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2 The Birth of the Clayton in New Orleans

Thomas Adam Clayton settled in Opelousas, Louisiana, some time in the early 1880s. The son of a doctor's family from the Scottish North had immigrated in 1878 into the post-bellum United States to become a cotton farmer. The St. Landry parish, in which Clayton acquired farmland, was dominated by vast prairie land, with few scattered farms, all of which struggled in the uncertain economic period after the war. Clayton soon joined the surge of the Southern populist movement, organizing and representing farmers' interest in reducing farming's economic uncertainty. Over the 1880s he embarked on a modest political role in Louisiana as secretary of the Farmers' Union. In 1890, the Governor of Louisiana entrusted him with a lay position in the state's Board of Health, where Clayton went on to join the ongoing campaigns of safeguarding New Orleans against yellow fever.

Violent waves of yellow fever had rolled over New Orleans in regular intervals, and mortality rates in the first half of the nineteenth century spiralled up to 8,000 per year. In 1853, yellow fever accounted for half of the city's annual mortality.[1] As reports of dead bodies lining the streets, benches, and public places mounted, tradesmen began to search for acquired and innate immunity, often underlined by racial divisions.[2] Meanwhile, the enduring debate between contagionists and anticontagionists went on to shape nineteenth-century reflection on yellow fever in the American Tropical South.[3]

A praising report on the history and present situation of the Louisiana State Boards of Health, published in 1904, following the establishment of the yellow fever etiology and its vector, *Aedes aegypti*, presents an intriguing outline of the state's attempts at the time to bring this enduring epidemic

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crisis under control. The report voices the firm opinion that the time prior to 1850 would best be characterized as a period of long apathy. Patchworks of different containment strategies, aligned with various theories and concepts about the nature of yellow fever, were applied with more or less success. The earliest traces of applying quarantine practices to halt spatial transmission of the fever were reportedly led by William C. Clairborne, a local physician who already at the dawn of the eighteenth century installed a mechanism to "subject the shipping entering the Mississippi river to those quarantine regulations which in other ports had proven salutary."[4]

The city invoked preliminary quarantine laws in 1816 and 1817. These were scrapped in 1819 so as to delegate issues of quarantine to the state Governor, who in turn installed the first quarantine station, indeed the first in the United States, in 1821. The station was located on the Mississippi River, sixteen miles south of the city, and was mostly used for checking ships and travelers for visible signs of illness and fevers. "It is probable," the report stated, "that some form of 'purification' was also practiced."[5] Initially celebrated as a triumph, the station soon lost its appeal. Yellow fever continued to plague the city and its trade, and the intrusive and costly practice of quarantine appeared as an unnecessary burden to the city's commerce.

As early nineteenth-century attempts to keep the fevers out by presenting physical barriers to its "poisonous" agents appeared to have largely failed, proponents of anticontagionism gained traction. They vocally argued that the disease was of local origin, and that it spontaneously emanated out of the moist grounds of the city and its surrounding swamps. They moreover believed that its human-to-human transmission was as impossible as was its transport in merchandise across the sea.[6] This argument was aptly supported by the costly toll quarantine took on the commerce of New Orleans.

"Yellow fever," Margaret Humphreys points out, "was a profound burden upon southern commerce."[7] This included losses from the direct impact of outbreaks as much as costs incurred from ships, tradesmen, and customers being held up in lengthy quarantine detention. Furthermore, Humphreys reports irregular quarantine checks on the railways, where arbitrary decisions were made regarding trains being disallowed from stopping in New Orleans. As the question of the disease's transportability was deeply associated with the question of commerce, opponents of contagious

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understandings of yellow fever were frequently, but not exclusively, seen as mouthpieces of commercial interests.[8] Yet, according to Humphreys, a noncontagious view of the disease was also shared by most southern physicians up until the 1850s. The disease's predominant appearance in towns and cities was explained by means of various theories, ranging from "overcrowdedness," to the number of living or dead animals, or the presence of unremoved piles of human excrement, and the constant upturning of soil during construction works, which exposed putrefying matter.[9] These largely miasmatic understandings of the fevers were challenged with an increasing awareness for the successive spatial distribution of outbreaks, when, for example, cases in smaller surrounding towns appeared regularly in short intervals after a larger outbreak in New Orleans. Still the idea of transmissibility in vogue during the 1840s was based on a concept of infection that kept its distance from the traditional understanding of contagion. If yellow fever could be carried by persons, it was believed to be spread not directly from them, but through their clothes or belongings, as it was believed that merchandise, material goods, and trapped air could be carrying the disease.[10]

Throughout the period and up to the middle of the century, quarantine systems were mostly retired, and, for a short period of time, completely halted. Whether or not the complete lack of preventive measures did indeed lead to the largest outbreaks of yellow fever in New Orleans history is subject to controversy.[11] In 1853 and 1854 over 10,000 people succumbed to the epidemic. Initially, medical professionals, under pressure from tradesmen, kept the public unaware of the spiralling mortality numbers. It took until July 1853, with already over 1,000 deaths from the fever, for the need to announce the ongoing epidemic and for the subsequent installation of a restrictive quarantine to finally outweigh commercial and political interests.[12]

The mid-nineteenth-century outbreak was widely regarded as a turning point for the southern port and its strategies of containing the fevers. In the aftermath of the devastating epidemics, the state of Louisiana went on to install the foundations of an ambitious system of disease surveillance and epidemic control in the South. The Board of Health in New Orleans—the first institution of its kind in the United States—had already been in place since 1804.[13] As a reaction to the large outbreaks of 1853 and 1854, a new State Board of Health was founded in 1855, formed of nine competent

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citizens, who needn't all be physicians but were required to refute theories of the local origin and spontaneous emergence of yellow fever. Six of them were named by the state governor, and an additional three by the New Orleans City Council.[14] The Board would govern the Southern response to yellow fever as an imported and foreign threat until the end of the century. Its influence was fostered by three consequent years of appalling yellow fever mortality. These had shifted opinion in large parts of the profession and the general public, fostering the conviction of a foreign origin and thus of a principal transmissibility of the disease. The old and defunct quarantine station was considered a faulty system due to a lack of control and rigorous protocols, raising additional concerns due to its proximity to settlements along the river. A new quarantine station was installed not less than 70 miles below the city, accompanied by two minor stations on Rigolets Pass along the Atchafalaya River (figure 2.1). New laws were put into place that also gave the resident physician at the Mississippi station supervisory powers over the installation of a new quarantine system.[15]

The problem with which the new Board had to grapple was simple. The repeated outbreaks of yellow fever had raised alarm in almost all neighboring states. The Board's task was not only to keep the disease out of New Orleans, but also to devise a system that would reassure the State's trade partners within the United States. The biggest economic challenge were so-called shotgun quarantines, imposed in an irregular manner by other states to effectively halt all traffic to and from New Orleans in response to what was perceived as an imminent threat due to the lack of control over the disease in the city. As Gillson has described in detail, the mammoth task of the Louisiana Board of Health therefore involved not only designing a functioning, modern, and reliable system of yellow fever prevention, but also earning the trust of national and international trade partners.[16]

