SCIENCE AND CORPORATE STRATEGY

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testing facility.[47] It appears that the Executive Committee paid close attention to Francis's stern warning. The committee approved his recommendation to establish a central department to deal with government powder sales, and it gave him and Moxham permission to open negotiations with Bethlehem for joint research on ballistics.[48] Soon the committee began to alter the original charter of the General Experimental Laboratory.

Although Executive Committee activity slowed down during the late summer of 1903, Moxham advised his colleagues on July 29 that they could expect to spend as much as $75,000 for the experimental laboratory they had earlier authorized.[49] Francis had issued his warning only the week before. By September, the committee had shifted completely to Francis's side and was prepared to spend far more for the new laboratory than Moxham had initially projected. Moxham reported on the matter of the experimental laboratory to the Executive Committee on September 8, 1903. He noted that he and Francis were considering what relationship should exist between his department's laboratory, as defined and authorized earlier, and the one approved by the Executive Committee to ensure that the military would consider Du Pont progressive.[50]

Responding to Moxham's report, the Executive Committee took a firm stance and established the policy that would serve as the initial charter of the General Experimental Laboratory. "[Our] policy should be one," agreed the committee, "of fully developing the Experimental Laboratory, embodying in that such tools and apparatus as may be needed for the smokeless powder end of things. We believe that in this laboratory should be concentrated everything of a general nature in the way of apparatus and tools for tests."[51] Moreover, the committee determined that even if the proposed joint venture with Bethlehem were to fall through (which eventually happened), Du Pont would build a ballistics research and testing facility. In addition to establishing these major policies about the direction of Du Pont research, the Executive Committee also concluded that research and development work on safety explosives – what would soon be known as "permissibles" – would be done by the new laboratory.

The Executive Committee's decision on permissible explosives research came in response to growing political pressure for federal regulation of mine safety. These pressures were part of the same political reform movement – Progressivism – that led to the enforcement of the Sherman Antitrust Act by the Theodore Roosevelt administration. In his regular report on "experimental matters," Moxham had argued that Du Pont must take up the study of safety explosives "along broad lines."[52] Reformers were seeking legislation that would restrict the types of explosives used in mining to those that would not, unlike nitroglycerin dynamites, set off "fire-damp," the dangerous mine gas consisting principally of methane.[53] The Executive Committee clearly recognized the importance of developing such safety explosives. But rather than instructing the High Explosives Operating Department to set the task before the Eastern Laboratory, the Executive Committee

approved Moxham's recommendation that the development of safety explosives should be the province of the soon-to-be-established experimental laboratory.[54] This decision, perhaps more than any other factor, headed Moxham and Barksdale toward the showdown of mid-1904 over what the proper role of the General Experimental Laboratory should be. Without question, the relatively new and not completely staffed Eastern Laboratory was the logical institution to work on safety explosives. But because Moxham had gained no say over the affairs of Eastern (even though Coleman had theoretically put him in charge of all experimental matters), he was unwilling to leave to others the filling of this urgent need in which Du Pont had "to take a proper lead."[55]

Six weeks after the Executive Committee broadened the mission of the General Experimental Laboratory, Moxham noted that "we are now considering the establishment of a temporary laboratory at [a small textile mill on the Brandywine River] pending the construction of the permanent laboratory."[56] A month later he had indeed secured space in a mill dating back to 1756. In addition to hiring researchers, Moxham noted, there were plans to employ a "patent office draftsman" at the laboratory, a sign that he envisioned the new facility as being an "invention factory" like the one Edison had founded a quarter-century earlier at Menlo Park, New Jersey.[57]

By the end of 1903 Moxham had made significant organizational strides. He had succeeded in convincing Coleman to rename his department simply the Development Department, and he had brought Coleman to accept a far broader definition of "development" than had been agreed upon in the earliest days of the Executive Committee. No longer restricted to raw materials procurement, development now meant strategic planning for economic growth. Moxham believed that the research program was an intimate part of that process, so the Development Department remained in charge of experimental matters.[58] He had also recruited the first permanent head of the new research laboratory: Francis I. du Pont. Dr. T. J. Wrampelmeier, who had been employed briefly at Eastern Laboratory, had served initially as the acting director when the temporary laboratory first opened. But in November 1903 he resigned to become Du Pont's European representative.[59] Soon Moxham reported that the establishment of the laboratory and the selection of Francis as its head had led the military to applaud the Du Pont Company's "progressive policy."[60] Francis's strategy had begun to work even before the new laboratory was fully functioning.

Moxham shared with the Executive Committee his and Francis's musings about how the company would account for the productivity of the laboratory's work – no small issue in the management of research in a modern corporation. They believed that the laboratory must "be put entirely upon its merits as a business department." In other words, the laboratory had to yield a profit. The difficulty was in determining how to account for the laboratory's work. Moxham and Francis proposed the following arrangement: the results of the laboratory would be comparable to patents or inventions acquired outside the company. In other words, a fixed sum or royalty could be assigned to the value of specific laboratory results. Therefore, any work done by the laboratory would be considered as its property, and once sufficiently developed, an invention, process, or product worked out by the laboratory would be for sale to the Operative (or Manufacturing) Department. If the Operative Department wanted to adopt the results of the laboratory, it could purchase them outright or pay a royalty. Moreover, Moxham and Francis argued that should the Operative Department not elect to buy the laboratory's work, the laboratory should be free to sell such work outside the company. "In this way," believed Moxham, "the Experimental Laboratory will be placed upon a commercial basis, and [at] the end of two or three years the records will be proper measure of its utility and value. The experimental work will of necessity call for considerable sums of money per annum if properly conducted, and we will act in the dark unless we have some contra account by which the wisdom of these expenditures can be measured."[61]

Moxham's and Francis's heady optimism that the new laboratory would quickly generate a profit remained undampened when the Executive Committee held a special meeting to consider more precisely how the laboratory, or Experimental Department, would be handled in an accounting sense. Moxham considered such a meeting critical because the Experimental Department was "getting down to a working bearing." The committee heard Moxham outline a procedure for the laboratory to charge other departments for its experimental work. He sought the committee's permission to allow his department "to exact payment for all expenditures on new developments before turning such developments over to [an] operating department." Maintaining that "it might well be that at the end of the year the department would be self-sustaining," Moxham nevertheless requested from the Executive Committee a monthly appropriation to cover the Experimental Department's expenses. The committee accepted Moxham's general guidelines regarding accounting methods, including the notion of property ownership, and granted Moxham $3,000 per month for Experimental Department expenses.[62] The experimental laboratory was "upon its feet as a going concern."[63]

The Operation of the Experimental Station

The new laboratory began to function almost at once. Moxham and Francis were assisted by D. M. McDonald, whose responsibilities included "having charge of the organization and records and the method of work." Under McDonald were the "chemists, assistants, draughtsmen, etc., each receiving instructions from the director and being made responsible for the carrying out of work assigned to him. . . . " Francis noted that "as soon as the laboratory undertakes a piece of work, it is given a card and index number and filed in an index of unfinished work, with the name of the man that has been made responsible for it. Here the card remains until the formal report is made, when the date of the report is marked on the card and it is transferred to a file of finished work." He reported that his research team had been supplied with basic apparatus for chemical and physical investigations, and when the laboratory was completed, it would include "an outfit for the manufacture of instruments and appliances to be used in the development of new processes."[64]

