The Political Economy of Safety Standards: The Different Approaches of France and Britain in the 19th Century

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Abstract

This paper offers a comparative history of safety practices around industrial risk in France and Great Britain in the 19th century. While the French government chose safety standards as its central tool for limiting the risk of explosion of steam boilers and gasometers (tanks for storing gas), the British government decided to rely on self-regulation by industrialists. The paper explores the political context in which safety standards emerged in France and the reasons for their rejection in Great Britain. While safety standards establish a minimum level of safety, the French Mining Administration that was responsible for devising and supervising the standards had significantly fewer resources than the specialized insurance companies that emerged in mid-19th century Britain that effectively controlled risk. With a century of hindsight, the paper compares the effects of these two different ways of regulating industrial risk. Ultimately, the promotion of safety depended as much on regulations and institutions as on social demand for a safer industrial environment.

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Contents

We live in a standardized world. Most of the objects around us have characteristics defined by codes and regulations. This applies to both large and complex industrial systems and seemingly innocuous objects. Nuclear power plants are subject to the regulations and supervision of the International Atomic Energy Agency (IAEA) and national safety organizations, just as ISO 11540 makes the hole at the top of ballpoint pen caps mandatory in order to reduce the risk of suffocation if swallowed.

Historians generally trace the origin of standards back to the end of the 19th century. The deployment of large-scale technical networks such as the electric power grid, the rise of international corporations selling high-tech goods, mass production and the system of interchangeable parts, as well as the desire to protect workers and consumers (particularly in the field of food adulteration) fueled a powerful movement led by hygienists, engineering associations, major corporations, and governments. Efforts accelerated and intensified at the turn of the 19^{th} and 20^{th} centuries, as marked by the creation of national standardization offices (the German Reichsanstalt in 1887, the British National Physical Laboratory in 1899, the American National Bureau of Standards in 1901, the French Commission permanente de normalisation in 1917), followed by the foundation of the International Federation of Standardisation Associations in 1926 (the forerunner of the International Standardization Organization, ISO). This paper looks at an earlier and lesser-known episode in the history of standards, linked not to the rationalization of production but to the securing of safety.

The project of making the new industrial world safer by specifying the shape of objects began in 1820 in France, in response to two specific innovations that arrived from Britain after the end of the Napoleonic wars: gas lighting and high-pressure steam engines.

The French government imposed technical safety norms on these potentially dangerous innovations. Standards were devised by the Academy of Sciences and supervised by the Mining Administration. Britain pursued a different strategy. In Britain, which was more industrialized than France at the time, the government chose to rely on the self-regulation by entrepreneurs. These divergent strategies of ensuring industrial safety in France and Britain provide important perspectives on the technological and political effects of safety standards.

Why the safety norm?

An 1828 official circular on steam boiler safety presents the first equation—to the author's knowledge—defining the legal shape of a technical object: $t = 0.018d(n\text{-}1)+3$, where t is the minimum thickness of a steam boiler, d its diameter, and n its maximum working pressure expressed in atmospheres.

In the 1820s, safety standards were an innovative administrative tool. Previously, safety had been determined locally and by professional communities. For instance, architects and masons defined local standards for buildings by punishing malpractice. The correct construction of, say, a chimney, was defined at local or regional levels by the associations regulating a particular trade, formalizing know-how through apprenticeships, and enforced through judicial trials in case of accident and poor workmanship. In cities, together with the various trade associations, the police played an important role in monitoring and controlling the safety of artisanal practices, prosecuting those who polluted or endangered their neighbors.

The choice made by the French government of imposing safety standards at an early stage of the diffusion of the technology is striking. The British government, despite being exposed much earlier to the problem of steam boiler and gasholders explosions, did not opt for this strategy. In 1817, the British government rejected a bill aimed at enforcing a safety standard on boilers used on steamboats. Despite repeated disasters, it was not until 1852 that steamboats' boilers were regulated. With respect to industrial steam boilers, a series of Parliamentary inquiries on boilers' explosions followed (1817, 1819, 1832, 1844, 1870), but the first regulations date only from 1902. In contrast, in France, from 1823, marine and industrial steam boilers as well as gasometers were subject to precise safety standards, even though at that time they had not yet caused any accidents in the country.

How can this difference be explained? In 1817 when the issue of regulating steam and gas safety emerged in the British Parliament, the country already had thousands of steam boilers and several dozen gasworks. Imposing a standard retroactively would have been impractical, and exempting older equipment would have created unfair competition. In contrast, France, at the start of the 1820s, had only about two hundred steam engines and a handful of gasometers. This allowed the French government to anticipate the spread of these potentially hazardous technologies and implement regulations before they became widespread. Paradoxically, it was France's relative economic underdevelopment compared to Great Britain that provided the opportunity to standardize these innovations.

