus is called a condenser because of the service provided by the syrup to the steam. The branding of the machine as a “serpentine condenser” leaves it unclear which of the liquid substances was the one being worked, and which of them was merely a medium used to aid in the processing of the other. The mutual impact of the steam upon the sugar and the sugar upon the steam is what was known as the “double effect.” In the single effect Jamaica train, a given amount of water heated into steam and piped under the pans could only evaporate out an equal amount of water content from the cane juice, because the vapor evaporated out of the cane juice was not harnessed, but immediately escaped into the air. Thus, it was a “single-effect” device. This is the sense in which sugar-processing became increasingly recursive in the post-1840 decades, in the sense that sugar was both the medium and the outcome of the production process.[[54]](#endnote-54)

So the material being processed is boiled down and then re-liquefied, its viscosity lowered and raised to pass it through different mechanisms. The movement of the material itself was serpentine, not linear. An odd, wending process of disassembly and isolation, where the same material doubles back on itself in condensed form, where the fuel and the throughput material exert mutual effects on one another in repeated fashion, in the sense that water in both liquid and gaseous form interacts, combines with, is extracted from, and helps to heat the juice in a complex and multifaceted set of interactions without the intervention of a human hand except as a regulator.

The point of all of this, according to Casaseca, went well beyond the usefulness of single machines. That had already been tried, and found wanting. The plantation technocrats were not awestruck by the wondrous operations of individual machines (they would have viewed such behavior as being more appropriate for unenlightened artisan sugar masters). On the contrary, they concerned themselves with how the heterogeneous elements of a multi-stage process might be linked together into a “sistema completo,” or “sistema entero.” Casaseca was most taken by “the wisely combined linkages among all parts of the apparatus.” The throughput mechanisms like the juice lifters and cane conveyors not only led to “the suppression of all hand transport.” They also, he thought, “ensure punctuality in execution, exclude all fear of delay, and avoid all accident.” Looping back to the orginal and fundamental point, Casaseca declared in favor of Derosne that “the entire system functions as if it were a single and unique apparatus, that receives sugarcane and puts out sugar at the point of crystallization, without nuisance, without uncertainty, and without anxiety.”[[55]](#endnote-55) The sugar chemist’s desire to alleviate “anxiety” helps explain the popularity of these costly devices. They could be read as enclosing and protecting an airless, hygienic space of pure whiteness – a secure space which could only be peered into by machine-like Asian workers or white chemists.

Tandem, steam-powered mills, and huge clarifying pans in turn required gigantism in the filtration stage. On the Ingenio Santa Rosa, Domingo de Aldama had installed twelve clarifiers of 400 gallon capacity, which could thus purify 4800 gallons of juice simultaneously. To keep pace with the considerable flow, he installed sixteen filters that each contained 10,000 pounds of bone black, as well as twelve Derosne condensers, two vacuum pans that are 7 1/2 feet diameter, and six English centrifuges, which power-dried the granulated sugar. “All of the Interior services are done by way of railways,” Cantero noted, which eased and accelerated the movement of materials inside the factory. Gas-illuminated to enable twenty-four hour operation, this design meant unceasing toil for the 300 slaves, thirty Chinese, and twelve white operatives who handled the harvest season.[[56]](#endnote-56) Most of these workers remained in the fields, cutting cane with machetes as they long had, but under increased pressure to bring the requisite amounts of cane to the mill.

Comparing the Derosne system to the cotton textile mills of England or New England is instructive: while the spinning and weaving machines were ingenious and quite complex, the transfer of materials from point to point in the production process was rudimentary. Powered by falling water until at least the 1870s, the textile mills of North America had nothing that approached the sophistication in throughput technology, and the ingenuity in fuel economy, that was starting to become common practice in the global archipelago of sugar knowledge. Yet the continual process of experimentation in the plantation laboratory had given rise to doubts about the appropriateness of Derosne’s system for the Caribbean context. Villa Urrutia and Casaseca had become enamored of the Derosne system in 1842, but several harvests separated their preliminary findings from the more measured impressions of Sagra, Cantero, Benjamin, and the mass of elite planters themselves. Harvests teach lessons, of both a budgetary and logistical nature. These two concerns were of course intimately related, especially in the context of fuel expenditures (ie the ultimate cost of production vs. proceeds from sales).