Work at the experimental laboratory was varied. The initial list of projects included the following: routine chemical analyses; moisture analysis of wood and fiber pulp; black powder analysis; study of dynamite; improvement of smokeless powder; investigation of the French explosive "Cheddite"; investigation of the German explosive "Amanol"; trial of a new smokeless powder; development of a method of bleaching and purifying cotton; an effort to purify guncotton without so much steam; the design of a continuously working smokeless powder press; an effort to manufacture colorless smokeless powder; efforts to improve black powder manufacture; work on nonfreezing dynamite; an examination of the explosive "Dreanite"; an attempt to make briquette charcoal; development of a smokeless powder charge for blank cartridges; and construction of a hexagonal die for making smokeless powder for a twelve-inch breech-loading rifle.[65]

Such diversity must have strained the resources of the staff, which was neither large enough nor adequately qualified to manage this array of tasks. The laboratory's director fitted the mold of the lone inventor far better than that of the credentialed chemist directing a scientifically based industrial research laboratory. Francis was the son of Francis Gurney du Pont, who had managed the company's black powder works on the Brandywine for some two decades and who in the 1890s had directed Du Pont's pioneering effort in smokeless powder manufacture at Carney's Point, New Jersey. Francis had graduated from Yale's Sheffield Scientific School in 1895 and returned to the Delaware Valley to work for his father as a plant chemist. Although a major part of his duties included training technicians and other workers to perform routine tests and analyses, Francis also found time to make important improvements in smokeless powder manufacturing processes.[66] Yet for all his technical and scientific talents, Francis I. du Pont would eventually demonstrate that he was not a successful research manager. By 1907, the Executive Committee (from which Francis had resigned in 1904) could not count on regular reports, nor could it find evidence of a well-organized and well-balanced approach to research and development. In 1907, Francis would step down as director of the Experimental Station.[67]

Francis's initial staff was severely lacking in scientific credentials as compared to Reese's staff at Eastern Laboratory. (See Table 1.2 for information on the charter members of the Experimental Station staff.) Of this motley bunch, three individuals need to be highlighted. The first is Fin Sparre, who was by far the best trained and most experienced chemist among the lab-

Table 1.2. *The Experimental Station's Research Staff, 1903*

Name	Position	Qualifications	Remarks
Francis I. du Pont	Director	BS, Sheffield Scientific School, Yale University, 1895. Significant inventions in smokeless powder processes, 1895–1902.	
Daniel M. McDonald	Assistant director and office manager	"Familiar with black powder."[a] No academic degree.	Monthly salary: $100.
Charles E. Arnold	Chemist	Attended Ohio State University. Chief Chemist, Dominion Iron and Steel Co., Sydney, Cape Breton Island, Nova Scotia	Associate of A. J. Moxham at Lorain Steel Company and at Dominion Iron and Steel Co. Monthly salary: $175.
George Gentieu	Assistant chemist	"Plant man from Carney's Point" smokeless powder plant.[b] "A plumber by trade."[c]	Monthly salary: $100.

oratory's charter members. Born in Bergen, Norway, in 1879, Sparre received undergraduate training in chemistry and engineering in Oslo and did some graduate work in Dresden, Germany. He worked in the Norwegian powder and munitions plant before emigrating to the United States in 1903. Thirteen days after arriving in the United States, Sparre accepted a position of chemist at the new Experimental Laboratory. Over the next decade he would demonstrate to the highest levels of management that he possessed outstanding abilities as a chemist and a rare ability to judge areas ripe for development. In 1911 he became director of the Experimental Station and in 1919 director of the Development Department, a position he would hold until his retirement in 1944. Indeed, much of Du Pont's diversification during this period can be attributed to Sparre's work. He was also a member of Du Pont's board of directors from 1930 until his death in 1944.[68]

J. N. Wingett, known to his peers as "the Wizard," is the second individual whose charter membership is noteworthy. As the inventor of a promising system of continuous black powder manufacture, Wingett had been hired by Moxham to perfect this system. Moxham guaranteed Wingett $65,000

Table 1.2. (*cont.*)

Name	Position	Qualifications	Remarks
Fin Sparre	Chemist	Undergraduate degree in chemistry and engineering, Technical College of Oslo, Norway (Kristiania). Graduate study at Technical College of Dresden, Germany. Plant experience: Norwegian government powder and munitions plant.	Monthly salary: $100. Later became chief chemist at Experimental Station and then director. Headed Development Department from 1919 to 1944 and was central figure in Du Pont's diversification. Member, board of directors.
J. N. Wingett ("The Wizard")	Independent inventor	No academic credentials. Held patent application for a continuous process for black powder manufacture.	Monthly salary: $300. Du Pont also paid $65,000 in cash for patent application. Salary was paid while the invention was being perfected.
Hudson Maxim	Independent inventor	Academic study at Kent's Hill, Maine, academy. Coinventor of transversely perforated nitrocellulose powder.	Monthly salary/retainer: $500. Brother of Hiram Maxim, inventor of machine gun and early automobile pioneer.

[a] Charles E. Arnold, Sr., *My Remembrances of the Du Pont Experimental Station* (n.p.: n.p., 1947), p. 8.
[b] Ibid.
[c] Frank P. Gentieu, "The First Fifty Years at Carney's Point," *The Carney's Pointer* (July 1951), B-6.

in cash solely for filing his patent application, as well as a monthly salary of $300 while he worked out the bugs in his system and put his application in order. According to a contemporary, the Wizard "had to have a room garlanded with sweet smelling flowers with canary and mocking birds to entertain him while he communed with the spirits to invent."[69] More impressive was the Wizard's Spook Room, a small room painted jet black and furnished with only a small black table and two black chairs. "If you were troubled for an answer to your problem," wrote another researcher, "just have a seance with the Wizard."[70] Wizard Wingett appears to have been far more the medieval alchemist than the modern industrial chemist. Yet this man drew the second highest salary of any member of the laboratory. Another independent inventor, Hudson Maxim, received the highest salary of $500 a month.[71]

Maxim had been the principal factor in Moxham's campaign to establish a laboratory for the Development Department. As an independent inventor, Maxim provided Du Pont with the means to become a successful manufacturer of smokeless powder. He and Robert Carl Schüpphaus had patented a transversely perforated nitrocellulose powder that won the favor of the U.S. government. In October of 1898, the older group of du Ponts, including Francis Gurney du Pont, purchased the American patent rights to the Maxim-Schüpphaus powder and began manufacturing it for the army at the Carney's Point plant. The du Ponts and Maxim hammered out an amiable relationship whereby, in effect, the company paid Maxim a monthly salary of $500. Working out of both his London home and his laboratory in Landing, New Jersey, Maxim continued to make refinements to his powder and to notify the company of such improvements. But on several occasions Maxim offered Du Pont options on related inventions and developments that, contended A. J. Moxham, needed to be evaluated in a laboratory. When the new experimental lab was established, Maxim's salary was taken directly out of its salary account.[72]

Later, in January 1905, Du Pont and Maxim broadened their agreement whereby any of Maxim's developments in explosives would become the exclusive property (in the United States only) of the Du Pont Company. Once this contract was signed, the Executive Committee began making special appropriations to the Development Department for Maxim's $6000 annual salary. The Du Pont Company agreed to pay Maxim 20 percent of its net profits on sales attributable to his work up to a limit of $200,000. Thereafter, the company would pay him 10 percent of profits up to an amount of $50,000 annually. Maxim's salary accrued as part of the respective $200,000 and $50,000 limits.[73] This agreement came on the heels of Maxim's invention of a new smokeless powder with apparently far better stability than the relatively unstable nitrocellulose powders consumed by the government. For this reason, A. J. Moxham dubbed Maxim's new powder "Stabillite."