Beyond this different economic context, national particularities also played a role. Safety standards were more easily conceived by the French government because they unfolded in the vacuum left by the abolition of trade associations during the Revolution. Safety standards emerged in new technological fields that lay beyond the expertise of established trades. Moreover, standardization reflected the confidence placed in applied mathematics to advance technology. Remarkably, academicians with no practical experience handling gasometers or safety valves were entrusted with defining the correct shape of these objects. This confidence rested on the belief in a technological optimum—the idea that a single, ideal standard could be imposed nationwide. Through safety regulations, the French government aimed not only to control hazardous technologies but also to "perfect" British machines, accelerating France's economic catch-up: a key term in the technological discourse of the time was "*perfectionner*." The ultimate goal was to harness mathematics in service of French industry, challenging Britain on its own technological terrain.

In Britain, the situation was markedly different. First, entrepreneurs strongly opposed the idea of subjecting their facilities to government inspection, often invoking the inviolability of private property. Second, Parliamentary inquiries reveal that many entrepreneurs viewed safety standards as overly presumptuous. With technology evolving rapidly, they argued it was counterproductive to impose solutions that would quickly become obsolete. Standardization, they feared, might interfere with the proper functioning of technology and even hinder progress—the true foundation of safety. For example, in 1820, the city of London prohibited a gas factory from dumping its liquid waste (resulting from gas purification) into the Thames. As a result, the company had to purify its gas using dry lime instead of water lime for gas purification, making the gas less pure for all gas users. A local nuisance that "only" killed fish was eliminated, but the gas distributed to customers became more hazardous. Third, entrepreneurs contended that safety and profit were inherently aligned: wasn't it in an industrialist's best interest to prevent gas leaks, which also resulted in financial losses? Or to avoid explosions that could result in substantial damage to both capital and reputation? In their view, encouraging the ingenuity of profit-driven industrial capitalists was far more effective than relying on rigid standards that risked becoming outdated the moment they were enacted. Finally, entrepreneurs and engineers were seen as having far greater expertise than scientists, undermining the latter's authority to intervene in industrial matters. Even members of the Royal Society, invited by Parliament to address industrial safety issues, admitted their relative lack of practical knowledge.

Minimizing and legalizing risk: The politics of the safety norm

The trigger for safety standards in France was a controversy within the Parisian bourgeoisie. In the early 1820s, gas and steam technologies arrived in the capital, sparking heated debates about their dangers. This conflict divided the bourgeoisie into two opposing factions. On one side, industrialists sought to continue operating within the city. Before the advent of railways, the cost of transporting materials over land was prohibitively high, making proximity to urban markets essential. These entrepreneurs aimed to protect their investments from legal challenges by disgruntled neighbors. On the other side, many Parisians viewed these new technologies—clearly polluting and potentially hazardous—with deep suspicion (refer to photo 1). They fought against the industrialists, whose activities threatened to reduce the value of their properties. Caught between these competing interests, the government enlisted the Academy of Sciences, requesting that this prestigious institution devise standards to ensure the safety of these innovations and mitigate the conflict between city dwellers and industrialists. The goal was thus to control industrial risk and also legitimize its presence in urban areas.

The controversy created by a very large gasometer built by French engineer Antoine Pauwels in 1822 in central Paris perfectly illustrates the dual nature of the safety standard. At the time, it was the largest gasometer in the world—ten times bigger than those established in London. During hearings in the House of Commons on gas safety, an English engineer remarked that Pauwels' device "must be virtually ungovernable." Influential bourgeois neighbors launched a campaign in the press against the gasometer, arguing—with the backing of several scientists from the Academy of Sciences—that placing such polluting and potentially explosive infrastructure in residential areas was utterly unacceptable. However, the factory had already been constructed, investments committed, and formal authorization granted by the previous government. Dismantling the facility would have entailed substantial compensation for the owner, prompting the government to seek a compromise through the implementation of safety regulations. The resulting standards mandated monitoring devices, rods to guide the gasometer's movement, and the use of noncombustible materials. While these measures enhanced safety, they also had a dire consequence: by legitimizing the use of gasometers—including oversized ones—they effectively sanctioned their installation inside cities across France. Because the standards were introduced after industrial investment had already been completed, they aligned with an existing reality that was already problematic. Unlike local regulations, the national scope of these standards paradoxically reinforced the presence of a controversial technology inside urban areas.

The case of steam boilers is similar. In 1823, the French Minister of the Interior, having learned of explosions in England and the United States, decided purely and simply to ban high-pressure steam engines near homes, which in effect meant banning their use in cities. The decision was heavily criticized by industrialists and experts who considered the steam engine essential to industrial development. In addition, the use of steam at high pressure increased the efficiency of the machines and therefore economized on coal. A compromise had to be found—and, once again, it was a safety standard defined by the Academy of Sciences.