Most considerations in the middle of the nineteenth century affected the time of detention given to ships in the quarantine station. Naturally, opinions differed over the appropriate number of days required to exclude the possibility of emerging cases of yellow fever. Ten days seem to have been widely accepted as a minimum. However, as reports of the Board of Health repeatedly show, contemporary understandings of the nature of yellow fever often suggested twenty-one days of regular quarantine for every ship arriving in New Orleans to be a more appropriate, but also a more costly, timespan.[17]

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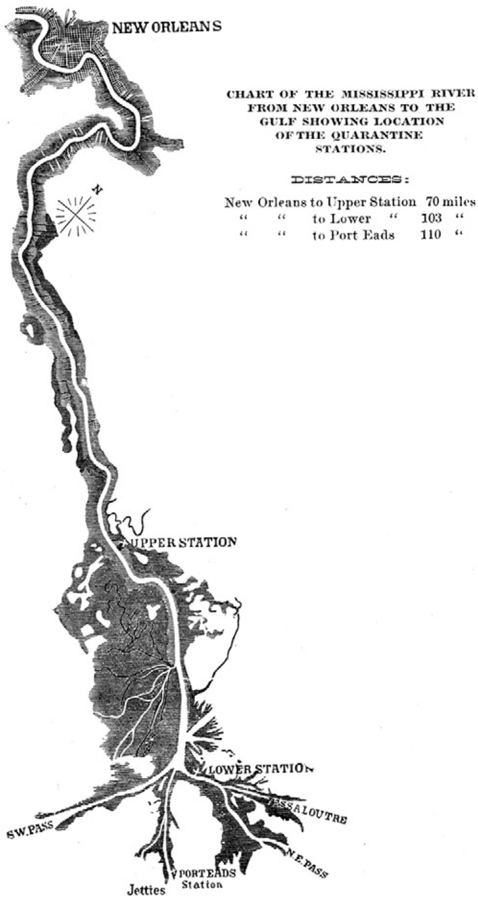

Figure 2.1
Map of quarantine stations at the Mississippi River from 1886.
Source: Matas Medical Library, Tulane University, "Louisiana Board of Health. *Annual Reports of the Louisiana State Board of Health*. New Orleans, 1886–1887," unnumbered plate following p. 40.

Meanwhile, tradesmen and politicians alike campaigned against an increase in the detention time and continued to assemble evidence for the local origin of the fever; a fundamental opposition to the assumption that quarantine would protect the city in any way remained in place. A prominent case was widely discussed in 1863, when it was argued that even a twenty-one-day quarantine of a highly suspicious ship from Cuba could not prevent the eventual outbreak in the city. Taken as evidence by some

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of the noncontagious nature of the disease, the case showed to others that twenty-one days of quarantine were still not enough for observing every latent infection, which might have developed en route.[18] Even then, some questioned, how could one make sure that the disease's agents were not still nesting in the ship's merchandise?[19] As Humphreys has argued, opinions regarding yellow fever in the southern states can hardly be limited to just two opposing factions. Rather, the nature of yellow fever was defined from a "continuous kaleidoscope of combinations" and even if the transmissibility was widely accepted, "it left undecided the species of quarantine required."[20]

The Civil War brought about a blockade of New Orleans during its Federal occupation between 1862 and 1865. General Benjamin Butler enforced a strict quarantine against any foreign port suspicious of yellow fever, and instructed the thorough cleaning of the city's streets. In these years not a single outbreak occurred, which bolstered the proponents of the general transmissibility of yellow fever and fostered public belief in the possible advantages of rigorous quarantine systems. But then again, neither in 1866 nor in 1867 did quarantine prove to be a successful protection for the city. Both yellow fever and cholera reached post-war New Orleans and, once again, the usefulness and efficiency of quarantine measures came under attack. Both commercial interests and anticontagionist physicians opposed the strict imposition of quarantine for vessels from Central and South America.[21] Furthermore, the state of Texas imposed another quarantine against New Orleans in 1871, thus contributing to a veritable quarantine crisis. Despite its many critics and a persistent lack of success, long quarantine continued to form a major obstacle to trade and commerce and became increasingly seen as a means of commercial warfare.[22]

In an attempt to resolve the conflict that had lasted for decades through scientific investigations, the Senator to Louisiana, William P. Kellogg, authored a House resolution in 1872 authorizing medical officers to determine "whether any system of quarantine [was] likely to be effective in preventing invasions of yellow fever, and if so, what system [would] least interfere with the interests of commerce at said ports."[23] Following on from the resolution and desperate to resolve a conflict detrimental to the health and trade of New Orleans, throughout the 1870s sanitary officers began to investigate mechanical and chemical solutions to overcome Louisiana's unreliable and costly quarantine system.

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Yellow Fever and Carbolic Acid

Humphreys has identified the formation of this new disinfection strategy as a consolidation of the etiology of yellow fever as a communicable disease.[24] By the 1870s most physicians seemed to agree that the fever was caused by some kind of germ, a "poison," often understood to be a living microorganism. The physicians and members of the Board "accordingly set out to destroy that germ with chemicals, and to deny it a hospitable environment through municipal sanitation."[25] Purification through gases and chemical solutions heralded a new scientific age in the prevention of yellow fever.

A report to the American Public Health Association in Boston, delivered by New Orleans physician Charles B. White in 1876, explained the minute details of the new disinfection practice. In an unparalleled attempt to free New Orleans from the scourge of yellow fever, dwellings, streets, and sidewalks throughout the city were disinfected. While the "poisonous cause" of the disease was considered to be not gaseous in nature, still the pathogen ("animal or vegetable") was understood to be attached to the soil, the walls, and surfaces in general.[26] It appeared evident that the agent preexisted signs of sickness. And it was considered to spread in close proximity to places in which cases of the fever had previously been observed. Such dwellings and structures were to be disinfected by "sprinkling floors with carbolic acid."[27] The chemical solution that was used across the city was made of crude carbolic acid and should, according to Perry, contain at least 18 to 24 percent acid.[28] This was at times mixed with cresylic acid, a substance derived from tar oils but that was considered even more unpleasant to residents, even though it was thought to be more deleterious to the yellow fever agents. For White, writing in the 1870s, the so-called "atmospheric disinfection" with gaseous substance was widely useless. For an effective application, the disinfecting substance required direct contact with the poison itself or at least with the surfaces that either produced or retained the cause of yellow fever.[29]

Work at the Louisiana Quarantine Station was accordingly dramatically transformed. In White's opinion, the practice of detention caused not only considerable commercial harm; the combination of long detention with the climatic conditions of New Orleans in summertime was leading to the transformation of ships into breeding grounds for the poison of yellow