Contracts such as those with Maxim and Wingett were common in the years from 1870 to 1900. Even companies possessing noteworthy in-house technical staffs often made far greater expenditures for both the talents and products of independent inventors than for their own research programs.[74] Du Pont was no exception. What Du Pont learned with Maxim and Stabillite, however, was that even a good invention almost always demanded expensive, painstaking, labor-intensive development work to perfect both product and manufacturing process. Maxim could not command such necessary resources. Moreover, such development work required patience and diligence as well – attributes not usually possessed by a compulsive inventor

such as Maxim. Hence the nascent industrial research and development laboratory, well-organized and efficiently run, would prove more often than not to be the most effective institution for bringing an idea or invention to the marketplace. Of course, some industrial R&D laboratories would provide safe harbors for a limited number of the more archetypal, compulsive inventors. But the primary attribute of the R&D laboratory in the twentieth century would be its capability of conducting organized assaults on particularly well-defined problems. The independent inventor could make no such concerted campaign; the case of Stabillite clearly demonstrates this while also illustrating the pitfalls of industrial research and development.

The Development of Stabillite

The Executive Committee was quick to push the development of Maxim's new smokeless powder. If successful, the new powder would give Du Pont an important proprietary advantage over its new competitor, the U.S. government.[75] Maxim's powder promised to be a definite improvement over pure nitrocellulose powders, not only because it seemed to be more stable than guncotton but also because its manufacture required neither the addition of a volatile solvent nor the slow drying process typical of nitrocellulose smokeless powders. Moreover, the powder appeared not to suffer from the normal shrinkage defects of nitrocellulose powders, hence the final size of the finished grain could be easily controlled. In the manufacture of Stabillite, nitrocellulose was mixed with what was known to chemists of the day as "the yellow compound" or "the yellow kid," trinitroanisole. Stabillite could then be worked like the early plastic celluloid, which meant that when heated it could be easily rolled into colloidal sheets and then slit and perforated to form grains of powder with suitable burning characteristics. The speed and flexibility with which Stabillite could be manufactured promised to revolutionize the smokeless powder business.[76]

Late in 1903, the Executive Committee granted Francis du Pont $2,000 for experimental work on Maxim's new smokeless powder.[77] Although Francis pursued research at the new experimental laboratory in 1904, most of the work was conducted at Maxim's personal laboratory at Landing, New Jersey, until the end of 1904.[78] Du Pont chemists aided Maxim. At the end of 1904, the Executive Committee instructed Moxham to secure an agreement with Maxim for the U.S. rights to his invention. Soon the committee appropriated $5,000 for more experimental work on the powder.[79] On the basis of Francis's sanguine report on Stabillite's future, the Executive Committee authorized Moxham to broaden the agreement with Maxim whereby he would also surrender his foreign rights to Stabillite for $115,000. The two parties quickly signed such a contract.[80]

Development work in Wilmington increased to a feverish pitch, and Du Pont tried to sell a large order of the experimental powder to Mexico, needs of Du Pont's businesses, particularly in smokeless powder. While working on Stabillite, the Station played a critical role in developing tests for long-term powder stability. By 1911, the Station possessed perhaps the most extensive facilities of any organization in the world for conducting constant temperature and constant humidity tests on powders. Without these facilities, understanding and improvement of stability would have been impossible. Du Pont's rapid introduction of diphenylamine as a stabilizer in 1908 resulted from this expertise. Once the Station found its permanent home along the Brandywine opposite its first, temporary location, outstanding ballistics research became one of the hallmarks of Du Pont's research program (just as Francis du Pont had hoped). The Station also made contributions to smokeless powder manufacturing during this period.[124]

The development of the permissible explosive Nyalite was one of the most significant contributions of the Station during this period. Moxham had had research on safety explosives in mind when he advocated establishing the Experimental Station. Like glycerin synthesis, safety explosives were firmly within the scope of Eastern Laboratory's work, but the Station pursued them as well as other areas of high explosives manufacture. On the basis of some European precedents, Station chemists formulated in 1905 the nitrostarch compound named Nyalite. In 1916, the head of Du Pont's Pittsburgh sales office called Nyalite "one of the best [permissible] explosives ever produced ... [which] made it easy sailing for Du Pont [sales] representatives."[125]

Although the Station met with success in developing an important permissible explosive, the financial panic of 1907 brought an end to the duplication of research efforts between Eastern Laboratory and the Experimental Station. The panic forced Barton and his superior, Pierre du Pont, to lay off seven of the Station's sixteen chemists and therefore to set priorities for research more carefully.[126] At the same time, the company established an experimental board composed of H. Fletcher Brown (a growing figure in Du Pont's smokeless powder business), Charles L. Reese, Francis I. du Pont, and C. M. Barton.[127] To the experimental board fell the task of more carefully allocating the company's research resources and settling disputes that had arisen between Eastern Laboratory and the Station. Some disputes were minor, such as the different rates charged by the two laboratories for identical analytical work. But the major ones were territorial in nature.

Since 1903, Moxham had advocated that the Station establish a model testing gallery for safety explosives. No doubt Barksdale bitterly opposed this plan, arguing that Eastern Laboratory was the rightful home for such a facility. A stalemate arose over the issue. With increasing outside pressure to develop newer and safer high explosives for mining operations, the experimental board ended the impasse in mid-1908 by giving Eastern Laboratory exclusive responsibility for the construction and operation of the expensive test tunnel. The board also ruled against the Station conducting work in areas related directly to high explosives, such as nonfreezing dynamite, continuous nitration of glycerin, and dinitroglycerin. With the board's guidance, the Station's manager focused research on "subjects connected with the study of smokeless powders and black powders."[128]

The experimental board's role grew in the period between 1908 and 1911. It began to evaluate the merits of undertaking new research projects and terminating existing ones. The board helped Reese and Barton make tough decisions about their research programs. For example, it advised Barton to terminate the glycerin-by-fermentation project in mid-1909 over the objections of his chief chemist, Fin Sparre.[129]

The establishment of the experimental board, coupled with Pierre's and Barton's much sounder management of the Station after 1907, eventually led to the Station's being moved back under the control of the Development Department, now headed by Pierre's younger brother, Irénée. In this and subsequent positions, including the company's presidency, Irénée paid careful attention to the company's research programs; he brought noteworthy chemical knowledge, judiciousness, and energy to his duties. In the brief period he was in charge of the Experimental Station, Irénée left his clear imprint. But good management aside, at the end of 1910, the Executive Committee wanted to know if its large expenditures for research work at the Experimental Station had yielded any profits.[130] After all, almost every member of the committee must have remembered A. J. Moxham's assertion at the founding of the research laboratory that it had to pay its way and his contention that it would quickly generate profits.[131]

When the Executive Committee asked for a profit and loss statement from Irénée, the Station's permanent facilities were less than six years old. Located on a site that Fin Sparre described as "allow[ing] almost unlimited extension of the work and almost unlimited constructions," the Station sported a fireproof laboratory, a rifle range, a fifteen-pound gun testing facility, and a variety of smaller support facilities.[132] Pierre had formulated an aggressive equipment acquisition policy, with funding equal to half the general operating budget.[133] Largely under Sparre's leadership as chief chemist, the Station significantly increased the quality and quantity of its research staff. The panic of 1907 had temporarily reduced the staff to nine chemists, but by 1911 Sparre had thirty-five chemists working under him, many with excellent academic credentials.[134]

Despite this impressive growth in numbers and quality, Irénée still had to decide whether research at the Experimental Station paid. His report left plenty of doubt. Stabillite, the black powder continuous process, the pulp keg, and the glycerin studies had yet to pay a cent. In fact, they had cost a king's ransom. There were a few clear-cut cases of Station projects turning a profit, but the vast majority were indeterminate from a profit and loss standpoint. Part of this, Irénée argued, resulted from an inadequate time horizon.[135] But the fact that there were no convincing concrete data that the Station had generated profits stemmed from the very nature of the Station's mission. It was handmaiden to the Development Department, subject to that department's beck and call for information on all manner of questions; it was also a kind of departmental laboratory for the Black Powder Operating Department, a business that was mature if not dying, and for the Smokeless Powder Operating Department, one that had not yet come fully into its own. Irénée might have added that a big chunk of the money sunk into research at the Station had been spent not with the aim of creating profits but of meeting federal regulations that, if not met, could be potentially catastrophic. In any case, Irénée probably knew very well that the accountant's calculations of profits generated by the Experimental Station would be dwarfed by those reported by Charles L. Reese for the Eastern Laboratory.