Photo 1. Steam boiler explosions like this one in Paris in 1868 exposed the public to the dangers of industrialization in urban areas

Steam boiler explosions posed a risk not only to the workers inside the building but also to the factory's residential neighbors.
Credit: French National Archives F14 4217.

In April 1823, a commission—which included prominent scientists Pierre-Simon Laplace and Andre-Marié Ampère—proposed an initial technical solution to limit the maximum pressure of boilers: a valve placed out of the reach of workers and two “self-fusing plates” made of an alloy designed to melt at a temperature corresponding to the maximum pressure. In both cases, the goal was to restrict the worker's control, as they were assumed to be the primary cause of accidents. A central steam engine commission was established under the Ministry of the Interior. In each of the 90 “département” (an administrative division of France set up in 1790), a mining engineer was tasked with verifying the conformity of boilers, affixing official stamps to the valves and fusible plates, and conducting annual inspections.

The thickness of the boilers was calculated to withstand a pressure ten times greater than their theoretical breaking point. This substantial safety margin was a cornerstone of the French safety strategy: the Mining Administration focused on preventing accidents through technical regulations rather than relying on regular maintenance. Anticipating the wear and tear of boilers was therefore crucial. As the Mining Administration explained, the thickness of boilers was necessary in order to be sure “that manufacturers will only put on the market boilers that, *despite long use*, will still be able to withstand the test pressure.” In 1828, French boilers were standardized according to key parameters: their thickness, the melting point of fusible plates, and the diameter of safety valves were all calculated based on the working pressure and boiler diameter. For the first time, equations dictated the legal form of a technical object, merging science and law into a unified framework of industrial regulation.

The roles of insurance and maintenance

Throughout the 19th century, British industrialists regarded French safety standards with suspicion. Nevertheless, after a series of explosions (happening at the rate of several dozen per year), the press called on the government to intervene.[1] In 1854, after a series of disasters, a group of industrialists in Manchester, England, led by the renowned engineer William Fairbairn, founded the Manchester Steam Users Association. According to Fairbairn, the entrepreneurs had to solve the problem of the explosions themselves or risk government intervention. After passage of the Factory Acts of 1844 (which imposed safeguards on the moving parts of machinery) and the 1852 Ordinance on Marine Steam Boilers, the Home Office now threatened to standardize industrial boilers.

However, French-style standardization would increase the cost of boilers and subject industrialists to further government intrusion into their factories. Fairbairn was particularly skeptical about the usefulness of defining the thickness of boilers. In his opinion, safety lay more in the quality of the metal than its thickness. Although there was no official standard in Britain, the Manchester Steam Users Association recommended a safety factor of five (compared with 10 in France). Fairbairn also rejected the use of an insurance system in the event of a steam boiler explosion because he believed that the amount compensated in the event of an accident in exchange for an annual payment could encourage manufacturers to relax their vigilance and make less of an effort to ensure safety. Instead of an insurance scheme, the Steam Users Association therefore offered its members five annual visits from a qualified engineer and advice on reducing their coal consumption. The aim was to eliminate the risk, not to compensate for it. The association was a failure: in the 1860s, the number of boilers under its control stagnated at less than 2,000. In 1859, the association's chief engineer defected to found the Steam Boiler Insurance Company with a London insurer. This was the first insurance issued to deal with the risk of steam boiler explosions. By 1865, the company was insuring more than 10,000 boilers. The company was very profitable and competitors multiplied, with the advent of the Midland Steam Boiler Inspection and Assurance Company in 1862, the National Boiler Insurance Company in 1864, the Yorkshire Boiler Insurance Company in 1873, the Engine and Boiler Insurance Company in 1878, and the Scottish and English Boiler Insurance Company in 1882. In the 1880s, half of the approximately 100,000 boilers in Britain were insured.