Sagra complained in 1860 that Derosne’s serpentine condensers exposed sugar to open air, as well as overheating the juice – the two main factors, were have seen, experts thought responsible for breakdown of sucrose, or, as they might have put it, the conversion of sugar into syrup. The particular ingenio he visited that day, which inspired these critical observations, promised that they would soon be phasing them out.[[57]](#endnote-57) Benjamin held similar misgivings. The Derosne system, he wrote, caused sugar to be “exposed to the open air in a state of minute subdivision as it falls in a cascade over the frame of pipes which form the condenser.”[[58]](#endnote-58) Also, the frame of parallel steam pipes are liable to be knocked out of square at some point and this is very hard to fix. And if they are not perfectly square the guarapo tends to collect in the corners (like silt gathering in corners of the quay where water slows down) and invert by being exposed to the heated pipe for too long. Its unceasing and carefully calibrated flow interrupted, cane juice turned bitter. Stasis brought destruction. Moreover, because the vacuum power of the strike pan created steam more quickly than the serpentine tubes could use it, the system still needed an auxiliary water injection condenser to re-create vacuum in the pan periodically. Furthermore, the Derosne double effect still lost all of the steam evaporating out of the juice while it dripped down the surface of the serpentine tubes. Cuban plantation experts concluded that a system which both wasted water, and put the vulnerable and frail substance of sugar at risk by failing sufficiently to account for the effects of tropical heat, had to be rethought. Sense of climatically-induced breakdown of whiteness into less valuable brownness, a sense of sugar’s vulnerability and the consequent need for gentleness, subtlety, and precision. Gentleness and subtlety in the boiling house hitched to terror in the cane fields; creative reuse of materials matched with prodigious consumption of people. The twin faces of a single process of production, each enabling and urging the other to refine the subtlety of its machinations and its technologies of enclosure and flow.

In 1847, a colonial agency gave 1,500 pesos per year to José Maria de la Torre, a geographer, statistician and historian at the University of Havana, to support his travels abroad in order to learn about the global advances in agricultural, industrial, and commercial techniques. Among other things, he was particularly interested in collecting information on, and samples of, the Rillieux vacuum pan in Louisiania.[[59]](#endnote-59) By 1857, a mere fifteen years after its introduction on the island, taking stock of the improvements that had been made in the intervening decade-and-a-half since the first experiments with the vacuum system, Cantero already referred disparagingly to the early condenser models as “*los antiguos serpentines de* Derosne.”[[60]](#endnote-60) A Paris-educated man of color from New Orleans, deeply familiar with the sub-tropical climate and el principio sacarino, as well as the French manufacturing scene, had already begun to rework the process.

**Sugar-processing in Caribbean Creole; the triple effect**

Norbert Rillieux’s clarifiers, filters, and vacuum pans were all borrowed from Derosne. Instead of maintaining the vacuum pans and serpentine condenser separate, however, Rillieux combined the two ideas by enclosing the serpentine tubes in the vacuum-sealed vessel. While Derosne’s serpentine condenser released the water vapor from the juice into the air as the juice dripped down the exterior surface of the serpentine tubes, Rillieux’s model conserved the steam evaporating out of the sugar, pumpted into the tubes of the next pan to further condense the juice. His design screwed tighter the recursive loop of reuse. Steam-heated versions of the Jamaica train only used the steam from the boilers once; Derosne serpentines used it twice, but then released it into the air; Rillieux’s system re-harnessed this waste steam a third time: hence, the triple effect. Focusing again on the fuel savings derived from this ongoing reciprocal action, Cantero explained that Rillieux’s first pan “can be considered as the steam generator for the other two.” With the improvements made by the New Orleans engineer, Cantero effused, “the system does not lose even an atom of steam.” In the Rillieux system, moreover, the juice is “evaporated in a close pan, and is excluded from atmospheric action.”[[61]](#endnote-61)