The Eastern Laboratory, 1904–1911

When in early 1911 Charles L. Reese submitted his report on the Eastern Laboratory's contribution to profits, he did indeed claim substantial savings through research. Taking four subjects alone – nitroglycerin manufacture, nitric acid production and use, glycerin refinement, and the low-freezing Lydol dynamite (dinitrotoluene) – Reese reported savings of $840,000 for 1908, 1909, and 1910. Total expenses of the chemical division of the High Explosives Operating Department (the Wilmington office and the Eastern Laboratory) amounted to about $338,000. As Reese concluded, "In consideration of the fact that only four of the many subjects worked upon at the Eastern Laboratory are included in the estimate of saving, it is safe to say that the Eastern Laboratory has justified its existence."[136]

The work of the Eastern Laboratory during the period 1904 to 1911 followed very closely along its initial lines. Chemists devoted their attention to process improvement (e.g., achieving higher yields, improving recovery techniques, and speeding up nitrating and separation processes), product improvement, and new product development. As Reese liked to point out, even small process improvements showed up in important ways on the accountant's sheets. For example, when glycerin supplies grew short in 1910, Reese was able to point to a long-established downward trend in the consumption of glycerin per pound of finished dynamite. Between 1905 and 1910, the consumption figure had been lowered by 20 percent.[137]

Process improvements accounted for much of this figure, but the laboratory's success in finding substitutes for glycerin in high explosives was also a factor. The search for glycerin substitutes led to entirely new classes of explosives, such as nitrohydrene powders.[138] In another instance, the laboratory sought to produce a low-freezing dynamite with a nitroglycerin base but developed a dinitrotoluene explosive, introduced commercially in 1907 as Lydol.[139]

The Eastern Laboratory's development of another important explosive, trinitrotoluene (TNT), resulted from an entirely different objective. Not only the product but also the way it was developed had important consequences for Eastern and indeed the entire Du Pont Company. The laboratory undertook the development of European-invented TNT primarily because of its potential as a military explosive for the United States.[140] Eastern's director gave the project to a young PhD chemist who had been employed by the laboratory in 1907, Charles M. A. Stine. In his first two years, Stine had already demonstrated his capability as an industrial chemist. He had helped solve the pressing problem of repeated fires in the manufacture of ammonium nitrate, and he had conducted some rather fundamental research in an effort to eliminate the leakage of nitroglycerin from dynamite cartridges. Borrowing initially from earlier German work on TNT, Stine carried out an extensive series of experiments on the nitration of toluene. These experiments ran across the research spectrum from applied to fundamental. On the fundamental side, Stine took pride in demonstrating that Beilstein's melting point for TNT was incorrect and that his own determination had become the standard. On the applied side, he worked out a three-stage nitration and refining process for TNT. Stine used TNT to demonstrate that similar development work could and should be carried out in a semiworks. Sized somewhere between a laboratory setup and a full-scale commercial plant, a semiworks provides data on the effects of scaling up a chemical process, which are critical for designing a full-scale plant and evaluating the quality of the product. This was a new concept at Eastern. Because Stine's work proved so successful, he firmly believed that a semiworks was "the only way properly to study processes of this type";[141] because he quickly moved up in the ranks of Du Pont research management, the use of semiworks became standard.

The research and development work at the Eastern Laboratory allowed the High Explosives Operating Department to change the mix of high explosives it manufactured. In the period up to 1911, the product line expanded from pure nitroglycerin dynamite to at least ten distinct types of high explosives. Eastern's work made it possible to sell specialty explosives at premium prices – one of the later hallmarks of Du Pont's business philosophy. Reese prided himself that during 1910, more than 30 percent of the dynamite sold "represented special powders which have been developed at the Eastern Laboratory."[142] In the case of what contemporaries called low- and nonfreezing dynamites, research provided the means to overcome the terrible dangers posed in handling frozen dynamite. Moreover, the Eastern Laboratory's work allowed Du Pont to meet federal regulations for permissible explosives.[143]

Though the long stalemate with the Experimental Station over which laboratory would get the mine-testing gallery for safety powders had hampered Eastern's development efforts, once the experimental board advised the Executive Committee that Eastern was the rightful location for the gallery, the laboratory moved quickly. It purchased the equipment for the testing gallery from Germany, where state regulation of explosives had earlier forced explosives manufacturers to study mine safety factors. The testing gallery allowed the laboratory to study the German Carbonite safety powders and the English Monobels. With this knowledge in hand, the laboratory formulated its own versions of both.[144] The testing gallery was the first such facility in the United States and was later copied by the Bureau of Mines, the federal agency that established whether an explosive was permissible or not.

The Eastern Laboratory's success stemmed in large part from the very nature of its mission. It was a departmental laboratory with clearly defined objectives. Yet there is more to the explanation of its unqualified success. The laboratory's research personnel played a critical role as well. Charles Reese may not have gotten along very well with his staff of chemists, but after 1906 this was no longer a problem. Hamilton Barksdale moved Reese into a higher supervisory position that year when he created the chemical division of the High Explosives Operating Department. Reese thus became the chemical director of the department. This promotion freed him from direct supervision of the Eastern Laboratory, although he was ultimately responsible for it. He continued to exercise leadership over the chemical operations of the entire department. Reese chose Arthur M. Comey as the new director of the Eastern Laboratory.[145] Under Comey's learned and meticulous management, Eastern became a spirited, high-quality research organization and a major breeding ground for an important segment of Du Pont's entire research management in the 1920s.

It is interesting that Reese chose his successor from outside rather than inside the Eastern Laboratory. He and Comey had first met in 1884 in Heidelberg, where both studied under Bunsen. Comey had pursued a far more successful academic career than Reese. He served as an instructor of chemistry at Harvard, where he organized the summer school for chemistry, and in 1899 he was appointed professor of chemistry at nearby Tufts College. Yet academic chemistry proved unsatisfactory to Comey. After four years at Tufts, he left to establish himself as a "consulting chemist" in Boston. During his early years as a consultant and analytical chemist, he assembled data for the first edition of what became a standard reference work, *A Dictionary of Chemical Solubilities: Inorganic* (1896).[146] Once he was at Eastern, Comey's reputation and his personal characteristics allowed him to recruit an impressive number of capable chemists. By 1908, he had succeeded in hiring Fletcher B. Holmes (later the first director of the Jackson Laboratory for organic chemistry research); Charles M. A. Stine (later Reese's successor as chemical director, the creator of Du Pont's well-known fundamental research program, and an Executive Committee member); Hamilton Bradshaw (later Stine's assistant chemical director); Clifford A. Woodbury (Comey's own successor at Eastern); E. K. Gladding (later head of the nylon division of the Rayon Department and successor to Fin Sparre as director of the Development Department); and E. G. Robinson (later assistant director of the Experimental Station and eventually the general manager of the Organic Chemicals Department). These are only some of the more prominent men Comey hired; he also employed exceptionally talented chemists who would remain within the research ranks at the Eastern Laboratory.[147]