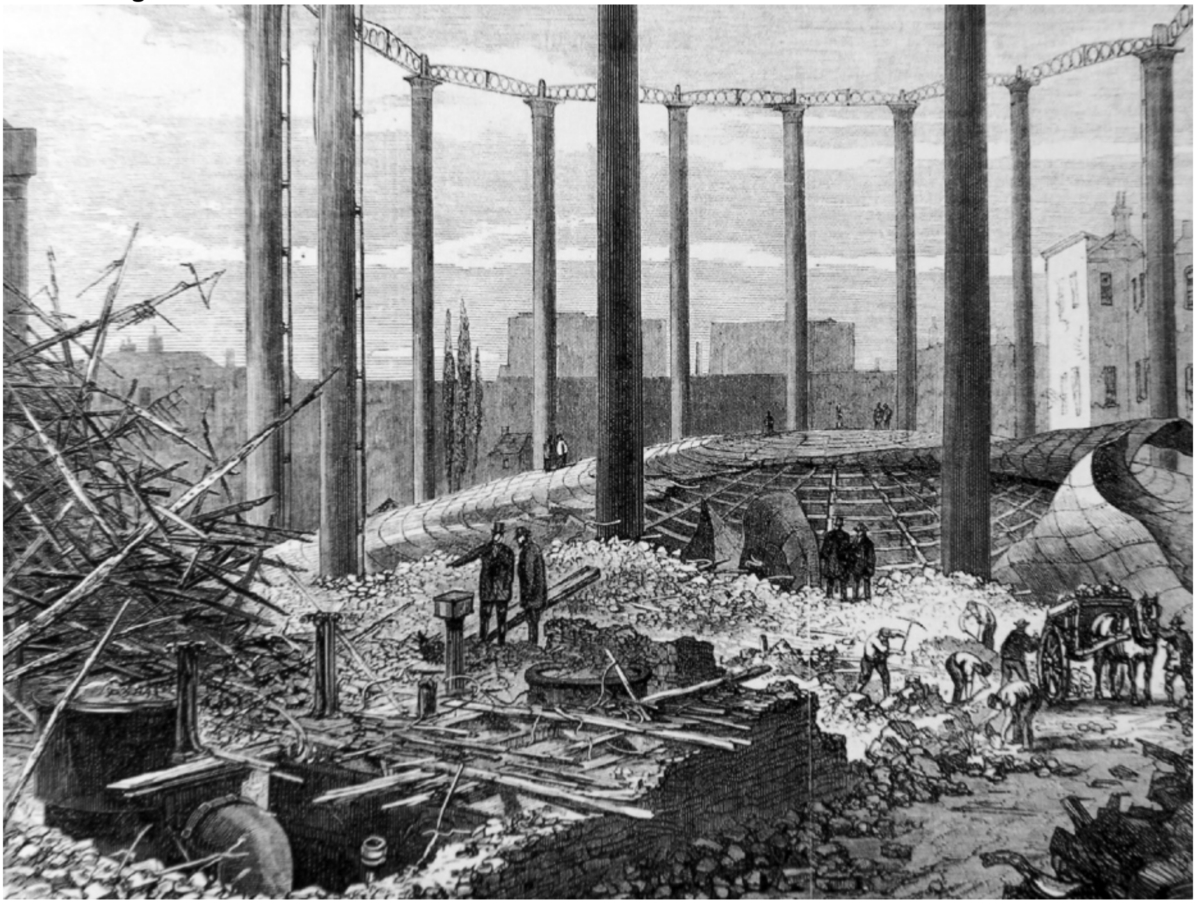
Insurance companies embraced a different safety culture from that of the engineers employed by the French Mining Administration. Fairbairn, a leading proponent of the inspection system, was also a pioneer in the study of material fatigue, highlighting the need for regular inspections of boilers. Whereas French engineers focused on the thickness of the boiler and the diameter of the valves, British insurers focused more on boiler maintenance and lifespan. In their perspective, explosions were less a consequence of flawed construction and more a result of wear and tear. The calculation of the risk premium was based on two criteria: the size of the boiler and, above all, the age of the boiler, which determined the main part of the variation in the premium.

British insurance companies also approached liability for boiler explosions differently. Since their goal was to sell insurance policies to entrepreneurs, it was in their interest to place legal responsibility for accidents squarely on the shoulders of owners. To this end, they actively engaged with legislators, highlighting the injustices suffered by injured workers and emphasizing the owners' duty to properly maintain their boilers. In contrast, after accidents, French mining engineers' reports often placed the blame on workers. The explosions highlighted the engineers’ own failure to properly monitor the boilers in their departments, so it suited their interests to attribute fault to the workers rather than acknowledge the poor condition of the machinery.