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fever.[30] Detention therefore needed to be urgently replaced by a rapid system of disinfection. From 1867 in New Orleans and from 1870 in the Upper Quarantine Station down the Mississippi River, carbolic acid was first introduced to support the washing of ships, their bilges, and the surfaces of cargo. At the same time, a simple sulphur-based fumigation was carried out to cleanse the air within ships, and to reach into the gaps and narrow spaces that could not easily be washed or sprinkled. To this end, blocks of sulphur were placed in small metal pots, sprinkled with alcohol, and burned in the holds of the cargo ships.[31]

However, at that time, these fumigation measures were far from central to quarantine operations. Looking back from 1904, after the vector of yellow fever had been identified, the author of the Health Board report described this as a critical oversight of the Board's work in the 1860s: "But the traditions of the station would seem to indicate that, by some of those in charge, this measure, the only one by which mosquitoes are destroyed, was regarded rather as an accessory part of the process and was often ridiculed because of its inability to penetrate masses of cargo."[32] To sanitary officers in the 1860s, washing with carbolic acid seemed to take priority. The acid was understood to be an aggressive means of cleaning, trusted with the thorough destruction of possible sources of infection. Yet it was also known to easily cause damage to sensitive freight such as tobacco and sugar. Although less toxic toward possible sources of infection, sulphuric acid seemed to be harmless to merchandise, and its vaporization allowed it to cover entire ships in quick succession.

The Introduction of Sulphur

Growing interest in sulphur in the early 1870s was not purely driven by its chemical qualities, but also strongly supported by its increasing availability, as well as by a drastic fall in its price. In 1869, the first sulphur deposit in the United States was discovered in Calcasieu Parish, Louisiana. Underneath a layer of limestone, a "typical caprock of a sulphur-bearing saltdome" was discovered by the French engineer Antoine Granet.[33] But while sulphur deposits were henceforth regularly uncovered by oil prospectors, over the next few years it remained considerably costly to unearth the "yellow magic" hidden under deep layers of rock. For over a decade various attempts by the Louisiana Petroleum Company failed to drive a high-yield

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shaft down into the sulphurous pockets.[34] Still, sulphur prices kept coming down, and the abundance of the mineral in the Mississippi area contributed to its reinvention as a substance fundamental to more scientific methods of disinfection.

One of Lousiana's Board of Health sanitary officers, Dr. A. W. Perry, indicated in 1873 that some preliminary tests had been proven successful and he therefore suggested the use of sulphur to build a more sophisticated system of disinfection. In an address to the American Public Health Association, he demonstrated how Louisiana could overcome quarantine as a system of involuntary detention. Enforced and abandoned "already two or three times at New York, Philadelphia and New Orleans," Perry argued, quarantine might perhaps be useful in preventing the importation of diseases from foreign territories, but only if rigorous detention times of over fifty days were applied. However, he argued, as a result of the current system, yellow fever as well as cholera had indeed been imported in various ports: "all these failures have occurred because the quarantine was not based on sound principles."[35] In all cases, no sick person was on board of the vessels, but, he observed, persons involved in the disembarkation of cargo were the first to be affected. One conclusion drawn from this was the possible need for a much longer detention time, and suggestions were made that periods of more than fifty days were desirable. Yet time, Perry argued, reflecting a wider capitalist mentality, was the one element in the quarantine system that was "most oppressive to commerce, the most costly, and at the same time, the least effective."[36] To actually simultaneously fight diseases and reduce detention time, a new method was needed, in which gaseous disinfectants could be used with a special apparatus, whose principles Perry went on to describe.

The new apparatus consisted of one or more force-blowing machines, put in motion by steam power. These were connected with a furnace for generating sulphurous acid gas. By the action of the blowing machines, air charged with the disinfectant was forced through flexible pipes into every compartment of the vessel until it was filled with a saturated atmosphere. The entire apparatus was to be placed on a small steam tug, which would then be moved alongside the vessel requiring disinfection. The air forced into one part of the hold was hence diffused everywhere, and penetrated every crack and crevice by virtue of its elasticity and diffusiveness.

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In 1873, Perry thus laid out for the first time the particularities of the system that would eventually be built in the Mississippi Quarantine Station by 1880 and then developed into the Olliphant and later the Clayton machine. The system seemed easily applicable, as steam vessels already provided the conditions to make this procedure highly effective. Most ships had a piping system already installed, with which smoke from an engine fire was distributed and vented equally through and out of the vessel. The very same pipes could be used to apply fumigation. Once a gaseous disinfectant had been injected with the blower, Perry argued, it would saturate every corner of the ship, as gases had been shown to eventually mix and equally saturate across a confined space.[37] The method appeared successful, Charles White reported in 1874:

> The Board during the past year, while insisting on the detention required by law, has made special effort in the direction of disinfection. By the aid of an apparatus planned by Dr. Perry (Quarantine Officer) and put in operations under his supervision, sulphurous acid gas in large quantities was forced into the holds of vessels: carbolic acid being freely used in the bilges, forecastles, etc. As was stated in a special report, either by coincidence, or as cause and effect, on no vessel so treated had a case of yellow fever appeared during its stay in the city.[38]

The 1875 annual report of the Louisiana Board of Health suggested that fumigation practices with large quantities of gas had indeed earned the status of being a reliable resource for the prevention of yellow fever.[39] The development of the first mechanical sulphur furnace raised hopes across the city that a transformation of quarantine legislation was imminent. Changing existing protocols and safeguards was crucial, even perhaps of existential importance, to the city's Chamber of Commerce, which had maintained its resistance against costly quarantines throughout the second half of the nineteenth century. Based on the Board's report, the Chamber issued the following statement:

> Be it resolved, that this Chamber recommends to the present Legislature to grant the Board of Health authority to permit, at its discretion, the passage of vessels from infected ports to the city, after the same have been satisfactorily and thoroughly fumigated and disinfected in lieu of the prescribed time of detention called for under the existing quarantine law.[40]

The Chamber asked for quarantine laws to be amended in order to integrate the new understandings of yellow fever's cause, as this had been proven

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by the practice of disinfection both at the quarantine station and in the city itself.

In 1875, mounting pressure from experts, commercial interests, and federal politics finally transformed into legislation.[41] Quarantine practice in Louisiana came to be redefined in terms of disinfection. This was mostly enacted through fumigation with sulphuric acid and then washing with carbolic acid. If applied in good measure, even ships originating from heavily infected ports could now sail into New Orleans without any prescribed time of detention. In White's words: "detention at the Quarantine has . . . for the first time been reduced to merely that required for disinfection."[42]

Experimental Disinfection

The experimental undertakings in Louisiana did not go unnoticed by the medical and scientific community in the rest of the United States. If indeed fumigation with sulphuric acid did achieve what it promised at the Mississippi Quarantine Station, it was certainly thought to be of much wider implication for public health both at sea and on land. Indeed, the Louisiana Board of Health's interest in substances, whose disinfecting qualities could be scientifically verified, was embedded in a much larger experimental system. Throughout the 1870s and 1880s, a veritable scientific investigation into the development of reliable disinfectants and the exact conditions (chemical composition, density, time of exposure) of their "germicidity" developed.