By 1911 Comey had become a seasoned manager of research and development at Eastern and an articulate spokesman for how successful research should be managed.[148] His staff included twenty-seven academically trained chemists, many with PhDs from U.S. and German universities, and an overall staff of eighty employees. These employees worked in sixty-six buildings on the fifty-acre grounds of the laboratory.[149] Certainly Comey did not radically alter the research program or philosophy established by Reese. Rather, he seems to have fine-tuned the work of the Eastern Laboratory. Overall, except for one important detail, the objectives of a departmental research laboratory so carefully laid out and forcefully argued by Hamilton Barksdale in 1904 appear to have been fully met.[150]

Barksdale had maintained that a departmental laboratory would be more productive than a central laboratory. The profit and loss reports submitted to the Executive Committee by Charles Reese and Irénée du Pont at the beginning of 1911 clearly bore out Barksdale's views. But Barksdale had also pleaded his case for the Eastern Laboratory on the basis that it would serve as a superb training facility for chemists to enter plant management. Judging from the record of early Eastern chemists entering plant management and moving on to higher responsibilities in manufacturing, Barksdale was correct. But on the debit side of the ledger, this sort of upward mobility played havoc with the research program of the laboratory. Reese had quickly detected this problem. As he later noted, "one of the functions of the [Eastern] Laboratory in the early days was to furnish men to fill positions in the works as works' chemists and Assistant Superintendents, but this plan, with the rapid growth of the Company, resulted in a constant change in the Laboratory organization, so that it was impossible to keep a force of men who were experienced in the principal lines of work for which the Laboratory was established."[151] Reese and Comey had recognized, in much the same way Pierre du Pont had, that continuity was a crucial element in the proper conduct of research. Nevertheless, in the future, many researchers would, in Comey's words, "make the laboratory a stepping stone to other positions to the manifest detriment of the laboratory."[152] This problem would be another of those perennial issues that the company would face in the decades ahead.

In spite of the laboratory being mined by the manufacturing division for its technically trained chemists, the Eastern Laboratory was successful. Its success played the paramount role in radically changing the management

The Eastern Laboratory's million-dollar annual "profit" stemmed from the tightly focused research that had prevailed since 1902. Chemical control work was the centerpiece of Reese's approach to industrial research. As Fin Sparre, director of the Experimental Station, remarked somewhat contemptuously, "It is clear that the quickest way of achieving financial returns in research work are in connection with the study of existing factory problems, particularly such as show inferior yields."[22] Certainly that was the major path pursued by Eastern. It continued to focus on questions relating to chemical control in the manufacture of high explosives and to the improvement of manufacturing processes. But the laboratory also succeeded in product improvement and the development of new high explosives.[23]

The Experimental Station, conversely, could point to few unambiguous instances of financially successful research and development work. Sparre wrote that although the Station was responsible for chemical control work for the Black Powder Operating Department, "there are no problems of chem-yields, the only research work being in connection with the quality of the powder." Smokeless powder manufacture was different, but as Sparre noted, chemical control work resided "with the management of the Smokeless Powder Operating Department or with the Main Office of the Chemical Department," not with the Experimental Station.[24]

Reese and Sparre sought to make the Station the smokeless powder equivalent of the Eastern Laboratory. Product improvement presented few problems, but process research proved difficult, if not impossible. The Station had never been fully equipped to carry out process research in smokeless powder production. In particular, it lacked semiworks apparatus for the nitration of cotton fiber. With Reese's support, the Station sought to rectify this deficiency, but the head of the Smokeless Powder Operating Department thought that handling the mixed acids used in the nitration process posed too many hazards to the Brandywine River, Wilmington's main source of water.[25] Reese and Sparre sought to compromise by building and operating a semiworks at Du Pont's Carney's Point smokeless powder plant – an approach reminiscent of the Eastern Laboratory. But the experimental board (of which Reese and Sparre were members) vetoed the idea, arguing that Station chemists could carry out process improvements based on experimental work conducted by the Smokeless Powder Operating Department at its manufacturing plants. Sparre assigned a Station chemist to assemble plant-generated data.[26] By the time this work was complete, war had broken out in Europe, and Du Pont's task became not radical process improvement but rapid expansion of capacity. As Sparre wrote Reese, "there would be little, if any, opportunity for experimental work for some . . . time to come."[27] Commenting later on the Station's deficiencies in process improvement, another research manager said, "better work could have been done and stronger men developed if this research laboratory had been located at Carney's Point."[28] Hamilton Barksdale's position of 1904 had proven correct. Nevertheless, the Station had been engaged in important work, and this centered on diversifying the company's business.

Early Diversification Efforts

The debate over whether the Experimental Station should have a complete smokeless powder semiworks points up the inherent conflict in the Station's charter. On the one hand, it was to serve for the black and smokeless powder businesses a role comparable to the Eastern Laboratory's for the high explosives business. But on the other hand, it was to serve as the company's center for more radical innovation – innovation not immediately tied to the company's existing businesses. As Sparre recognized when he submitted the Station's two-year profit and loss statement, a return on investment was far easier to achieve with the former approach than with the latter. Innovation – broadening the company's scientific and technological basis – captured the greater part of Sparre's attention both as chief chemist and, after Barton's transfer to another position in Du Pont, as director of the Experimental Station. Du Pont's early diversification efforts – stimulated by attacks on "the Powder Trust" – turned Sparre's attention to this endeavor. Research work aimed at diversification would not necessarily pay immediate dividends. In fact, Sparre later argued, the odds were overwhelmingly against any particular project succeeding.[29]

Du Pont's Executive Committee moved rapidly to initiate a broad-based research program on nitrocellulose after the Naval Appropriations Bill was passed in January 1909. Their aim was to find ways to use the company's smokeless powder plants to manufacture other products. For this reason, the committee selected Irénée du Pont to replace the ailing William B. Dwinnell as manager of the Development Department and put the Station back under his control. Irénée's duties included developing new articles and new processes of manufacture and securing supplies of raw materials. The department, anticipating Congress's hostility, had already begun to gather information on the manufacture of artificial silk, artificial leather, and celluloid when Irénée took the helm. Although these three products were attractive because Du Pont could conceivably use some of its smokeless powder plants for their production, the question remained whether Du Pont could make a profit in these businesses.[30]

In the case of artificial leather, Irénée believed Du Pont should proceed immediately to build a plant. Irénée submitted to the Executive Committee an appropriation request to cover design costs on the same day the committee reviewed the Development Department's progress report on alternative uses for guncotton and other products of the company's smokeless powder plants. Though eager to find ways to guard against owning idle plants, the Executive Committee rejected Irénée's request and asked him to prepare a full report on artificial leather manufacture, including prospects for its development and growth vis-à-vis natural leather.[31]

In subsequent discussions with the committee, Irénée focused attention on one particular point: No one had manufactured a high quality, premium-priced product, which the market seemed ready to accept. Irénée thought that Du Pont's superior know-how and its nitrocellulose capacity would combine to allow the company to produce much-higher quality material with a greatly enhanced profit margin.[32] The Executive Committee, influenced by Irénée's thinking about artificial leather and other such products, worked toward a diversification strategy of developing premium-quality products that would command premium prices. Du Pont's R&D capabilities would make this strategy attainable. Although some members were opposed, the Executive Committee granted the Development Department funds for the further study of artificial leather. Soon it would fund an experimental plant for the manufacture of this new product at one of the smokeless powder plants that the company was closing.[33] The committee also asked Irénée to look further into the manufacture of artificial silk.