A comparison of French and British ways of regulating risk

With the benefit of a century's hindsight, we can assess the impact of safety standards. First, these standards deserve credit for establishing a baseline level of safety requirements and likely accelerating the process of improving safety in France. The case of gas lighting offers a striking example. In 1820, according to evidence gathered by an inquiry by the British Parliament, many gasometers in London or Manchester were built in a remarkably rudimentary fashion. Despite a twenty-year headstart, lower material costs, and the availability of skilled workers and engineers, the safety standards of British gasworks lagged far behind those of the first installations in Paris. At the Whitechapel gasworks in London, for instance, massive sacks with a capacity of 15,000 cubic feet were used as gasometers. The use of repurposed materials was common practice: at the Brick Lane factory, old beer barrels were converted into gasometers. To cut costs, a Manchester entrepreneur even floated his gasometers in a pond rather than investing in the construction of proper basins. Elevated tanks, designed to avoid excavation expenses, frequently ruptured under water pressure. Wood was extensively used in the construction of these facilities—from elevated tanks and gasometers to the roofs and frames of sheds—despite the fact that iron, a safer material, was significantly cheaper in England than in France at the time. These makeshift methods had clear consequences for gas distribution in London. By the 1830s, companies advised customers to closely monitor their gas burners, as the flames could shoot up a foot high or suddenly extinguish—a severe hazard when the gas flow resumed. The gas was so sulphurous that some people preferred to install their burners outside, adding reflectors to direct the light indoors. By the 1850s, growing public frustration spurred a wave of editorials, lawsuits, petitions, and proposed legislation. This movement—dubbed the "gas agitation" by newspapers—gained momentum after the explosion of a gasometer at the Three Elms factory in 1865 (refer to photo 2). Finally, in 1872, a Board of Gas was established in London to oversee factory safety and gas quality, adopting the very practices that France had introduced half a century earlier.

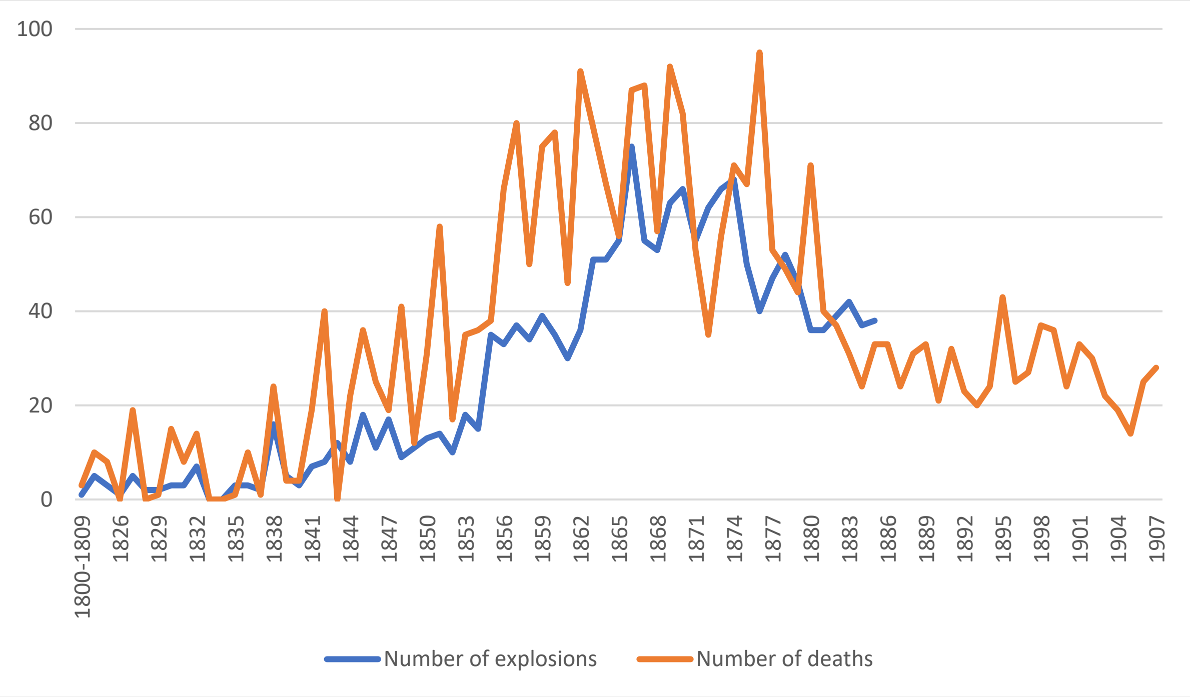
Photo 2. The explosion of the gasometer at the Three Elms factory in London in 1865 was especially devastating



The explosion killed 12 people, injured many others, and caused great distress among Londoners.
Credit: Illustrated Times, November 11, 1865.