In 1884, the American Public Health Association appointed a committee to examine the subject of antiseptics, germicides, and disinfectants in their specific relationship to preventive medicine and sanitation.[43] Drs. George M. Sternberg (Surgeon to the U.S. Army), Charles Smart (National Board of Health), and George Rohe (Professor for Hygiene at Johns Hopkins University) investigated by means of experiments the germicidal value of various substances that had been so far employed as disinfectants in homes, streets, and ports. The question was, what were the germicidal capacities of carbolic acid and sulphur, and how did these substances interact with a range of common materials to be found in the holds of vessels and in private homes? Systematic research began in the biological laboratory of Johns Hopkins University in 1884 with the exposure of a variety of microorganisms to increasing amounts of the two gaseous substances.

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The researchers first aimed to verify the effectiveness of carbolic acid, which in liquid form was widely understood to have excellent disinfecting capacities and had long been used both in laboratories as well as in quarantine and increasingly also in private households. Historically, carbolic acid was attributed to Friedlieb Ferdinand Runge, who had discovered the antiseptic in 1834 in its distillate form of coal-tar. In 1876 the substance was brought to prominence by Joseph Lister who introduced it into antiseptic surgery.[44] Carbolic acid was well known across the globe for its ability to halt putrefaction, but its capacity for killing disease agents was subject to controversy. Progress in determining the concentration in which it was indeed "successful in destroying the virus" was made in experiments on vaccines in Britain.[45] There, John Dougall carried out inoculation with "infectious matter" that had been exposed to carbolic acid, and his research demonstrated that such cultures did not lead to any symptoms or illness; the agent was therefore considered neutralized.

As American researchers quickly discovered, carbolic acid's germicidal capacity diminished when it came to its gaseous vapours. The atomization of 5 percent carbolic acid failed to achieve the same disinfecting power compared to washing of surfaces with the original liquid. Furthermore, bacteria of various diseases in exposed liquids were destroyed by vapors of 7.5 percent carbolic acid, while bacteria on clothes could withstand even an atomized 12.5 percent solution, when the clothes were damp. In summary, the report confirmed the well-known disinfecting properties of a 5 percent liquid solution of carbolic acid against almost all bacteria and fungi.[46] But the large proportions necessary for acquiring true disinfecting qualities led the report to conclude that a vaporized form of carbolic acid should not be assumed to be effective in any way.

As was widely assumed, the researchers could show that the case was different for sulphuric acid. Sternberg referred to the French chemist Émile-Arthur Vallin and his authoritative treatise on disinfectants to argue that sulphur dioxide was one of the most promising substances for the future of practical disinfection.[47] Back in 1882, Vallin had countered Robert Koch's scepticism on the efficacy on sulphur dioxide by conducting his own experiments with the substance, which left him satisfied that it was "a powerful disinfectant."[48] Indeed, Sternberg argued, "no gaseous disinfectant known is more extensively used, or has a higher place in the confidence of leading sanitary authorities at the present day."[49] Still, a critical revision of literature

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and the experiments conducted by other bacteriologists led Sternberg to a much more critical conclusion. While he believed that a range of experiments demonstrated that exposure to the gas killed various live bacteria, he also showed that bacteria in fabrics or other porous materials did regularly survive gasing at a wide range of exposures and densities of the gas. As a result, he queried whether "sulphuric acid" was a reliable agent only when it came to killing microorganisms suspended in atmosphere and nesting directly on nonporous surfaces. Surely, Sternberg concluded his report, the existing methods of washing with carbolic or other acids were much more reliable.[50]

Yet laboratory conditions could not easily be translated into the situation on the ground. To verify the usefulness—if indeed there was any—of disinfection with gaseous substances, J. H. Raymond, Professor of Physiology and Sanitary Science in Long Island College Hospital and Health Commissioner of the City of Brooklyn, devised an experimental setup in a common living quarter in Brooklyn, New York. The experiment was performed in 1884 at the request of the U.S. Commissioner of Health so as to establish if "sulphurous acid gas" could be used as a reliable disinfectant in the country's main gateway to the East.[51] "Sulphurous acid gas" was experimentally applied by Raymond to a closed room, which had been equipped with various prepared infectious materials from Sternberg's laboratory at Johns Hopkins. After all cracks and crevices were closed with cotton, the materials were distributed in the room: small pieces of blankets were soaked in the blood of a rabbit that was killed while being affected by septicemia; other pieces where soaked in the blood of another rabbit, which was infected with anthrax. Some of the blanket pieces were folded and some were hidden under or within furniture in the room. Furthermore, a container with live vaccines in liquid solution was placed in the room. In a large coal scuttle filled with wet ashes, sulphur was moistened with alcohol and subsequently lit, and the room was fumigated for ten hours. In a follow-up experiment, blood as well as organic matter taken from the linen was used to inoculate healthy rabbits. Both septicemia and anthrax prevailed, and most of the subsequently infected rabbits died. However, further experimentation with the same setup would show that the particular gas was able to kill the live vaccines that had been directly exposed in agar.[52] The questions remained: which was the right solution, what was the time required for effective germicide, and what were the appropriate

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means of application in different spatial contexts? This was not an isolated experiment. Indeed the 1880s saw the onset of an extensive national and international debate over the germicidal properties of a long list of chemicals.

On the other side of the Atlantic, both Pasteur and Koch had investigated the capacities of sulphur-based gases. In Germany, Dr. G. Wolffhuegel experimented, in 1880, in Koch's laboratory with sulphurous acid in closed rooms to investigate the density required to kill insects.[53] In France, in 1879, Pasteur experimented with sulphuric acid as a reliable method to suspend the development and virulence of the bacteria causing fowl cholera.[54] The 1880s hence witnessed the emergence of an international landscape of experimental approaches to the disinfecting capacities of sulphur-based gases whose application as a means of disease prevention appeared promising in hospitals, warehouses, private homes, and sewage systems.

From the Holt System to the Clayton Apparatus

In parallel to the scientific validation of the disinfecting qualities of "sulphuric acid gas," New Orleans undertook in the 1880s a thorough modernization of its quarantine stations. This was both motivated by the success of the experiments developed locally and encouraged by the international scientific ratification of the germicidity of SO_2. In 1884, the state of Louisiana was invited to an interstate quarantine conference aimed at resolving tensions and dissolving the atmosphere of mutual suspicion between the southern American states. A notable decision of the conference was the abolition of "non-intercourse"—a term referring the absolute ban on trade and traffic from Louisiana justified by epidemic threats. On the one hand, the decision was supported by the increasing scientific accountability of disinfection methods. On the other hand, the proposition of a new reliable system of maritime sanitation was high on the agenda.