The Development Department's intense interest in nitrocellulose for non-powder applications soon began to penetrate the research program of the Experimental Station. In late May 1909, Sparre outlined for Barton an ambitious program of research on nitrocellulose. Although Sparre's program would greatly benefit the company's smokeless powder business, it was also consciously designed to generate the knowledge Du Pont needed to diversify its product line based on nitrocellulose chemistry and technology. As Sparre wrote, "this company should be thoroughly conversant with [nitrocellulose chemistry] . . . so as to be prepared to the greatest extent to enter business[es] other than the present manufacturing of powder. . . ."[34]

Barton sent copies of Sparre's letter to members of the experimental board asking them to review it so as to avoid "undesirable duplication of work on this subject at the various laboratories."[35] The board found no objection to Sparre's plan. Irénée also approved it but encouraged Barton to submit the proposal to J. A. Haskell, head of the Smokeless Powder Operating Department.[36]

Although generally in favor of the Station's proposal, Haskell raised an important question. He wondered if "someone from your laboratory should be sent to the other side [i.e., to Europe] to look into and make a careful report as a starter of the investigations made in England and on the Continent." As Haskell explained, on his trip to Europe in 1908 H. Fletcher Brown had observed "that at each of the large Nobel plants one research laboratory was kept practically exclusively for guncotton [i.e., nitrocellulose] work."[37] Haskell believed that the Station could gain access to this research under the terms of the 1907 agreement between Du Pont and the Nobel–Dynamite Trust Company, Limited (the European explosives cartel with which Du Pont had been contractually aligned since 1897).[38]

Some members of the experimental board were skeptical that Du Pont could obtain broad information on nitrocellulose, but Haskell argued that Du Pont should at least try to secure the European research reports. As Haskell reminded Barton, such reports might "not be absolutely conclusive," but if used by Du Pont chemists in conjunction with a tour of European factories and laboratories and with research at the Station, they could save the company time and money.[39]

The experimental board cautiously attempted to secure information from the British by asking one of Du Pont's representatives touring Nobel facilities to confer with "the Gun Cotton research laboratory at Ardeer, and ascertain what work has been done at Ardeer along these lines, and ask for copies of any reports to their investigations, so that we may not go over the same grounds."[40] The British obliged. Soon Irénée du Pont, C. M. Barton, and Fin Sparre began planning for Sparre to take an extended tour of Nobel facilities to study principally nitrocellulose-related topics, including artificial silk and celluloid.[41]

Sparre spent much of the fall of 1909 in Europe, and his trip played an important role in his rise as one of Du Pont's chief diversification strategists. He codified his findings in twenty-one formal reports and dozens of personal letters to Barton, which soon began to shape the Station's research program and the company's diversification strategy.[42] If there was a common theme to Sparre's findings, it was that the research force at the Experimental Station was capable of carrying out a major diversification program based on nitrocellulose chemistry and technology.

Much of Sparre's attention was focused on artificial silk. He concluded, "My impression is that artificial silk is a good thing and that we could manufacture it easily. However, it would be a pretty bad thing to develop ourselves, because there are so many fine points about the machinery and I presume also about the process itself."[43] Henry de Mosenthal, chief executive of the English Nobel trust and an accomplished chemist, sought to convince Sparre that the business "could not be run in connection with powder factories." The British had tried it and "had found that out too late." But Sparre remained convinced that Du Pont's "knowledge of nitration, acids, ether, alcohol, etc. must be valuable also for this industry, and if we buy rights and experience, we can do it as well as other people." De Mosenthal also argued that in the future viscose silk would be the cheapest process and would undermine the profitability of nitrocellulose silk – a point Sparre found hard to accept.[44]

Sparre had also considered the manufacture of celluloid. His discussions with German experts from the Vereinigte-Köln-Pulver-Fabriken, part of the Nobel group, confirmed his earlier views. He had been advocating that Du Pont should not integrate fully in celluloid but should only sell nitrocellulose to U.S. celluloid factories thus utilizing excess smokeless powder plant capacity. The Germans thought this approach best for Du Pont.[45] The

Experimental Station would still have to do basic studies on the chemical stability of, nitration processes for, and purification of nitrocellulose. These studies would be a major part of the Station's research program for 1910.[46]

Irénée du Pont fully supported the Station's program even though much of the immediate pressure to find alternative uses for Du Pont nitrocellulose was off. The federal government had recently submitted large orders for powder, and there was a "decreased likelihood" of Congress banning the army and navy from ordering Du Pont powder.[47]

Nevertheless, the earlier pressure to find outlets for nitrocellulose had already propelled the company into the artificial leather business. In September 1909, Irénée had received funds from the Executive Committee to build an experimental artificial leather plant at the company's Oakland, New Jersey, smokeless powder plant.[48] Within six months chemists and engineers from the Station had achieved the premium grade product Irénée sought by using an advanced process they thought was unique. The key to this process was solvent recovery, which Du Pont had brought to a fine art in its smokeless powder plants. Irénée believed Du Pont could gain market leadership in artificial leather with this technology.[49]

Irénée's confidence was soon shattered. Word got out that the Fabrikoid Company, the U.S. pioneer in artificial leather, had had a fire in its solvent recovery area. Development Department personnel concluded – quite erroneously – that if Fabrikoid had developed its own solvent recovery process, the rest of its process must have also been as advanced as Du Pont's. Irénée convinced the Executive Committee (with a dissenting vote from Alfred du Pont) to buy Fabrikoid for $1.2 million.[50]

Once the contract to buy Fabrikoid had been signed, the Development Department learned that it had bought a pig in a poke. At Irénée's request, Fin Sparre spent two days in Newburgh, New York, carefully going over Fabrikoid's processes. His report to C. M. Barton was a tale of backward, inefficient, and often dangerous processes and included a long list of areas in which research at the Experimental Station could lead to substantial process and product improvements. Sparre made it clear that science had had no place in the Fabrikoid works.[51]

Sparre pinpointed one major problem with Fabrikoid's operations – the use of inferior solvents. But it took Du Pont executives several months to realize the full extent of this problem. Not long before Du Pont bought the Fabrikoid plant, its owners had substituted cheap "acetone oil" and "P2" solvents for the more expensive amyl acetate. The products made after this substitution were inferior and resulted in "a profound distrust of [Fabrikoid] on the part of its entire clientele," a response that became apparent only after Du Pont's acquisition.[52] Two years passed before Du Pont could straighten out the Newburgh factory and repair the damage done to the Fabrikoid name in the marketplace.

Under Sparre's leadership, first as chief chemist and after 1911 as director, the Experimental Station contributed to making Du Pont Fabrikoid a successful enterprise yielding healthy profits until the post–World War I recession.[53] In February 1911, the Station issued its first formal research report on Fabrikoid topics, and by the end of the decade the number of reports had grown to fifty-eight. The bulk of these reports involved product and process research, but the Station also conducted basic studies of importance to the Fabrikoid business under the rubric of "nitrocellulose research."[54]

Irénée's active interest in Fabrikoid never waned as he moved up the company ranks toward the presidency. His older brother, Pierre, also closely followed the business, primarily because he saw enormous potential for better grades of artificial leather in the automobile industry. Indeed, as the automobile industry grew in the 1910s, so grew Fabrikoid's business.[55] Irénée's and Pierre's close watch over Du Pont's artificial leather business suggests how they viewed research and how Irénée regarded Charles L. Reese as a research director.

Both du Pont brothers recognized that Fabrikoid artificial leather was decidedly inferior to genuine leather – even after Du Pont had straightened things out at Newburgh. They proposed that a research program be undertaken "to produce a grade of Fabrikoid which would measure up with the best quality of leather."[56] The principal defects of artificial leather were unequal stretching (the nitrocellulose coating was laid on a woven cloth backing and hence stretched too much along the diagonal of the cloth), "clothiness" (rapid wear of the coating at folds and corners thus exposing the backing), and poor resistance to the weather (a major drawback, because Du Pont intended artificial leather for automobile tops and upholstery).