After Derosne died in 1846, his partner Jean Francois Cail, having seen up close the advantages of Rillieux’s approach, adapted them into his own model. Cail then partnered with Rillieux, installing Rillieux triple effect vacuum pans on a variety of plantations, which is interesting, because his was a competing model.[[62]](#endnote-62) Cail likely borrowed the triple effect idea from Rillieux, then built a triple effect evaporator in Europe for the first time. So it was a product of the global-tropical archipelago of sugar knowledge, and made its way *back* to the center of industry in western Europe.[[63]](#endnote-63) Spending time on Justo German Cantero’s *Ingenio Güinia de Soto* in the valley of Trinidad in 1842, as well as the estate of Julián de Zulueta, where he and the planter “performed all kinds of experiments,” Derosne had ample opportunity to witness the shortcomings of his original model in practice. And Derosne, based on his hard won experience in the boiling houses of the tropical archipelago of sugar knowledge, and his desire to continue manufacturing machinery for Cuban planters, took careful note. As of 1857, Zulueta actually had three generations of steam condenser technologies in the boiling house at the same time While Zulueta still had fourteen Derosne serpentine condensers, he had also purchased an updated vertical tube condenser, and finally a brand-new set of three fully enclosed, steam tube, triple effect pans.[[64]](#endnote-64) The newest model, however, was not Rillieux’s. It was Derosne’s latest model, manufactured by Cail, incorporating Rillieux’s newest concepts, and fully hybridized for the Cuban setting: a European machine translated into Cuban Creole.

The new “Derosne” apparatus used a three-vessel vertical tube system which borrowed heavily from Rillieux’s concept of total enclosure while also answering Benjamin's complaints about cane juice sitting on those old horizontal tubes and caramelizing. Juice was admitted into the first tank until it had entirely submerged the set of tubes, while waste steam from the mill engine was admitted into the tubes themselves. At the same time, the mill engine drove a vacuum pump that began to suck the air out of the upper portion of all three vessels. The juice being quickly brought to a boil in this low-pressure environment, the evaporated steam from the juice passed out the top of the first vessel, through a pipe, and into the upright tubes of vessel number two. The juice, now slightly condensed, passed out the bottom of the first vessel and into the second vessel, bubbling around the steam filled tubes. The tubes in vessel number two pulled double duty. Not only did they reheat the juice, but they acted as condensing surfaces for the vapor that had evaporated out of vessel number one. The condensation of this vapor helped create the vacuum in the first vessel, obviating the need for a vacuum pump on the first vessel itself (the vacuum pump really acted directly only on the third vessel, where the vacuum was strongest. Multiple effects like the one I just described create the vacuum in the first two pans. Increasing strength of the vacuum from pans one, to two, and three suctioned the cane juice through its tubes.). As the vapor condensed, it passed its latent heat to the juice in the second vessel, bringing the juice to a boil.

The dynamic between the second and third pans was much the same as between the first and second, the only difference being that the vacuum is strongest in the third vessel and brings the sugary mass to the point of crystallization. Before passing to the strike pan (the final vessel) the condensed juice was removed from vessel number two and run through the filters for a second time.[[65]](#endnote-65) Due to the difference in air pressure between the vacuum pan and the open air, granulated sugar, still in need of some draining and centrifugal action, had to be suctioned out of the last pan by a pump often worked off the main vacuum pump.[[66]](#endnote-66)

The mutual effect of steam upon sugar and vice versa in the “antique” serpentine model and the Derosne triple-effect of the late fifties, while similar in concept, were quite different in execution. Not only did the process remain enclosed, safe from the inversionary impacts of tropical air, but another loop in the recursive cycle was added (like epicycles in the Copernican retrograde orbit of Mars). The basic sugar making concept of the “triple-effect,” rooted in the insights of Rillieux and gradually improved upon in a collaborative network of plantation technocrats through an array of real-time experiments, became the state-of-the-art in sugar mills until the early twentieth century.