The effect of the safety standard in the case of steam boilers is quite different. Admittedly, the safety standard ensured a minimum safety level, but the monitoring work carried out by the French mining engineers was inferior to that carried out by the British insurance companies. While the latter organized five inspections a year, including one internal inspection, the French mining engineers conducted only one inspection a year (and only an external inspection). French mining engineers generally checked compliance with regulations (presence of safety devices, the fusible plate, and a water-level indicator). For their part, British insurance engineers noted the evolution of corrosion and proposed repairs. The main aim of the insurance companies was not to compensate for the risk but to eliminate it. For example, the Steam Boiler Insurance Company charged 17 shillings per year for inspection and only 3 shillings for insurance for each boiler. In short, the insurance companies did a job equivalent to that of the French *ingénieurs des mines* but with greater resources. In the 1870s to 1890s, the annual reports of the various British insurance companies reported that the boilers they insured were extremely safe but they also recognized that about half of all boilers still escaped their inspection.[2] The safety of British steam boilers thus varied, with insured boilers being very safe and uninsured boilers being more dangerous than the average French boiler. Overall, the steam boiler inspections carried out by insurance companies succeeded in reducing the risk of steam boiler explosions in Britain. The number of explosions and casualties fell in the 1870s, despite the increasing use of steam (refer to figure 1).

Figure 1. The number of explosions and casualties from steam boiler explosions in Britain began to decline in the 1870s with the spread of regular inspections by insurance companies

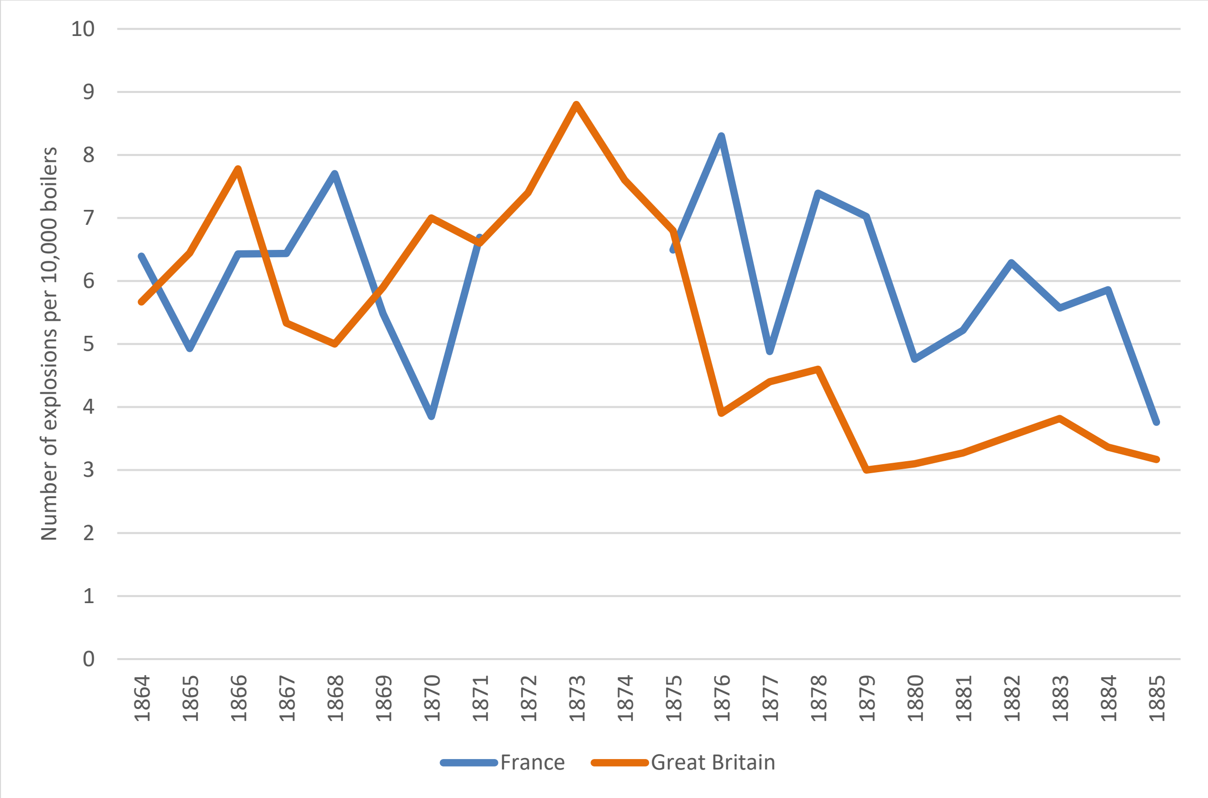


Sources: Chaloner (1959); Walford (1881).
Note: The data exclude locomotives' boilers and steamboats' boilers.

The effects of the insurance system is also evident in figure 2. In the 1860s, the rate of boiler explosions in France and Britain were similar, averaging about 6 explosions per year per 10,000 boilers. But the explosion rate for boilers in Britain subject to insurance company inspection was lower (about 2 per year per 10,000 boilers). From the 1870s onward, the effect of the inspection and maintenance by insurance companies brought down the British explosion rate.