The new vision was brought forward by a prolific Quarantine Officer, Joseph Holt, who became the director of the Louisiana Board of Health in 1884. A few decades later, he was acknowledged as the architect of the new scientific mode of quarantine that would finally overcome what Holt framed as "barbarous" detention.[55] The brainchild of a public political figure, Holt's legacy was not built solely around the mechanical improvement of the quarantine stations protecting New Orleans. It also involved

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raising questions of quarantine and disinfection in countless public lectures, speeches, and published pamphlets. Holt believed quarantine and commerce to be ultimately aligned in their interest. Both public health and commerce would eventually profit from a quarantine system, if this were solely erected upon those practices of disinfection that had been verified by rigorous scientific observations. Quarantine, Holt argued emphatically, should be limited to a "sharp, narrow channel, obstructive to importation of pestilence, but open as a highway to commerce."[56]

When Holt took over, the mechanical furnace originally designed by Perry and slightly modified by his successor Joseph Jones had been in place for almost a decade. Six years before Holt took office, a large outbreak of yellow fever in 1878 had put to bed illusions that the new furnace would be a rapid as well as a safe method for incoming vessels. Furthermore, the Board's severe lack of funds had prevented it from installing additional furnaces to arrive at the required capacity to deal with the growing commercial traffic across the Mississippi.[57] Instead, the Louisiana quarantine system became embroiled in national controversies regarding initiatives for a national quarantine system. Due to the lack of a functioning system of disinfection and fumigation, and as the furnace was no longer believed to provide satisfactory results, in 1884 (just before Holt took up his position in the Louisiana Boards of Health) New Orleans saw the brief return of involuntary detention times of up to forty days for all ships arriving from suspicious ports. Given the public protest against the return of a costly, unreliable, and outdated practice, Holt defined his mission as the abolition of detention time in exchange for the implementation of a fumigation system based on sound scientific principles.[58]

To reconcile commercial interest, quarantine requirements, and public health, Holt presented his new design of "Maritime Sanitation." The new director of the Board declared that "time was no factor in clearing a ship of danger; but that decisive action in the immediate cleansing of a vessel and of all that she carried aboard, offered the only rational hope of defence."[59] Attacking the ship's uncleanliness using the force of local fire departments instead of leaving it to broil under the July sun was, according to Holt, not just the only rational and humane thing to do, but was also proven to be practicable and scientific. As Gillson argues, "Holt's celebrated system of maritime sanitation introduced in 1885, was basically pragmatic in its

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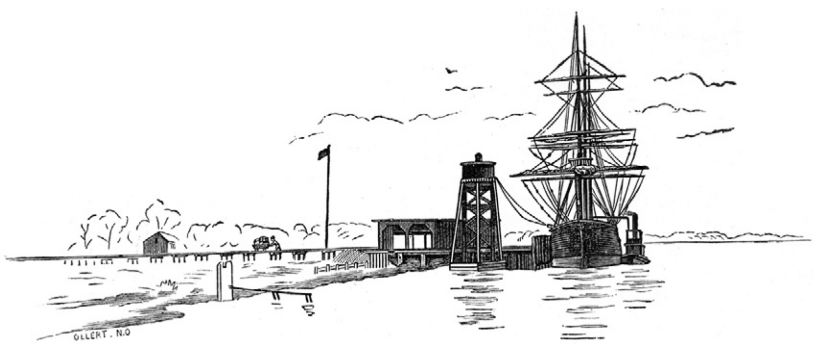
application."[60] His new system rested primarily on two quarantine stations and two supplementary points of inspection along the Mississippi River.

The regulations required all vessels to be inspected in Port Eads, 110 miles away from New Orleans. Here logs were controlled and a sanitary officer would take a sworn statement from the captain regarding any incident on the vessel's journey. All ships were immediately sent to the Upper Mississippi Quarantine Station (figure 2.2).[61] If found clean and arriving from a healthy port, they were sent along to New Orleans. If, on the other hand, a ship was found to have arrived from an infected port, its passengers and crew had to disembark, while the ship was washed in a solution of bichloride of mercury, its holds were fumigated, and any luggage was disinfected. To this end the Board had invested in a tugboat (figure 2.3), which was equipped with a "complete outfit for generating and applying germicidal gas, for displacement of the entire atmosphere within the ship."[62] Eighteen furnaces delivered the rapid combustion of sulphur. The gas was blown through pipes so as to enter the holds of the ship (figure 2.4). The gas then permeated every kind of cargo, even excelling at the highest test: the disinfection of coffee. Everything that could be removed from cabins, such as



(PLATE 2.)

View of disinfecting wharf, showing tug fumigating vessel; elevated tank containing 8000 gallons of bi-chloride of mercury solution, 3 leads of hose from tank to ship. Gangway leading to building containing super-heating chamber.

Figure 2.2

Illustration of the Upper Mississippi Quarantine Station, with a moored barque, attached to a tugboat with a fumigation apparatus.

Source: Matas Medical Library, Tulane University, "Louisiana Board of Health. *Annual Reports of the Louisiana State Board of Health*. New Orleans, 1886–1887," unnumbered plate following p. 40.

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linen, luggage, curtains, and other fabrics, was placed in the large superheating chamber at the station, which sterilized large amounts of goods in quick succession. Infected ships carrying human cases would undergo the same treatment, but would be directed to the lower quarantine station where a hospital and isolation stations were equipped to deal with the patients.

The system remained in place for the subsequent years and yielded to astonishing success. Dr. Kennedy, a physician from New Orleans, wrote in 1885 that the city had finally removed quarantine from the "dark shadows of the ignorant past," and placed into the "bright sunlight of science."[63] Holt took pride in having revolutionized the quarantine system and believed that he had contributed to a vast improvement of morale in the city as an effect of the kind of safety his system promised.[64] Indeed, not a single case of yellow fever was imported along the Mississippi River until 1892, raising interest into Holt's Maritime Sanitation system on a national and international level. In 1888, the Marine Hospital Service dispatched the emerging bacteriologist J. J. Kinyoun to inspect the system and to report on whether it was feasible to install it nationwide.[65] Kinyoun found the results to be impressive but also noted some mechanical failures, which the Board began to correct immediately in 1889. Subsequently, Surgeon General Hamilton ordered all national quarantine stations to secure the necessary apparatus and to build heating chambers, as well as fumigating devices, as devised by Holt.