**Conclusion**

The sugar-processing train evolved quite rapidly between 1830 and 1860. This thirty-year period witnessed a dizzying set of improvements on the Pacheco train, which had been the norm in sugar processing for over two centuries throughout the Americas. From multiple fires under open copper pans, planters transitioned first to the single-fire Jamaica train, then to the steam-heated, open-air pans. At the same time, planters cobbled together an array of hybrid solutions partially incorporating early vacuum technology, to which Derosne added the double effect apparatus, thus working out the first “complete system.” Rillieux’s triple effect intensified energy economies even more, and finally Derosne adapted the idea to please Cuban buyers.[[67]](#endnote-67) A product neither simply of ingenious European craftsmen, or of ambitiously capitalistic slaveholders, the Derosne system, otherwise known as a “modern train,” or “the complete system,” was a protean artifact, a product of Atlantic capitalism, and of course a formidable piece of industrial infrastructure when understood as overwhelmingly aimed at rapid and energy-efficient throughput. Inexorably linked to the *barracón*, which was an architectural testament to the social reproduction of labor at its barest, the boiling house, together with the cane fields and the linkages between them constituted a unified, but ever-shifting system of production which was itself the ultimate image in the minds of plantation technocrats — a machine of machines, within which a single piece of hardware had to find its place, be altered so that it fit in, or be consigned to the dustbin.

Each step along this path required increasing amounts of capital, and thus intensified experimentation to be able to calculate their utility before purchasing. Elite and rarified, planters who obtained and tinkered with the Derosne system focused on saving resources, accelerating time, and ramping up the quality of their final products. Not a French, English, or even simply a Cuban invention, the tren moderno was a piecemeal artifact that underwent continuous editing and translation in the global archipelago of sugar knowledge. While the earliest efforts of any new technology amounted to transplanting European technologies to the Caribbean setting, experimenters quickly found, and consistently emphasized, that a uniqueness of climate, botany, the labor system, and Cuba's economic position required translating the machine so that it could function well in its new environment. Plantation technocrats like Wenceslao Villa Urrutia, Justo Cantero, Jose Luis Casaseca, Judah Benjamin, Norbert Rillieux, and others accessed and articulated a tradition of Creole science in the Americas that challenged the easy application of metropolitan knowledge in a colonial setting. The facts of nature, this tradition insisted, were geographically variable. As Cuban chemist Carlos Moissant put it in 1861, “science is universal; but its methods of application should be purely local.” By this time, plantation technocrats had been translating and adapting machinery, in the process reinventing the apparatuses and finding places for them in the upper tiers of Cuba's socioeconomic complex of sugar. Thus we should think of the Derosne triple effect vacuum pan as a creolized or translated document, written neither in English French or Spanish, but in the abstract, locally grounded, and utterly labor-free graphic language of the sugar archipelago's Republic of Blueprints.

Historians often trot out the Derosne system as evidence of the industrial modernity (or what-have-you) of Cuba’s sugar boom, without differentiating among generations, or recognizing how fast the models were changing. The same goes for Cuban railroads. It is not enough to continue pointing out that Cuba had railroads before this or that country. What is interesting is that observers looking back from 1860 thought of the first railroads in Cuba (1837-1840) as utterly backwards in comparison to the transportation system of their own day, much as they disdained the “antiguos serpentines de Derosne,” which had been a powerful indicator of modernity fifteen years earlier. In the historiography of slavery, “keywords” like “railroads,” “steam engines,” and “industrial” tend to take on a talismanic character: invoke the term, and all is explained. What I have tried to do in this chapter is begin to demystify those terms by figuring out what exactly the technologies were used for, how they evolved, and why they were adopted as widely as they were.