Unlike the French Mining Administration, which compiled precise statistics, there was no census of the number of steam engines in Britain, except for those used in the textile industries at specific dates. But it is certain that steam engines spread much more quickly and widely in Britain than in France. An 1838 census of British textile industries counted more than 3,000 steam engines, approximately the same number as those for the entire industrial sector in France at the time. British insurance companies estimated that there were 80,000 steam engines in Britain in the 1860s (compared to 25,000 in France); by the 1880s, the number had grown to 120,000 in Britain (but only 60,000 in France) (see *Statistiques de l'industrie minérale,* 1899, Paris, Imprimerie Nationale for the figures on France).

Figure 2. The number of explosions from steam boilers in France and Britain began to converge in the 1870s as inspections and maintenance improved in Britain



Sources: Statistics Relating to Boiler Explosions, Manchester, 1869; Chapuis 1982; Walford 1881.
Note: The British numbers are somewhat uncertain because, in the absence of administrative records, the exact number of boilers is unknown. Insurers' estimates agree that the number of boilers rose from 90,000 in the 1860s to 120,000 in the late 1880s.

From the 1860s onward, the technical safety standard in France was increasingly criticized. French industrialists were quick to blame it for the slower rate of industrialization in France. They claimed that the safety margins on the thickness of boilers imposed by the administrative regulation were stifling manufacturers' initiative. It is true that according to the 1828 formula, large internal furnace boilers required very thick sheets of metal. It is also true that the cost of boilers tended to be higher in France than in Britain. In 1860 the French government undertook an enquiry prior to the establishment of the Franco-British free trade agreement. French boiler manufacturers were concerned that their British rivals were managing to produce boilers 30 percent to 40 percent more cheaply. But boiler manufacturers did not blame safety standards for the price difference. They instead cited the price of raw materials (coal, iron, and copper) and, above all, the scale of British workshops and the greater use of machine tools, which made British workers more productive.[3] It is unlikely that the important difference in the number of steam engines between France and Britain in the mid-19th century was due to the existence of safety standards—coal was more expensive in France and the country was generally less industrialized.

French efforts at standardization were criticized from their inception. For instance, the influential Société Industrielle de Mulhouse refused to strictly apply the 1828 decree on steam engines because it considered it dangerous: putting the second safety valve under a lock, for example, made it impossible to check whether the disc was sticking to the boiler. In 1830, a Manual on the Steam Engine, published by the École centrale des arts et manufactures, explained that the mining engineers knew little about steam boilers and that their orders were counter-productive: compliance with safety standards provided legal protection for the owners, whereas most accidents were in fact due to poor maintenance.

With the rise in the number of steam engines and steam specialists coming from the industry, the French government delegated more and more of the work of inspection to the industrialists themselves—to the point that the standard was no longer actually applied. In January 1865, under the pressure from French industrialists, steam boiler safety standards were lowered as a decree abolished the regulatory requirement for the thickness of boilers. Only a second safety valve and a water-level indicator remained compulsory—devices that were generally used in Britain, as well (Fairbairn 1851). The 1865 decree aimed at making boiler manufacturers freer and more accountable: what was the point of improving the quality of materials if you could not reduce the thickness of the metal plates? The 1865 decree also abolished the requirement for annual inspections by mining engineers. In 1865, the Société Industrielle de Mulhouse founded an "Alsatian Association of Steam Engines Owners" based on the model of the Manchester Steam Users Association.[4] A subsequent decree in 1880 made it compulsory for boilers to be inspected internally and externally once a year, but did not specify who was to make this inspection. Between 1870 and 1900, 11 steam engine owners' associations were created in France. At the beginning of the 20th century, about 30 percent of the 100,000 French boilers were registered and inspected by a steam user association. French regulation finally converged with the British system, with the Mining Administration providing minimal oversight.

One lesson from history is that the safety standards did not hinder innovation. On the contrary. The gas lighting entrepreneur Antoine Pauwels, whose huge gasometer attracted so much controversy between 1822 and 1823, was also the engineer who invented the most important safety devices of his time. His gigantic gasometer was the first to be equipped with a guiding rod that prevented it from oscillating. Twenty years later, he designed the second generation of gasworks: a system of articulated pipes made the movement of the bell more precise and regular, and the cast iron retorts were connected to the gasometer by a suction system that prevented the gases from escaping. Pauwels' most important invention was the "gas compensator," patented in 1846, which made it possible to regulate the gas pressure in the network, avoiding significant leaks and dangerous oscillations of the flame.

