

# Technological Systems Compete at Otis

## *Hydraulic Versus Electric Elevators*

Anne Millbrooke

### Introduction

Professor Thomas P. Hughes defined technological system in his book *Networks of Power*, which is about the history of electric power, as follows: “A system is constituted of related parts or components. These components are connected by a network, or structure. . . . The interconnected components of technical systems,” Hughes continued, “are often centrally controlled, and usually the limits of the system are established by the extent of this control.”<sup>1</sup> A less formal definition appeared one Sunday in the “Shoe” comic strip. There Jeff MacNelly, creator of the strip, compared a toothbrush and a dental care system. He concluded, “A ‘system’ is anything that costs over 80 bucks.”<sup>2</sup> By either definition, the elevator is a technological system.

While working at a bedstead factory in Yonkers, New York, in 1852, Elisha Graves Otis (1811–1861) invented a safety mechanism for the standard hoisting systems of his day. The revolutionary Otis safety was a simple device,<sup>3</sup> consisting of a spring atop the elevator platform held taut by the hoisting rope, and ratchets along the walls of the hoistway. A broken rope would release the spring and force the pawls or ends of the spring into the ratchets and thereby stop the elevator from falling. Thus the name Otis became immediately associated with safety elevators—“so constructed that if the rope breaks the platform cannot fall,” according to advertisements of the 1850s.<sup>4</sup>

When Otis invented his safety device, hoisting machinery carried freight and freight handlers. He established his elevator works in 1853 to produce elevators for the existing freight market. Early customers included a furniture manufacturer, a melter and refiner, coffee and spice mills, and textile mills. The concept of safety



*E. G. Otis*

Elisha Graves Otis (1811–1861) founded the Otis elevator works in 1853. (*United Technologies Archive*)

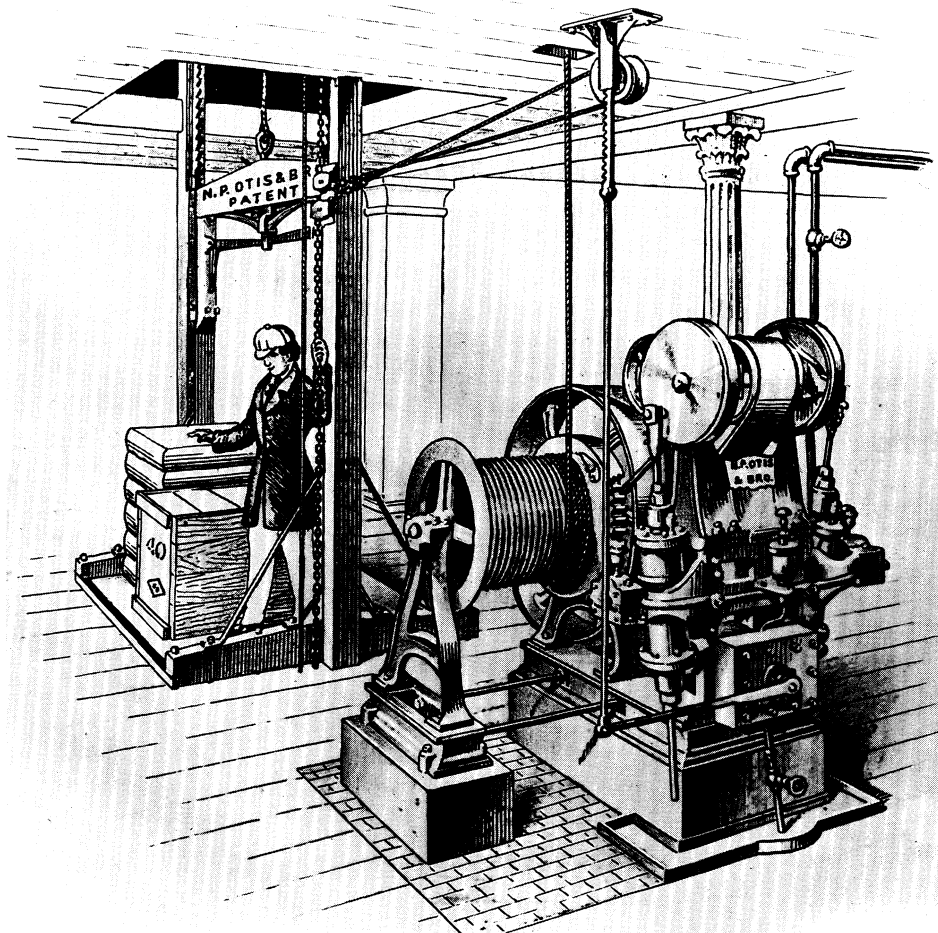
inherent in the invention, however, opened a vast new market for hoisting machinery—the passenger elevator market. Otis shipped his first passenger elevator to a china store in New York City in 1857. Thereafter, the market for passenger elevators gradually expanded. In the late 1860s, Otis Brothers & Company (successors of E. G. Otis) advertised the “novel luxury” of the passenger elevator.<sup>5</sup> By then, the company had introduced the “Palace Elevator” for hotels and “other public establishments.” The passenger elevator became popular in the 1870s—in retail stores, like Lord & Taylor in New York City; in large hotels, like the St. Charles Hotel in New Orleans; and in office buildings, like the State and War Departments building in Washington.