1. For statistics that show this rapid transformation between 1830 and 1868, see Leví Marrero, *Cuba: economia y sociedad*,vol XII, 212-213. [↑](#endnote-ref-1)
2. World-systems theory suggests that the three wealthy, dynamic, slavery-centered economies of the mid-nineteenth century (the antebellum South, Cuba, and south-central Brazil) might best be understood as “semiperipheral areas.” Neither core nor periphery, such zones have characteristics of both, and play an important mediating role between the opposing extremes. Semiperipheries were marked by their likelihood to change position within capitalism’s global division of labor. They were fluid, dynamic, indeterminate spaces struggling for position, often “generating new institutional forms that transform system structures and modes of accumulation.” World system theorists emphasize that “the semiperiphery is fertile ground for social, organizational, and technical innovation and has an advantageous location for the establishment of new centers of power.” Christopher Chase-Dunn and Thomas D. Hall. *Rise and Demise: Comparing World-Systems* (Boulder, CO: Westview Press, 1997), 79. [↑](#endnote-ref-2)
3. Britain's equalization of sugar duties in 1846 encouraged the push to make more “plantation white,” but with the mounting dependence of Cuban producers on the North American market, this change did not outweigh the negative impact of differential sugar duties which encouraged the production of lower quality byproducts in need of refining, and made the production of plantation white very expensive. [↑](#endnote-ref-3)
4. Santamaria and García, *Economía y colonia*, 198. Marrero, *Cuba*, vol 10, 32. [↑](#endnote-ref-4)
5. Moreno Fraginals, Manuel. *El Ingenio: complejo económico social cubano de azúcar*. Vol. 3. 3 vols. Havana: Editorial Ciencias Sociales, 1978, 35-36. [↑](#endnote-ref-5)
6. Laird Bergad, “Slavery in Cuba and Puerto Rico, 1804 to Abolition,” in *World Encyclopedia of Slavery*, vol. 4, Stanley Eltis and Seymour Drescher, eds. Cambridge University Press, forthcoming. [↑](#endnote-ref-6)
7. Marquese and Tomich, “Naturaleza, tecnología y esclavitud en Cuba. Frontera azucarera y revolución industrial, 1815-1870.” Unpublished paper, 2008. For the ways in which innovations in each phase of sugar production necessitated complementary improvements elsewhere, see Antonio Santamaria Garcia and Alejandro Garcia Alvarez. *Economia y colonia: la economia cubana y la relacion con españa, 1765-1902* (Madrid: Consejo Superior de Investigaciones Cientificas, 2004), 188. [↑](#endnote-ref-7)
8. The changeability of slavery across both time and space has led scholars to refer to it as “the protean institution.” See especially Joseph Albert, “The Protean Institution: The Geography, Economy, and Ideology of Slavery in Post-Revolutionary Virginia’’ (Ph.D. diss., University of Maryland, 1976). This kind of flexibility is perhaps one of the most important reasons why slave societies were a fertile ground of the emergence of new forms of scientifically-informed commodity production, especially in a broader Atlantic context in which craftsmen still wielded considerable control over activities on the shop floor. [↑](#endnote-ref-8)
9. In particular, increasing competition from European beet sugar (which brought the engineering and experimental spirit of the English and French industrial revolutions to refining), the rise of new cane sugar plantations in places like India, the Pacific islands and East Africa and a long-term dip in prices. For a succinct summary of these changes, see Dale Tomich. “World Slavery and Caribbean Capitalism: The Cuban Sugar Industry, 1760-1868,” *Theory and Society* 20, no. 3 (1991): 297-319. Finally, changing understandings of political economy led to increased commodity exchange *across* imperial boundaries, intensifying competition among manufacturers. For the price swings that have been characteristic of the modern market in sugar, see Noel Deerr. *The History of Sugar*, Vol. 2, (London: Chapman and Hall, 1949) 527-533. See also the price series table in Alan Dye. *Cuban Sugar in the Age of Mass Production: Technology and the Economics of the Sugar Central, 1899-1929* (Stanford: Standford University Press, 1998), 30. [↑](#endnote-ref-9)
10. Archivo Nacional de Cuba (henceforth ANC), Fondo Real Consulado y Junta de Fomento (henceforth JF), Leg 95, exp 4000, exp promovido por Dn Federico Augan con objeto de que esta Junta examine su proyecto para la elaboracion del azucar. 31 Jul 1842. For more on the early forties sense of crisis among planters, see ANC, JF, Leg 95, 4001. [↑](#endnote-ref-10)