In April 1890, the newly appointed Board president Samuel R. Olliphant gave an address to the public to outline the new policy and plans of the Board of Health.[66] While he emphasized the pivotal position of New Orleans, shouldering the responsibility to safeguard the commercial interests for the entire United States, he also praised the achievements of what was now known as Holt's "system of 'maritime sanitation.'"[67] The report of the Board's quarantine committee was then read by its newest chairman, none other than Thomas A. Clayton. After he had been appointed by Govenor Nicholls in early April 1890, he had joined the quarantine committee to represent farmers' economic interests and to integrate their demands into the health policy of the state.[68] In his report, Clayton described his own first encounter with the sophisticated and spectacular system that was now in place at the quarantine station. A Portuguese barque, *Maria*, had arrived on April 17, 1890, from Rio de Janeiro. The barque was towed to the

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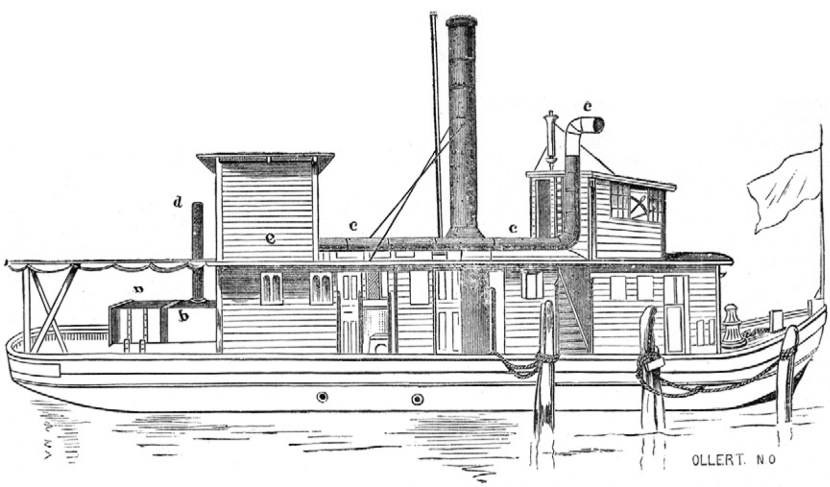
quarantine station, linen and clothing were removed and brought to the hot air cylinders, while surfaces had been washed with bichloride of mercury. Only then could the new fumigation system be brought into action. In this case, the ship was brought alongside the wharf, where a fumigation apparatus on rails rolled adjacent to the vessel to then commence two hours of intensive fumigation with sulphuric gas. Clayton pointed out that the capacity of the stationary apparatus was limited. Citing the growing demand, he motioned for a further tugboat to be equipped with an apparatus for fumigation operations on anchored vessels midstream.[69] Clayton declared publicly his trust in the system to effectively prevent the introduction of any disease while providing for an almost seamless transfer of goods.

In 1890, Olliphant could proudly present the Board's successful abolition of the "old brutal and haphazard quarantine methods": Holt's system of Maritime Sanitation had proved to be scientifically reliable and economically sustainable.[70] In June of the same year, a triumphant Olliphant



(PLATE 1.) TUGBOAT WITH FUMIGATING APPARATUS.

a. Furnace. *b.* Reservoir for reception of gas. *c.* Discharge pipe, conveying gas to ship's hold. *d.* Escape pipe for gas when fan is at rest and sulphur is burning; closed by a valve when fan is in motion. *e.* House protecting from weather the machinery for driving fan and containing accelerating gearing.

Figure 2.3
Illustration of the New Orleans tugboat with a fumigation apparatus installed.
Source: Matas Medical Library, Tulane University, "Louisiana Board of Health. *Annual Reports of the Louisiana State Board of Health*. New Orleans, 1886–1887," unnumbered plate following p. 40.

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invited officials for a formal visit of the quarantine station operations, so the govenor and a group of selected physicians could "see for themselves the effective system of disinfection and fumigation in operation at the mouth of the river."[71] Five years later, Olliphant could also point out that many faults and problems with the original system had been fixed; the danger of damaging cargo or merchandise was practically nil. Clothing and bedding of passengers continued to be treated in heating chambers. Olliphant happily presented his own modification of the apparatus aimed at overcoming its previous flaws. Due to limits in the combustion system, the saturation of the SO_2 gas had previously not exceeded 4 to 8 percent in the process of displacing the oxygen in the holds. His modified furnace was hence equipped with a second pipe to extract the oxygen used to ignite the sulphur directly from the vessel's hold. It thus effectively exchanged the air inside the ship directly with the germicidal gas, and the resulting circulation could eventually deliver highly effective solutions saturated to up to 15 or 20 percent.[72]

Olliphant presented letters from doctors and researchers supporting the validity of his claims and promised to continue the "movement," brought into motion by Joseph Holt, of setting quarantine on scientific basis. When cholera reared its head again in 1892, Olliphant got in touch with over sixty quarantine stations around the world, asking for the specifics of their disinfection methods and the substances used. After reviewing the answers, he concluded that nothing could be done to improve the running service at New Orleans, that it was clearly the best system available worldwide.[73] In January 1893, the apparatus was patented as an improved Fumigation Apparatus.[74] The patent was issued in the name of both Samuel R. Olliphant and Thomas A. Clayton. In their application, the inventors defined the objective to provide a fumigation apparatus, which would produce a "gas of ample and certain strength so that it would be absolutely sure to kill all disease-causing germs."[75]

These efforts were supported by the dramatic decrease in the cost of sulphur, which became an increasing focus of the commercial landscape in Louisiana. This was the result of a breakthrough delivered in 1891 by the engineer Herman Frasch. Frasch had patented a new sulphur extraction method, which he had tested on his own property, located right by the unsuccessful mining operations of the Louisiana Petroleum Company. His method, called until today the Frasch process, would eventually

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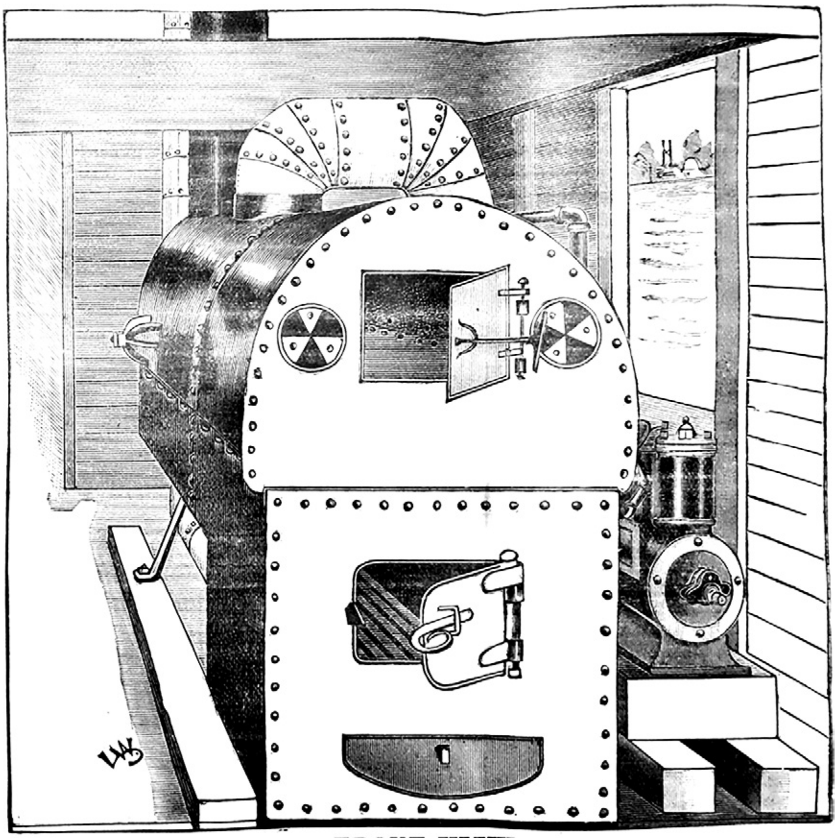

FRONT VIEW.
Of Improved Furnace for the production of Sulphur Dioxide Gas, showing sulphur furnace with fire box underneath, and curved pipe carrying the gas into reservoir.