The nineteenth century was the age of steam power, and so steam powered these early passenger elevators as well as most of the freight elevators of that period. The earliest Otis elevators could be adapted for water, hand, or other power, but steam was the preferred power for several decades and remained an option into the twentieth century. Often belts transferred power from the steam engine to the elevator. That was the case at the first World’s Fair held in the United States. At that fair several steam engines on exhibit were used to drive machinery also on display, including the Otis safety elevator. There, in New York City in 1854, Elisha Graves Otis dramatically demonstrated the safety of his elevator by riding on the platform while the rope was cut.<sup>6</sup>

Belt elevators were designed for establishments that already had power in use for other purposes. Many nineteenth-century factories and warehouses, for example, had water or steam power. Consequently, Otis and his sons initially sold elevators mostly to manufacturers and warehouse owners. These were freight elevators. The Otis “Universal” model included platform, safety ratchets, sheaves, and wire rope.<sup>7</sup> It came with or without the belting necessary to transmit power to the machine. During the 1860s and 1870s, the Otis brothers sold the Universal elevator to factories, mills, shops, and other businesses with power already in use.

Elisha Otis recognized the value of an independent or dedicated engine to power his elevators. He sold steam engines, and he invented and patented improvements in steam engines.<sup>8</sup> By providing power to an elevator, the independent engine expanded the market for elevators beyond buildings with an existing power source. Charles and Norton Otis, sons of Elisha, also developed and sold steam elevators. Otis Brothers & Company, in fact, became “dealers in all kinds of machinery required in the application of steam for hoisting purposes”—including steam boilers, pumps, gauges, and pipes.<sup>9</sup> Otis Brothers sold “Metropolitan” and “New York” steam engines for elevators.

A new kind of elevator, driven by hydraulic pressure, appeared in the 1870s, and it supplanted the steam elevator in the 1880s. The steam elevator was actually a fairly complicated system comprising boiler, fuel, and water, and requiring a skilled operator for the steam plant (not for the elevator car). While steam-powered elevators remained common in factories, the “Otis Standard Hydraulic Elevator” carried both passengers and freight in the skyscrapers then being built in American cities, as well as in lower-rise buildings around the world. Water under pressure drove the hydraulic piston and thereby the elevator. The hydraulic elevator reached the height of its popularity at the turn of this century, a decade after the appearance of electric elevators.



Elisha Graves Otis and his sons, Charles R. and Norton P. Otis, sold steam engines and steam-powered elevators, like this 1861 freight machine. (*United Technologies Archive*)

The competition between two elevator systems—one hydraulic and the other electric—illustrates the evolution of the newer, electric system and its components. Hydraulically powered elevators included several types, most notably the direct-plunger type and the rope-gear hydraulic. Similarly, the electric elevator appeared with variations from maker to maker and through time, the worm gear and gearless traction being the most common types. The competition between hydraulic and electric systems also reflects business factors, including the infamous Elevator Trust and the turn-of-the-century merger movement. Otis, despite its high name recognition (then and now), was not the only elevator company. By 1877, for example, twenty-one elevator manufacturers were doing business in Boston alone.<sup>10</sup> Otis, as Otis Brothers & Company and later as the Otis Elevator Company, provides a case study of the competition of technological systems within a company and an industry.