In the case of steam engines, safety standards probably did not hinder innovation. On the contrary: the need to define a safety norm and the involvement of the French government in this field led the greatest physicists of the time—from Ampère to Régnault—to take an interest in the steam engine and to study ways of improving its efficiency. The cost of coal, which was higher in France than in Britain, encouraged manufacturers to quickly adopt the high-pressure (and higher-efficiency) steam engines developed by Richard Trevithick and Arthur Woolf, while British manufacturers remained attached to James Watt's low-pressure engine for longer. Finally, the emphasis placed on safety and boiler thickness seems to have played an important role in the emergence after 1850 of a key innovation in boiler design: the water-tube boiler, developed by the French engineer Julien Belleville. This innovation, which involved heating water by circulating it through tubes, made it possible to avoid the use of so-called "fire tube" boilers that had a larger diameter and therefore a greater thickness according to the French safety standard. Belleville promoted his boilers by extolling their explosion-proof nature. Belleville water-tube boilers enjoyed international success, especially for marine boilers. In the 1890s, the Royal Navy even chose to equip its cruisers with Belleville boilers, before turning to the national company Babcock & Wilcox, which had in the meantime bought out its French competitor. Other French engineers (Du Temple and Le Normand) also enjoyed international success in the field of water-tube boilers.

By contrast, the risk of boiler explosions was much higher in the United States than in France or Britain. As many boilers exploded in one month in the United States as in one year in Germany, whereas the number of steam boilers was about the same (refer to table 1). Apart from steamships boilers, there were no safety standards in the United States in the 1800s. The Hartford Boiler Insurance Company, founded in 1867, did not succeed in attracting customers and reducing the risk as in Britain, France, or Germany. It was not until 1914 that the American Association of Mechanical Engineers published rules for the construction of stationary boilers.[5]

Table 1. Risk per 10,000 steam boilers, 1882–92

Country	Number of explosions	Number of people killed
United States	20	29
United Kingdom	4.9	2.4
France	4.8	4.7
Germany	2.2	1.4

Source: Statistiques de l'industrie minérale, 1899, Paris, Imprimerie Nationale; Thurston (1907, 717); Crum (1910, 17–18); Hunter (1986).

Conclusion

This paper presented two distinct safety strategies in France and Britain, which gradually converged by the late-19th century. However, neither the safety norm imposed by the government, the self-regulation by steam engine owners' associations proposed by entrepreneurs, nor the insurance and inspection system were the true determinant of safety. Local context also played a crucial role in the level of risk. For instance, the much more frequent explosions of steam boilers in the United States was in part due to their widespread use in sawmills scattered across forests, often relying on low-quality machinery with minimal safety oversight. Similarly, in France, the "locomobiles"—mobile steam engines used for threshing grain in the fields—were less safe than industrial or marine boilers, which benefited from stricter supervision and more consistent maintenance.

Another key factor was the political pressure exerted on entrepreneurs. Ultimately, safety was not just a technical matter but a deeply political one, shaped by the balance of power between entrepreneurs, neighbors, and regulators.

Finally, workers also played a crucial role in ensuring workplace safety. For the labor movement, industrial accidents were not merely a technical issue but a deeply economic and social one: the pursuit of profit and the subordination of workers were seen as the root causes of workplace accidents. In France, enginemen regularly criticized mandatory safety devices—such as the valve placed out of reach and the self-fusing plate—arguing that these measures undermined their autonomy. A mechanic working on a steamboat highlighted this tension, explaining that the problem of explosions was, above all, a matter of authority on board. He recalled instances where, following the captain's orders, he had been forced to carry out maneuvers he knew to be dangerous. Because the engineman quite literally held the passengers' lives in his hands, he believed he should have the right to refuse reckless commands or insist on necessary repairs (Smith 1852). Statistics on boiler explosions reinforced this view, showing a clear correlation with the economic cycle—the push to maximize production often meant pushing boilers to their limits and delaying maintenance. In the aftermath of explosions, workers' newspapers not only called for stricter safety regulations and harsher penalties for negligent employers but, most importantly, for greater decision-making power for the workers themselves. Ultimately, by the mid-19th century, alternative visions of workplace safety were emerging—shaped neither by the Mining Administration nor by insurance companies, but by the political demands of workers. These proposals reflected a broader struggle for workplace authority, underscoring that the fight for safety was also a fight for power.

Notes

[1] In Britain between 1852 and 1879, 4,200 miners died from methane explosions in mines and 822 people died from steam boiler explosions.

[2] See the reports from *Steam, A Boiler Insurance Monthly* in the 1880s; Bailey (1887); Chaloner (1959).

[3] Conseil Supérieur de l'Agriculture, du Commerce, et de l'Industrie, 1870, 425–35.

[4] The Association de propriétaires des appareils à vapeur et électrique (APAVE) still exists and is a major company in the field of risk management, carrying out control, inspection, and certification.

[5] *Statistiques de l'industrie minérale*, 1899, Paris, Imprimerie Nationale; Thurston (1907, 717); Crum (1910, 17–18); Hunter (1986).

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