Figure 2.4
Illustration of the new and improved furnace inside the New Orleans tugboat, used to produce sulphur dioxide gas.
Source: Matas Medical Library, Tulane University, “Louisiana Board of Health. *Annual Reports of the Louisiana State Board of Health*. New Orleans, 1886–1887,” unnumbered plate following p. 40.

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revolutionize the industry and cut to a fraction of the original price the cost of sulphur-mining in areas where it was not found close to the surface. Frasch exploited the fact that sulphur melted at 240°F, and after drilling a mining hole with common petroleum extraction equipment, he inserted a number of pipes, some of which were perforated. Pumping large amounts of boiling water into the sulphur pockets melted the sulphur, and through a different pipe and the introduction of pressurized air, the liquidified sulphur could be extracted onto the surface. There, it was simply laid out to dry, before the yellow rocks were ready for shipping at the Mississippi port close to New Orleans, which carries until today the name Port Sulphur.[76]

In 1893 a model of the quarantine system of Louisiana was exhibited at the World's Columbian Exposition in Chicago. The accompanying leaflet boasted: "The improved system, as operated by the Louisiana State Board of Health, aims at the complete destruction of all germs of disease, wherever existing, with the least injury to private property and the minimum of detention to vessels and passengers."[77] Its inventors presented the model as one that could achieve the purification of the vessel, as well as the full disinfection of anything carried on board. The brochure emphasized the blowing mechanism made by Olliphant, which enabled a saturation of over 18 percent sulphur dioxide in the ship's atmosphere. It also placed the apparatus at the center of the disinfecting operations in Louisiana, including the washing with bichloride of mercury and the steaming of fabrics and personal belonging.

The System of Maritime Sanitation was further characterized by the location of inspection and quarantine stations, which allowed for the calibration of measures and preventive procedures according to the kind of threat that separated infected and "foul" vessels from those arriving from infected ports with clean records. It was within this system of locations, practices, and calibrations that a fumigation apparatus began to take on an essential role: replacing unreliable and dated detention times with modernized and specified interventions, as it is "against the *germ* alone that modern sanitary science urges the warfare of quarantine."[78] With a celebratory note, the model of Louisiana's sanitation system in the Exposition announced that "through the operation of this complete system of quarantine work, the Board has succeeded in keeping out foreign pestilence, and at the same time has fostered the commerce of its State and section to a gratifying extent."[79]

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As already mentioned, the new apparatus was patented under the name of Olliphant, as well as Thomas A. Clayton. But Clayton was destined to further develop this new, revolutionary method of maritime fumigation, leading to a machine that would be employed not only in the American South but eventually across the globe. Born in Banff, Scotland, in May 1852, Clayton had arrived in Louisiana in 1878, were he conducted various businesses for twenty-two years. He first purchased a plantation in the St. Landry parish and became a successful cotton farmer, despite his lack of experience in this field. In 1882, Clayton took charge of the Farmers' National Commission office in New Orleans and became an outspoken proponent of the alliance movement: the National Farmers' Alliance and Industrial Union ventured to became a stronghold of farmers' economic cooperation across the American South and sustained pressure on the state and the nation in terms of transportation, valuation, land ownership, and access to markets.[80] Clayton had organized the alliance lodge in the St. Landry parish, near New Orleans, and became subsequently a secretary of the executive committee of the state alliance and joined later the populist cause of the people's party. As a manufacturer, he was known across Louisiana's society to possess "courteous and agreeable manners."[81] Furthermore, as the chief purchaser, he acted as a wholesale agent for the acquisition and sale of farm products for the state's farmers. After Clayton was appointed by Govenor Nicholls to the Board of Health in April 1890, various entries in the records suggest a strong bond between him and Olliphant across the various businesses of the Board.[82] But already in 1891, Clayton saw himself quickly embroiled in a scandal, as he stood accused of having tampered with health certificates to slaughterhouses, rather then following the rigid routines of sanitary inspections. Despite his claims to the contrary, Clayton immediately resigned.[83] His next appearance in the city's newspaper came when his newly opened garbage incineration plant did not work as promised.[84] Due to low capacity of garbage—so Clayton defended his failing business—the plant did not work properly, thus sending the smoke down to the city's center instead of over to the Mississippi Delta.

Clayton, an avid merchant, seemed to have moved into the business of producing fertilizers and chemicals by 1895.[85] It might have been here that he discovered the astonishing fire-extinguishing capacities of the sulphuric gas used in the Olliphant apparatus installed at the quarantine station. Perhaps motivated by the falling price of sulphur at the time, he investigated

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further. At the time, chemical solutions to the task of fire extinguishing usually relied on carbolic acid, a good mixture usually requiring about 15 to 20 percent density to have the desired effect on blazing flames. By contrast, with sulphuric acid, as Clayton found out, a density of only 5 percent had similar effects. In the last years of the nineteenth century, Clayton began to develop his very own apparatus that would provide both functions in one machine: an apparatus that would be usable both as a fumigating as well as a fire-extinguishing device. He thus registered his patent on June 7, 1899, filed as "Method of and Apparatus for Fumigating and Extinguishing Fires in closed Compartments."

Clayton and Olliphant appear to have pursued common commercial interests already from 1892, seeking to capitalize on the success of their apparatus. As the *Washington Post* reported in December 1897, Olliphant and Clayton had pursued the registration of their patent not under entirely fair circumstances. Holt's original invention had been made freely available to the public, intended explicitly for the benefit of humankind. After they had appropriated the system and registered patents in their name, Olliphant and Clayton approached Walter Wyman, Surgeon General of the Marine Hospital Service, to sell their patent to the US government. Wyman rejected the offer "on advice of patent authorities and law officers" and added: "Claim entirely untenable."[86] However, the grand jury that was tasked by the Board of Health to dispute the patent saw itself overwhelmed by yet another outbreak of yellow fever in 1897.[87] As the Board of Health resigned, the case was eventually dismissed.