## Otis Brothers

Charles R. Otis (1835–1927) and Norton P. Otis (1840–1905) succeeded their father upon his death in 1861.<sup>11</sup> For a few years the brothers managed the firm as a partnership, first under the name N. P. Otis & Brother, and later as Otis, Brothers & Company. A financial backer, John Hubbard, became their silent partner. In 1867 the two Otis brothers and Hubbard reorganized the company and incorporated, in New York, as Otis Brothers & Company. From the reorganization in 1867 until 1898, a board of trustees managed the company for the benefit of stockholders.<sup>12</sup>

The first meeting of the Board of Trustees of Otis Brothers & Company occurred on Friday, November 8, 1867. The original board of trustees consisted of three stockholders. These three stockholders—Charles and Norton Otis and Hubbard—had sold their assets in the previous partnership for stock in the newly organized company, of which they owned 100 percent. Charles Otis, the older brother, became president of the company; Norton Otis began as secretary and treasurer, but at the second meeting of the trustees he resigned as secretary. The trio promptly elected Hubbard to that office.

Charles and Norton managed Otis Brothers & Company, while, as a member of an importing firm, Hubbard was often absent in Europe. In 1869 a scribe at R. G. Dun & Co. (predecessor of Dun & Bradstreet) recorded in a credit ledger that the Otis business was “believed to have made some money . . . but it is evident they over rate themselves.”<sup>13</sup> At one time the three trustees considered merging with the Tufts Elevator Works of Boston. According to the prospectus of the proposed Union Elevator Company, the merger would result in less competition, enhanced profits, and perfected products.<sup>14</sup> The merger did not happen. In 1878, however, Otis Brothers purchased a large interest in the Hydraulic Elevator Company of Chicago from William E. Hale & Company, also of Chicago. According to the Otis trustees, the acquisition removed “one of our most efficient competitors” from the western territory.<sup>15</sup> Furthermore, the western company became a customer for Otis products.

With the acquisition of hydraulic technology, Otis Brothers acquired the talents of William Hale, who led a new management team during the 1880s. Hubbard, the secretary, sold his stock and left the company in 1880. He later accused Charles and Norton of fraudulently lowering the market value of the company’s stock in order to obtain his stock at less than its actual value.<sup>16</sup> Obviously annoyed by Hubbard’s legal action, Charles cited “claims,” “shyster lawyers,” and the threat of “blackmail,” as well as his own poor health, in 1882 when the brothers were negotiating a five-year absence from the board.<sup>17</sup> In addition to resigning from the board and their respective offices, Charles and Norton sold stocks and patents to a group of financiers headed by Hale. Hale naturally became president of Otis Brothers and promptly hired the brothers as consultants.

Shortly thereafter, William D. Baldwin and Abraham G. Mills joined the management team. Recently back from Europe, Baldwin had been handling foreign business for the Auburn, New York, firm of D. M. Osborne and Company, a manufacturer of harvesting equipment. He became treasurer of Otis Brothers, which was already selling elevator equipment to foreign customers. Mills, then president of the

National Baseball League, became secretary of the company. Both remained with the company well into the twentieth century.<sup>18</sup>

The business included Otis Brothers & Company, the Hale and Hydraulic elevator companies, and soon, in 1884, the American Elevator Company, which had offices in England and France. Charles and Norton Otis rejoined the Board of Trustees in 1887, while Hale was still president of Otis Brothers. Hale remained on the board, but relinquished the presidency. Norton, the older brother, who had served as mayor of Yonkers and in the New York Assembly, became vice president of Otis Brothers. Charles again became president. When he retired in 1890 due to ill health, Norton became president. Norton presided until 1898, when hydraulic elevators still dominated the high-rise market, but electric elevators had moved into low-rise buildings.