After February 1, 1911, all Fabrikoid research came under the direction of Reese and the newly established Chemical Department. Reese proved unenthusiastic about the development of artificial leather.[57] Meanwhile, Irénée (particularly after he became chairman of the Executive Committee in 1915) pushed Reese by providing him with many concrete suggestions on how improvements might be made in artificial leather. These ranged from using a felt backing rather than woven cloth to doing fundamental studies of genuine leather to developing an artificial leather entirely different from the conventional nitrocellulose and castor oil film spread on a cloth backing.[58] Irénée forcefully reminded Reese that the "possibilities for a successful product of this character are so great that we should give the study energetic attention." As chairman of the Executive Committee, Irénée asked Reese, "Won't you please advise me in detail of what you propose to do and who you propose putting on this work[?]"[59] At the same time, Frank Kniffen, head of the Du Pont Fabrikoid Company, the subsidiary in charge of Fabrikoid operations, also prodded Reese and told him that "we are anxious to be the pioneers" in developing nonnitrocellulose artificial leather. Kniffen stressed that ultimately Du Pont should aim for the development of a commercially viable artificial shoe leather.[60]

Reese eventually responded to these pressures. Charles E. Arnold of the Experimental Station was put in charge of Fabrikoid research after the first chemist, Walter E. Masland, resigned from the company. Arnold first conducted a thorough literature survey of how artificial leather had been made and how it might be made. This search yielded more than eighty approaches that put Reese somewhat at a loss on how to proceed. Reese conveyed his feelings to Irénée when he sent him Arnold's report.[61] Irénée had no such problem. He wrote Reese that "it would seem that others have worked in a more or less random way" and that Du Pont would do better if it approached the subject more rationally. He suggested which lines of research the Experimental Station should pursue and why.[62]

During the next four years, Arnold and his staff of researchers at the Station pursued the kind of research recommended by Irénée.[63] Although this research failed to yield an artificial leather that matched the quality of genuine leather, definite improvements were made. In September 1916, Pierre du Pont took time to congratulate the Experimental Station on these improvements, which included embossing the coating to imitate a wide variety of leathers.[64]

When wartime circumstances led to increased use of rubber soles in boots and shoes, Du Pont's Fabrikoid executives concluded that the Chemical Department could develop a satisfactory artificial leather for shoe uppers.[65] Researchers worked hard to achieve this goal and even went so far as to do product testing by outfitting some forty mail carriers in Wilmington with shoes made from the Station's most promising grade of artificial leather. Encouraged by the results, they arranged for a local shoe store to sell 150 pairs of artificial leather shoes. Their appearance was good, they wore well for inexpensive shoes, and they were waterproof. But they also lacked ventilation, their coating was too soft, and they cracked from frequent bending.[66]

Despite Irénée's and Pierre's hopes, Du Pont research and development failed to produce an artificial leather satisfactory for boots and shoes. Nevertheless, Du Pont know-how clearly aided the development of the Fabrikoid business. Under Du Pont's management, the Fabrikoid business improved its return on investment from 0.5 percent in 1911 to 20 percent in 1919 – the figure that Irénée had projected when, as head of the Development Department, he purchased the Fabrikoid Company. Profits had averaged about 15 percent during this period.[67]

Although pressure to diversify abated when the company began receiving increased government orders for smokeless powder late in 1909, the Development Department and its Experimental Station continued to follow closely developments in artificial silk and celluloid manufacture.[68] After making an initial survey of the celluloid business, the Development Department concluded that its best strategy would be to sell its nitrocellulose to existing celluloid companies rather than getting into the messy business of celluloid fabrication. Sparre shaped the Experimental Station's research program to accord with this strategy. At the same time, however, he undertook a program at the Station to see if Du Pont could secure a competitive

advantage in celluloid manufacture. Seeing celluloid's expensive plasticizer, camphor, as a target of opportunity, Sparre proposed looking at camphor substitutes, especially acetaldol, in which he had long been interested. By the time the Station had obtained some initial encouraging results, the Chemical Department had taken control of the Station. Sparre reported these findings to Reese and counseled him to send them to Irénée because of the latter's great interest in the subject.[69]

Reese followed Sparre's advice. Although he suggested that follow-up work would be done, Reese warned that the Germans had recently developed a substitute for camphor that seemed so good that they began marketing the new celluloid immediately. All signs pointed toward success, Reese noted, until winter came and the celluloid "developed a degree of brittleness which made it unfit for use." He feared that Sparre's acetaldol substitute might exhibit the same tendency.[70]

Encouraged by Irénée, Sparre proceeded with a more rigorous study. By 1913, the Station had made significant progress and had succeeded in fabricating good transparent sheets of celluloid with acetaldol as the plasticizer.[71] The Station's work provided Du Pont with the bargaining chip it needed to secure more extensive information about the celluloid business from the Germans. Du Pont had found it impossible to gain the information from U.S. celluloid manufacturers. If Du Pont were to go into the celluloid business, it would need far more information than it currently possessed. Pierre du Pont and the development director, R. R. M. Carpenter, achieved an agreement with the Germans to allow Walter S. Carpenter, R. R. M.'s assistant and younger brother, to make a thorough study of the Germans' celluloid-manufacturing operations and business.[72]

Walter Carpenter had left Cornell University in 1909 during his senior year to help manage Du Pont's nitrate interests in Chile. On his return to the United States in 1911, he became R. R. M.'s assistant when the latter was named director of development. The younger Carpenter took responsibility for the Development Department's celluloid study during the second half of 1913 and throughout 1914. Following his detailed analysis of the German business, in February 1914 Carpenter issued a comprehensive report on Du Pont's options for entering the celluloid business.[73] This report demonstrates Carpenter's penchant for details, clarity of thought, and superior strategic thinking – characteristics that would lead him eventually to the presidency of the company.

Carpenter laid out four means by which Du Pont could enter the celluloid industry. First, repeating Irénée's and Sparre's earlier statements, Du Pont's interests would best be served if it could simply sell nitrocellulose to celluloid manufacturers. But he doubted if this were possible, because celluloid makers already produced their own nitrocellulose. Second, Du Pont could pursue an alternative strategy of trying to get celluloid manufacturers, faced with expanding their business, to buy Du Pont's nitrocellulose rather than add capacity of their own. Carpenter also saw this as unrealistic. Third, Du Pont could enter the business from scratch, relying on its R&D capabilities. Fourth, the acquisition of an existing firm would bring Du Pont into the business, but this option would largely negate the still-perceived need of employing the company's nitrocellulose plants.