11. Planter and government advisor Joaquin Santos Suarez foreshadowed the solution. He opined that the spread of a new technology would be “one of the most effective resources in the depth of the crisis in which we find ourselves.” ANC, GSC, Leg 1476, Exp. 58365, Dn Joaquin de Arrieta, com agente de los Sres Derosne y Cail, solicitando cédula de privilegio para un nuevo sistsma de fabricar azúcar, 1842. [↑](#endnote-ref-11)
12. It was not only on the plantation that Cuban science and technology developed in a dynamic fashion. For a more general picture of Havana as “a port of entry and exit of the circulation of techno-scientific ideas and practices, a nexus between local knowledge…and knowledge produced overseas…” see Leoncio López-Ocón and María Isabel García-Montón “La Habana, un núcleo y portal de la ciencia (1857-1867),” In Agustín Guimerá and Fernando Monge, eds. *La Habana, Puerto Colonial (Siglos XVIII-XIX*) (Madrid: Fundación Portuaria, 2000). [↑](#endnote-ref-12)
13. For another account of failed attempts to replicate European agriculture in New World plantations, giving rise for need to creolize, see Max Edelson, *Plantation Enterprise*. [↑](#endnote-ref-13)
14. Which is not to say that national, linguistic, and racial identities did not matter. In an insightful piece, Martha Hodes challenges the notion that the constructed, inconstant character of race, often proven by showing how racial ideas vary across geographical space, somehow mitigates racism's social power. On the contrary, she concludes, it is precisely in the flexibility and adaptability of racial thinking that its “abiding power” resides. Martha Hodes, “The Mercurial Nature and Abiding Power of Race: A Transnational Family Story,” *The American Historical Review* 108, no. 1 (2003). [↑](#endnote-ref-14)
15. Jonathan Curry-Machado, “Privileged Scapegoats: the Manipulation of Migrant Engineering Workers in Mid-Nineteenth Century Cuba,” *Caribbean Studies* 35, no. 1 (2007). Think not only in terms of creolization, but of syncretism that has so long defined scholarship on Cuba. See Benitez-Rojo, *Repeating Island*, as well as Bill Maurer on creolization theory. [↑](#endnote-ref-15)
16. Jonathan Curry–Machado, *Cuban Sugar Industry: Transnational Networks and Engineering Migrants in Mid-19th-Century Cuba*, 87. [↑](#endnote-ref-16)
17. “While the tramping *maquinistas* facilitated the ramping up of Cuban sugar production by way of selective mechanization, it was this very path of sugar mill industrialization that brought planters and merchants on the island increasingly into the clutches of English and North American capital. The machines of sugar manufacture were shockingly expensive and increasingly indispensable, necessitating an ongoing cycle of borrowing and indebtedness that propelled the gradual takeover of this most lucrative undertaking by foreign bankers in the wake of the successful but destructive wars of independence in the final quarter of the nineteenth century.” Daniel Rood, Review of *Cuban Sugar Industry: Transnational Networks and Engineering Migrants in Mid-19th-Century Cuba*, Jonathan Curry–Machado. *Hispanic American Historical Review* 93, no. 1 (2013). [↑](#endnote-ref-17)
18. Scholars who have highlighted the transnational circuits in which nineteenth-century sugar technologists traveled include Humberto García-Muñiz, “Louisiana's 'Sugar Tramps' in the Caribbean Sugar Industry,” *Revista/Review Interamericana* 29, nos. 1-4 (1999) and Jonathan Curry-Machado, “‘Rich Flames and Hired Tears’: Sugar, Sub-imperial Agents and the Cuban Phoenix of Empire,” *Journal of Global History* 4, no. 1 (1999). [↑](#endnote-ref-18)
19. Susan Scott Parrish, James Delbourgo, Neil Safier, and Jorge Cañizares-Esguerra, to name just a few. [↑](#endnote-ref-19)
20. Oddly, the Jamaicans whom Cubans credited with development of the technology in the 1780s called it the “French method.” Moreno surmises that this type of boiling train had its origins in the French Caribbean, but that Cubans learned it from Anglophone planters. For once, no one seems interested in taking credit for methods of sugar processing. [↑](#endnote-ref-20)
21. Cantero, *Los Ingenios de Cuba*, author’s 1857 introduction. [↑](#endnote-ref-21)
22. Sagra, 109. [↑](#endnote-ref-22)
23. José Luis Casaseca, Paris Memoria, 1842. ANC, JF, Leg 95, exp 3996, exp sobre comision conferida al Sr. Dn. José Luis Casaeca para examinar en los paises estrangeros los progresos en los procederes de elaborar azúcar. [↑](#endnote-ref-23)
24. Judah Benjamin, "Article III. – Louisiana Sugar," *The Commercial Review of the South and West. A Monthly Journal of Trade, Commerce, Commercial Polity, Agriculture. Manufacturers, Internal Improvements, and General Literature*, Volume 2 (January 1847).