### Hydraulic Elevators

In the late 1870s Otis Brothers introduced their “safe, simple, economical” hydraulic elevator.<sup>19</sup> The company acquired the technology from the Hale hydraulic elevator company and from Cyrus W. Baldwin, an inventor from Boston. Otis Brothers also acquired the management skills of William Hale and technical services of Cyrus Baldwin. Additionally, Otis purchased domestic and foreign patents “covering any auxiliary point to aid us in making our elevators.” In matters of safety, utility, and economy, the hydraulic elevator quickly proved itself superior to steam elevators. Furthermore, the Otis company advertised that its hydraulic elevators were superior to the competition’s in safety, smoothness and noiselessness of motion, speed, economy of operation, and durability.

The Otis Standard Hydraulic Elevator could be adapted for use in hotels, public buildings, stores, office buildings, flats, private houses, warehouses, and factories. The financier J. P. Morgan purchased one, a passenger model, for his residence in New York City. Marshall Field & Company bought four hydraulic elevators—two passenger units and one freight machine for its retail store in Chicago, and one freight elevator for its warehouse there. The Westinghouse Air Brake Company bought two freight elevators for its facility in Allegheny City, Pennsylvania. The Capitol Hotel in Houston, Texas, received one hydraulic passenger elevator. The United States Capitol obtained two passenger models, and the Baroness Rothschild acquired one for her chateau in Geneva, Switzerland. Otis Brothers listed these customers in an 1882 sales brochure.<sup>20</sup>

The Otis Standard Hydraulic Elevator operated by water pressure from street mains, from a tank in an upper story, a tank on the roof, or a pressure tank in the basement. If the pressure came from municipal waterworks, no skilled attendant was needed; otherwise someone needed to maintain the pressure tank in the basement or the steam pump or gas engine used to raise water from a discharge tank in the basement to the supply tank above. Gravity provided the pressure for water taken from the supply tank. The water under pressure went into a bored cylinder, and therein acted upon a solid piston, which, via ropes and gears, drove the car. In other words, the Otis Standard was a rope-gear hydraulic elevator.<sup>21</sup>

»: THE OTIS :«

**STANDARD**

---

**HYDRAULIC ELEVATOR**

*For Passengers and Freight.*

ADOPTED BY U. S. GOVERNMENT,  
Upon Report of Eminent Experts appointed by the Secretary  
of the Treasury.

SAFE, SIMPLE,  
ECONOMICAL.

---

ADAPTED TO USE IN  
HOTELS,  
PUBLIC  
BUILDINGS,  
STORES,  
OFFICE  
BUILDINGS,  
FLATS,  
PRIVATE  
HOUSES,  
AND FOR  
DUMB  
WAITERS,  
ALSO IN  
WAREHOUSES  
AND  
FACTORIES.