Not long after Walter Carpenter submitted his report, his older brother proposed to the Executive Committee that Du Pont purchase the Fiberloid Company's celluloid business for $1.5 million. The committee rejected the proposal. Instead, it suggested that the Development and Chemical departments pursue the internal-generation route.[74]

By the fall of 1914, all factors pointed toward Du Pont's entering the celluloid business through its own research and development efforts. Sparre and the Experimental Station had continued to pursue camphor substitution and had developed an excellent celluloid using a plasticizer of 50 percent camphor and 50 percent acetaldol.[75] The Station also pursued substituting cheap short-staple cotton for the more expensive tissue paper as the basis of celluloid. The company, unable to convince American companies to buy Du Pont's nitrocellulose, had hired an expert in celluloid manufacture who had worked for both the Fiberloid and the Viscoloid companies.[76] Sparre and the Carpenters believed that Du Pont possessed all the necessary resources to penetrate the celluloid business in a big way. In seeking funds from the Executive Committee to build an experimental celluloid plant at the Experimental Station, the Development Department argued that

> a celluloid plant [built and] operated by the du Pont Company will not be without its own advantages.... Among these advantages may be mentioned probably cheaper source of part of the raw materials manufactured by the du Pont Company, such as acids and alcohols, more efficient method of nitro-cellulose manufacture which should result in cheaper cost of production, probably greater knowledge of cellulose, which many result in a cheaper substitute of the expensive tissue paper now nitrated by celluloid companies, and advantage of a large sales force to press a more active campaign than is now customary in the celluloid business.[77]

The Executive Committee concurred and granted the appropriation for the semiworks.[78]

The Experimental Station moved quickly. But before it could issue a single report on the operation of the semiworks, the Executive Committee had done an about-face. This change resulted not from a reversal in thinking among Executive Committee members but rather from a complete reshuffling of the committee's membership following the second reorganization of the company in 1914. As R. R. M. Carpenter pointed out to the new committee, the former committee had rejected a proposition to buy into the celluloid industry, "believing that it was better to build a plant at one of our smokeless powder plants." But the new, younger committee opted to buy into the business, especially after Pierre du Pont, the influential acting president, let it be known that he favored this approach.[79]

Before proceeding to buy a firm, the Executive Committee gave the Experimental Station about nine months to demonstrate that cheap, short-staple cotton could be used to make celluloid.[80] When in September 1915 the Station had failed, the Executive Committee voted to purchase the largest manufacturer of celluloid in the United States, the Arlington Company of Arlington, New Jersey, for $8 million. This sum represented the second most expensive acquisition by Du Pont in the period up to 1924.[81] In reporting the Arlington acquisition to the board of directors, the Executive Committee stated that the company would enlarge Arlington's present profits through Du Pont know-how – the same know-how that the Development Department and the Executive Committee had earlier championed when advocating building rather than buying a business.[82]

But in spite of Du Pont's assumed expertise in nitrocellulose chemistry, the Arlington purchase proved to be a poor investment by the company's own standards. Between 1916 and 1920, the average return on investment was only 4.3 percent – far below the company's goal of 15 percent.[83] Du Pont research failed to contribute markedly to the celluloid business, even though the Chemical Department, seeking to emulate Reese's success with the Eastern Laboratory in high explosives, established a research and development laboratory there in 1917 – the Delta Laboratory – and placed one of its leading organic chemists in charge. The Delta Laboratory was initially devoted exclusively to process and product research, but eventually Reese turned over to the laboratory responsibility for chemical control of the Arlington plant.[84]

The Experimental Station took another major tack to secure a cost advantage for the Arlington works. It tried to develop a commercially viable process for synthesizing camphor. The Station's work, based on a purchased patent, resulted in the erection of a small commercial camphor plant. In the context of World War I, with camphor prices rapidly rising, the plant was successful. But as soon as the war ended, the plant became a commercial disaster. Only later in 1933 did Du Pont build a successful, 4.5-million-pound synthetic camphor plant utilizing entirely different chemistry.[85]

Du Pont's acquisition of the Arlington Company was its last major play in trying to realize the company's initial diversification strategy – a strategy based on using the company's nitrocellulose plants and its R&D capabilities in nitrocellulose chemistry. At the time of the Arlington purchase, the war was already pushing the company toward a major overhaul of its diversification strategy. By 1916, aided greatly by Fin Sparre, the Development Department had formulated an entirely different strategy. This approach would lead Du Pont into new areas of business and would greatly strain Reese's Chemical Department.

The Experimental Station had played a significant role in Du Pont's initial diversification efforts. Particularly in the first years after the reorganization of 1911 when he had not fully consolidated power over Sparre and the Station, Reese had been something of a bystander in the matter of diversification. But two corporate reorganizations of 1914 allowed Reese to centralize fully the management of Du Pont's entire research program and brought him to a more critical position in the diversification of the company.

The Reorganizations of 1914

In January 1914, at Pierre's urging, Coleman du Pont returned to Wilmington to reassume his duties as full-time president of the company (Pierre had been serving as acting president on and off since 1909 while Coleman recovered from a severe stomach ailment and while he managed the construction of New York's famous Equitable Building). Coleman's resumption of the presidency coincided with his and Pierre's full realization that Hamilton Barksdale was not willing to turn over the job of general manager to the young Irénée. This precipitated a short-lived reorganization, effective March 1, 1914, that abolished the general manager's position and created eight vice presidents who reported to the president. As a vice president, Barksdale continued to be in charge of the Manufacturing; Chemical; Engineering; and Light, Heat, and Power departments. Therefore, during this brief period, Reese reported to Barksdale without having to go through Irénée du Pont. Irénée assumed responsibility for the Purchasing, Nitrates, and Development departments.

Barksdale bridled at Coleman's reorganization, and during the next few months he, Arthur J. Moxham, and William du Pont (son of an earlier, powerful Du Pont Company president and a major stockholder living in Orange, Virginia) became sore points between Coleman and Pierre. By August 1914, Coleman offered to sell Pierre all his Du Pont Company stock. After several exchanges between the two cousins, they reached an accord they thought would solve the executive managerial problems of the company, particularly the question of executive succession. Although this new arrangement set off bitter family battles, it prepared the company for the challenge and opportunities presented by the larger, bloody war in Europe.[86]

Effective September 19, 1914, Irénée du Pont became chairman of an entirely new, younger Executive Committee, which was given "full power in the control of the Company's affairs."[87] All the seasoned incumbents gave up their administrative and executive duties. Although Coleman (whose severe stomach problems would soon return) retained the title of president and Pierre assumed the position of acting president, both stepped down from the Executive Committee and gave up their attendant responsibilities. They continued to serve on the Finance Committee, however, which now reported directly to the board of directors.

The reorganization of September 1914 affected the Chemical Department in one important respect: The chemical director now reported directly to the chairman of the Executive Committee.[88] Evidence suggests that Irénée would have liked to replace Reese with Sparre as chemical director. When asked by Coleman to suggest ideas for reorganizing the company a month prior to the second shuffle of 1914, Irénée gave Reese poor marks as a research director. "So far as chemical control of our manufacturing operation is concerned, this Department is satisfactory," wrote Irénée. But, he continued, "I have misgivings for the progress of research work under Reese, as I do not think he is a deep thinker on research matters; his chemical knowledge is not as broad as another available man [Fin Sparre] and his mechanical knowledge is meagre."[89] Irénée evidently lacked the power to replace Reese. The votes were not there. But Irénée never changed his mind about Reese's deficiencies as a research director, even though Pierre arranged Reese's election to the board of directors in 1917.[90]

Irénée nevertheless made the best of the situation, as did Reese. As general manager, Barksdale had continued to advocate preserving as much of the Eastern Laboratory model of organization as possible. But under Irénée, who favored a strong central research organization, Reese was quickly able to consolidate power. Soon he was issuing a single annual report for the Chemical Department rather than passing on the reports of the respective laboratory directors.

Not long after the war in Europe began seriously to affect Du Pont's diversification strategy, Irénée secured the services of Sparre for the Development Department. It would be Sparre who, working under R. R. M. and Walter S. Carpenter, would formulate Du Pont's new strategy of diversification, while Irénée exercised leverage over Reese. Irénée saw research as critical to the company's development strategy. During his tenure as chairman of the Executive Committee and later president of the company, Irénée insisted, as he had said earlier, that "research work should be continued and on even a larger scale."

The situation created in Du Pont by the war would add new meaning to Irénée's words, for within a four-year period, Du Pont's R&D expenditures would grow sevenfold. During this period, however, as research became more tightly centralized, the company's diversification strategy was pushing Du Pont's organizational structure to its limits. Reese would struggle to maintain a powerful Chemical Department, but eventually that centralized structure would give way.