    334. [↑](#endnote-ref-24)
25. Ramón de la Sagra, *Cuba en 1860, ó sea cuadro de sus adelantos en la poblacion, la agricultura, el comercio y las rentas publicas. Suplemento a la primera parte de La Historia Politica y Natural de la Isla de Cuba por D. Ramon de la Sagra* (Paris, 1862), 81. [↑](#endnote-ref-25)
26. Benjamin, “Louisiana Sugar,” 334. [↑](#endnote-ref-26)
27. Casaseca. “In the last 2 1/2 hours of this processing, its temperature never goes below 230°F, which surely causes a lot of the material to change into uncrystallizable sugar, known in vulgar terms as syrup.” [↑](#endnote-ref-27)
28. Benjamin, “Louisiana Sugar,” 331-332. [↑](#endnote-ref-28)
29. Luis Martinez-Fernandez, *Torn Between Empires*. [↑](#endnote-ref-29)
30. Villa Urrutia was also a competitor with Casaseca in terms of diffusing the latest knowledge. One thousand copies printed and distributed free of charge to hacendados who request it.Wenceslao de Villa Urrutia,“*Informe presentado a la Real Junta de Fomento de Agricultura y Comercio de esta isla, por el Sr. Dn. Wenceslao de Villa Urrutia sobre los resultados de la zafra que este año ha hecho su ingenio en un tren de Derosne*.” (Habana: Oficina del Faro Industrial, 1843). Sgnificantly, Derosne was denied patent protection for same reason. ANC, GSC, Leg 1476, Exp. 58365, Dn Joaquin de Arrieta, com agente de los Sres Derosne y Cail, solicitando cédula de privilegio para un nuevo sistsma de fabricar azúcar, 1842. [↑](#endnote-ref-30)
31. Cantero, author’s introduction. [↑](#endnote-ref-31)
32. Benjamin, “Louisiana Sugar,” 339-340. Pneumatics, the study of air pressure, manipulation of vacuums, hold an important place in the history of European science. See especially Shapin, Steven, and Simon Schaffer. *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life*. Reprint edition. Princeton, N.J: Princeton University Press, 2011. [↑](#endnote-ref-32)
33. Villa-Urrutia. [↑](#endnote-ref-33)
34. Casaseca repeated this point throughout his report. The Derosne system, he reiterated, “embraces the whole fabrication process.” I have translated guarapo, jarabe, and meladura (which were names given to cane juice at different densities) all as cane juice to avoid confusion, but differences mattered, and the fact that they had different monikers is interesting. Different objects from the point of view of production. [↑](#endnote-ref-34)
35. Casaseca, Paris Memoria. [↑](#endnote-ref-35)
36. Casaseca’s translation of Derosne, 15. [↑](#endnote-ref-36)
37. Cantero, [↑](#endnote-ref-37)
38. Casaseca, Paris Memoria. “Dragging the cane to the rollers or cylinders of the mill,” Casaseca emphasized, the conveyor “not only regularizes this operation, and not only gives rise to the most effective arrangement of the cane on the belt, but favors pressing to such a point that the juice obtained can reach two thirds of the weight of the fresh cane.” [↑](#endnote-ref-38)
39. This incredibly rigid spatial order means we don’t see the prominent role of the enslaved as arbiters of innovation in sugar mills like we do in other industries. I’m overplaying the perfection of the system, here. [↑](#endnote-ref-39)
40. Sagra, 57, 61. [↑](#endnote-ref-40)
41. Elizabeth Esch and David Roediger, “One Symptom of Originality: Race and the Management of Labour in the History of the United States,” *Historical Materialism* 17 (2009): 3-43. [↑](#endnote-ref-41)
42. Cantero, 191. Of course, the boilers competed with large boyadas and dotaciones, as well as cane plants, for this water. [↑](#endnote-ref-42)
43. Cantero, 190. [↑](#endnote-ref-43)