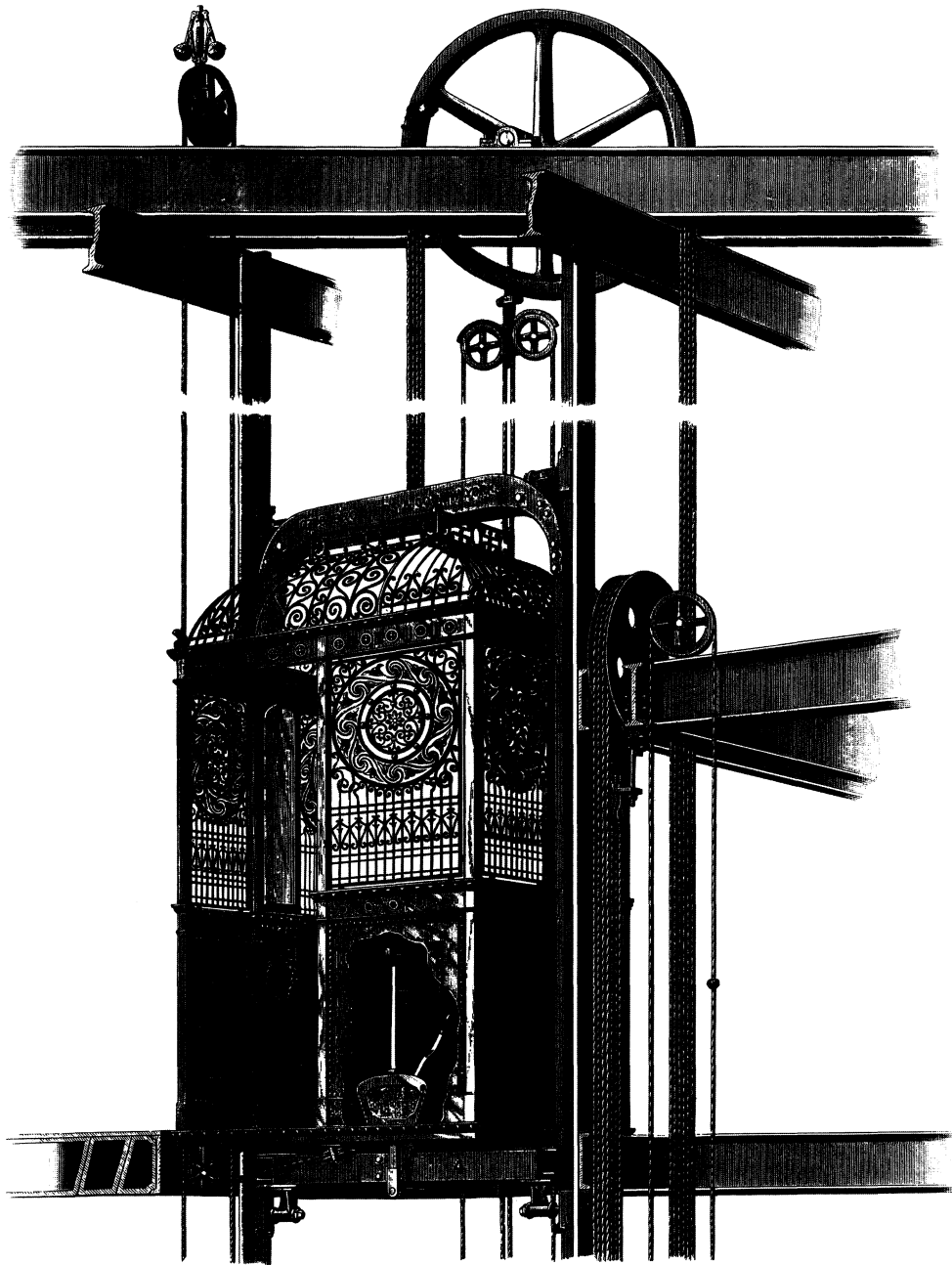
OPERATED BY  
**Water Pressure**  
FROM  
STREET MAINS,  
OR FROM  
A TANK in Upper Story,  
or on Roof of Building,  
OR  
PRESSURE TANK IN BASEMENT

**Always Ready for Use,  
NIGHT OR DAY.**

**COSTS NOTHING**  
WHEN  
NOT IN USE.  
CAN BE MANAGED  
BY ANY  
LADY OR YOUTH.

**Manufactured by OTIS BROS. & CO., Yonkers, N. Y.**  
Q. N. EVANS & CO., Agents for New England; also, makers and designers of Steam and  
Water Heating Apparatus for public and private buildings.  
N. Y. Office, 60 DUANE STREET. Office, 72 SUDBURY STREET, BOSTON.

The Otis Standard Hydraulic Elevator, which operated by water under pressure, was introduced in the 1870s. It is shown here in an 1882 advertisement. (*United Technologies Archive*)



—THE OTIS—  
PASSENGER ELEVATOR CAR  
WITH  
TOGGLE GRIP SAFETY AND STEEL SAFETY FRAME AND GIRDL.

OTIS BROTHERS & CO.,  
36 & 38 PARK ROW,  
NEW YORK.

The cutaway portion of this elevator cage shows the Otis Controller, a lever connected to the rope control. (*United Technologies Archive*)