The Clayton apparatus advanced into global trade despite its apparent failure to protect New Orleans in 1897. A reason could perhaps be found in the design of the 1899 patent by Clayton, which described an advanced apparatus, smaller and more powerful than the machine he had built previously in collaboration with Olliphant in 1894 (figure 2.5).[88] The new machine did fit easily on a bed plate and could be transported without too much effort. It consisted of a generating furnace, in which sulphur was burned, a cooling system to regulate the temperature of the sulphurous acid gas, and a power blower through which the gas could be expressed with high pressure. The furnace was a plain insulated chamber, divided horizontally by a wire netting. A door through which dry sulphur pieces could be introduced was placed at the front, and two pipes at the rear of the chamber. In Clayton's new design, an additional system of pipes allowed

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the fumes to circulate within the machine so as to achieve a rapid enrichment of the vapors, which could afterward be cut off through a by-pass. Through this system, the burning sulphur was supplied with large quantities of air by an induced draught. The high temperatures of regularly about 1800°F achieved in the furnace enriched the SO_2 with SO_3 and other sulphur oxides, before it was cooled down. Compared to the burning of sulphur in open fires, where SO_2 remained the almost exclusive compound, the burning in the furnace achieved the production of nearly a sixty-fold amount of SO_3. This, it was assumed, drastically raised the toxic capacities of the gas and contributed also to its excellent fire-extinguishing qualities. Another advantage of the resulting gas was its cloudiness, which was again a result of SO_3, which made it visible to those operating it and thus obviated accidents. Lastly, a second circuit with flowing water allowed the gas to cool down toward a temperature that had been shown to increase its germicidal as well as it fire-extinguishing capacities.[89]

A central idea embodied in this, as well as in the previous model developed in collaboration with Olliphant, was to establish a continuously circulating flow of air and gas. The air, extracted out of the holds of the ship, was used to raise the temperature in the furnace to thus continuously increase the amount of SO_2 in the mixture. A problem with the old Olliphant system, however, had been that, already at about 5 percent of gas, the fire in the furnace would start to diminish. In other words, at about 5 percent the mixture produced in the furnace had acquired such fire-extinguishing capacities that they became detrimental to the continuous burning of sulphur. To solve this problem, Clayton developed his design further, aiming to achieve two objectives. Clayton's patent states: "Preferably I contemplate the generation of gases or vapours in a furnace the intake and outlet of which are connected with a closed compartment and through which and the compartment a forced circulation is maintained, so that the gases will be rapidly enriched to the desired point, whereupon I cut the furnace out of the circuit by means of a by-pass."[90] Clayton thus added a valve that registered whenever the returning air from the compartment reached 3 percent, so that a connection between the return pipe and the furnace would be closed, and another valve would be opened to induce fresh air into the system to keep the fire in the furnace burning. With the same mechanism the circulation was shut off while the furnace continued to pump gas into

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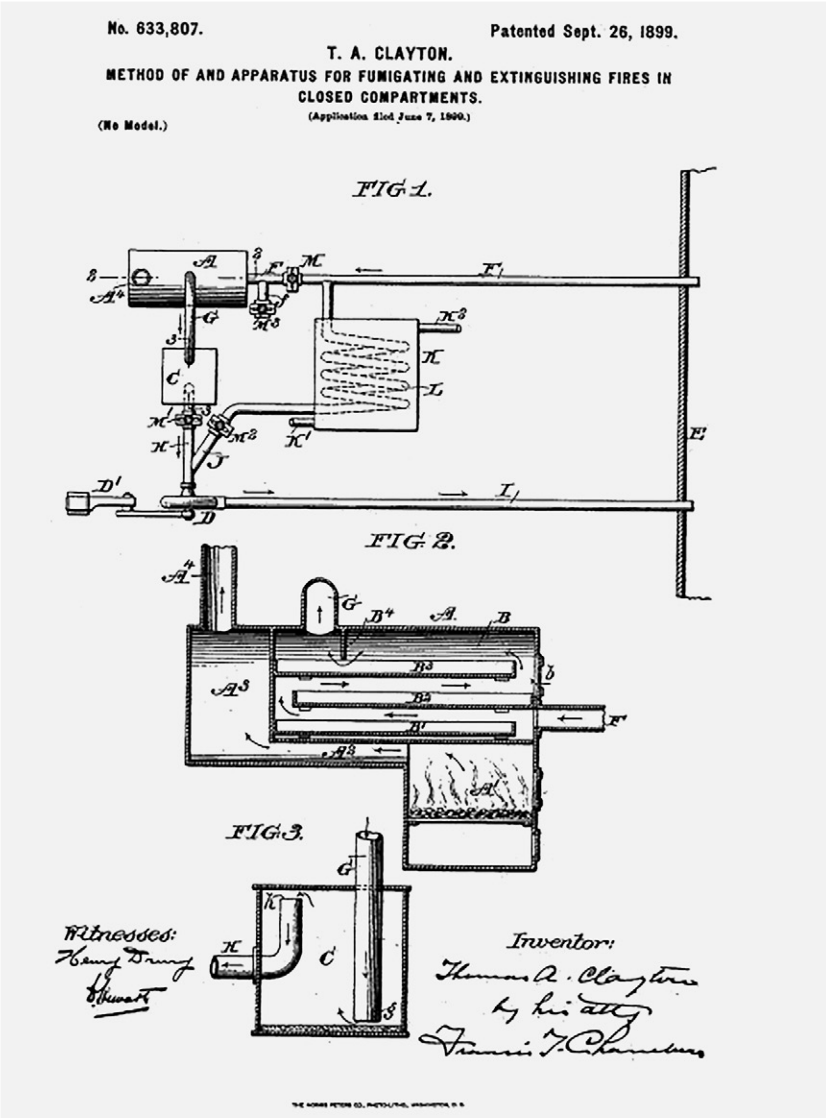

Figure 2.5
Diagram of the Clayton apparatus.
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the ship, thus raising the effective density inside the fumigated compartment well above 12 percent and up to 15 percent.

It would be wrong to assign the chain of events that led to the development of the Clayton apparatus to a breakthrough in the scientific understanding of disinfection and the germicidal capacity of disinfectants, or indeed to just see it as a result of the bacteriological revolution. Rather, the birth of the Clayton machine in New Orleans is a history driven by the abolishment of "barbarous" detention times and the experimental reinvention of the old sanitary practice of sulphur-based fumigation. A process characterized by an experimental employment of machines and contraptions, whose design informed and impacted a scientific discourse about what disinfectants actually do. But even more importantly, this was a process that involved the successive design of furnaces, power blowers, and cut-off valves aimed at producing a gas capable of killing all germs in all possible circumstances. Between 1875 and 1900, this involved an entangled history of chemical and mechanical engineering, as well as of medical theory, through which maritime quarantine was radically redefined, if not actually abolished. What had been a vaguely defined barrier to diseases transmitted by humans became a system of practices set up to eradicate germs. It was not human carriers, but goods, merchandise, surfaces, and porous materials that were identified as the penetrable hiding grounds of pathogenic agents in the experimental setups of New Orleans.

The origin of the Clayton machine in New Orleans is a history of developing a reliable industrious method of disinfection. The aim of Holt and his successors was to mobilize a method proved to destroy the pathogenic capacity of bacteria into the large-scale conditions of maritime trade. Not only did this practice promise ultimate security against bacteria hiding on the porous surfaces of the vessels' walls and floors, it also provided an effective—although perhaps unintentional—instrument against insects. Yet, with a predominant focus on bacteria and their possible hiding grounds, the experimental systems erected in New Orleans sidelined rodents and, in particular rats, which had in the meantime moved into the focus of comparable systems on the other side of the Atlantic.

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Sulphuric Utopias

A History of Maritime Fumigation

By: Lukas Engelmann, Christos Lynteris

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