44. Cantero, 177. Ingenio Armonía, Matanzas, Alacranes (Miguel de Aldama and José Luis Alfonso). [↑](#endnote-ref-44)
45. Cantero, 148. (Matanzas) [↑](#endnote-ref-45)
46. Cantero, 136. [↑](#endnote-ref-46)
47. Cantero, 171. [↑](#endnote-ref-47)
48. Cantero, 165. [↑](#endnote-ref-48)
49. Sagra, 95. [↑](#endnote-ref-49)
50. Cantero, 160. Ingenio Asunción. Mariel (Lorenzo Pedro). [↑](#endnote-ref-50)
51. Benjamin, 334. Everything solid melts into air. [↑](#endnote-ref-51)
52. Sagra, 95. [↑](#endnote-ref-52)
53. Benjamin, “Louisiana Sugar,” 339-340. [↑](#endnote-ref-53)
54. Recursivity is used by philosophers who want to emphasize that every speech act simultaneously is governed by ideology remakes that ideology in the act of speaking within its terms. Jasinski, James. *Sourcebook on Rhetoric*. SAGE, 2001, 481-482. [↑](#endnote-ref-54)
55. Casaseca. [↑](#endnote-ref-55)
56. Cantero, 142. [↑](#endnote-ref-56)
57. Sagra, 97. [↑](#endnote-ref-57)
58. Benjamin, “Louisiana Sugar,” 341. For a nice take on Rillieux’s improvement on Derosne, see J.A. Heitman, *The Modernization of the Louisiana Sugar Industry*, *1830-1910* (Baton Rouge: Louisiana State University Press, 1987),, 36-37. For a nice analysis of the political economy of sistema entero adoption in Louisiana, see ibid, 34-36. [↑](#endnote-ref-58)
59. Marrero, *Cuba*, vol 10, 40. Jorge Macle Cruz, “José María de la Torre: A Reference Obliged in the History of the Cuban Cartography.” Paper presented at the 21st International Conference on the History of Cartography. Budapest, Hungary (2005). [↑](#endnote-ref-59)
60. Cantero, 148. Historians often trot out the Derosne system as evidence of the industrial modernity (or what-have-you) of Cuba’s sugar boom, without differentiating among generations, or recognizing how fast the models were changing. The same goes for Cuban railroads. It is not enough to continue pointing out that Cuba had railroads before this or that country. What is interesting is that observers looking back from 1860 thought of the first railroads in Cuba (1837-1840) as utterly backwards in comparison to the transportation system of their own day. Fast fashion indeed. [↑](#endnote-ref-60)
61. Benjamin, “Louisiana Sugar,” 341. For a nice take on Rillieux’s improvement on Derosne, see Heitman, 36-37. For a nice analysis of the political economy of sistema entero adoption in Louisiana, see ibid, 34-36. [↑](#endnote-ref-61)
62. Sagra, 83. [↑](#endnote-ref-62)
63. Moreno, *El Ingenio*, III, 204. [↑](#endnote-ref-63)
64. Cantero, 148. (be sure you add elements of Z’s biography as slave trader, financier, etc. to this discussion). [↑](#endnote-ref-64)
65. Ingenio Asunción. Mariel (Lorenzo Pedro): Cantero, 159. [↑](#endnote-ref-65)
66. Deerr. [↑](#endnote-ref-66)
67. Cantero, (Antonio Parejo), 190. Energy economies: Ingenio Santa Rosa, Domingo de Aldama (Matanzas), 144, note 157. It was common for an ingenio to have a workshop where workers founded, forged, and worked raw iron as well as tending to the animals and the necessities of the machines. They had a lathe, as well as a forge, typically. On the Ingenio Santa Susana in Cienfuegos the building to revivify the bone char also has a steam powered sawmill, carpentry shop, forge, boilermaker shop, a lathe, and in the upper floor rooms for the employees. Put with broken stuff, second-hand market, tandem engine in case of breakdown or for cleaning, etc. Recycling, sustainability the preserve of the wealthy. energy flows: On Zulueta’s ingenio, there was also a sawmill and a carpentry shop with a small 6 hp steam engine. [↑](#endnote-ref-67)