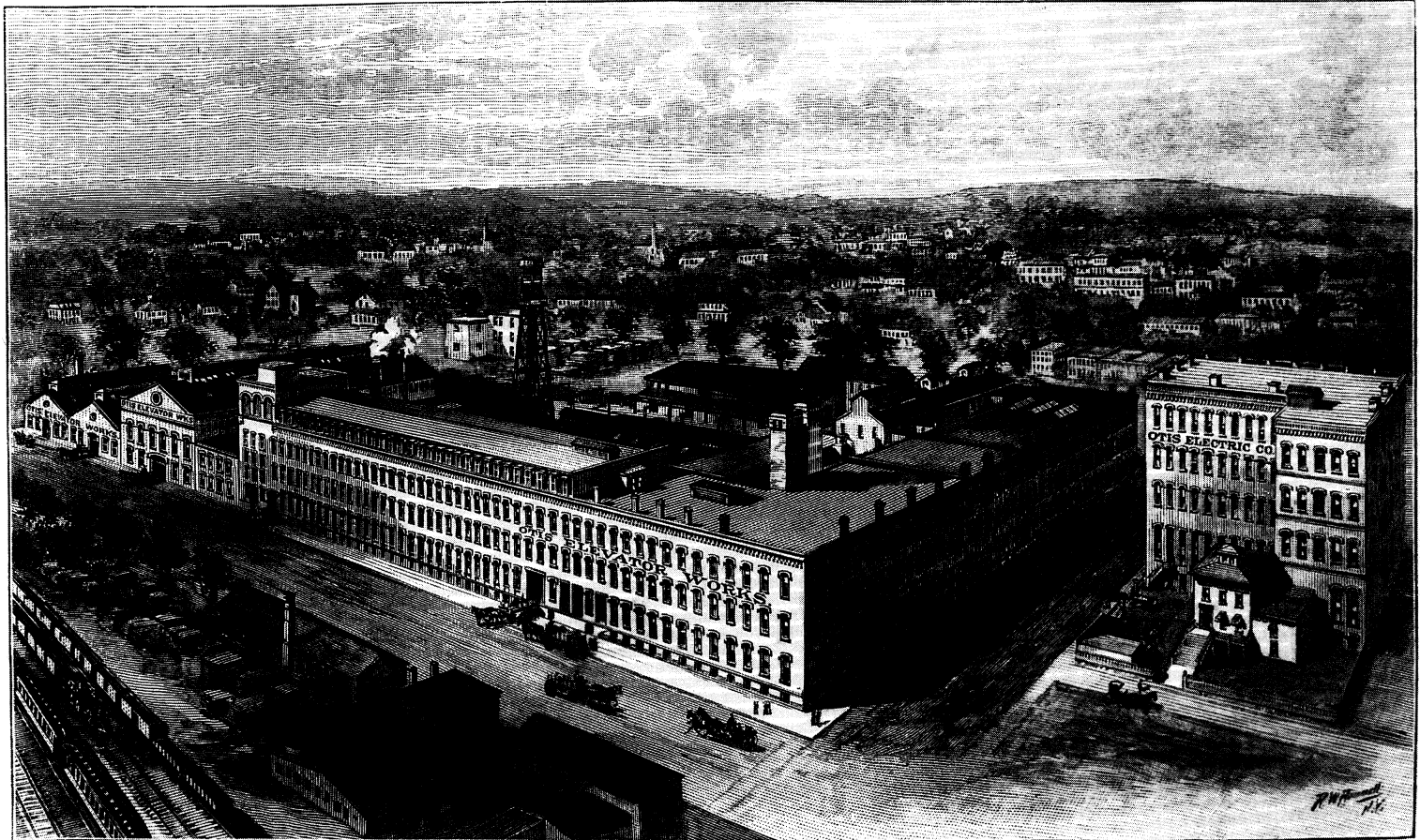
The passenger controlled the movement of the elevator car or cage by pulling a hand rope, the same as in a steam-powered elevator. Each pull adjusted valves in the motor. A downward pull on the rope control caused the elevator to rise. An upward pull started the descent. By applying “brake power” to the hand rope, the passenger stopped the elevator. Four wire ropes supported the Otis cage. If a single rope stretched or broke, safety “catches” prevented the cage from falling. Also for safety, a regulator prevented the elevator from exceeding a certain speed. The passenger did not have to activate any of the safety devices. While Otis claimed that the hydraulic elevator could “be managed by any lady or youth,” some skill was required to control the speed of the car and to bring the car to a stop level with the desired floor.<sup>22</sup>

Safety and ease of operation made the Otis hydraulic elevator popular for private homes, fancy apartment buildings, hotels, stores, and office buildings, including the skyscrapers that raised city skylines during the last quarter of the century. As builders turned to structural steel in construction of taller buildings, the hydraulic elevator provided the means for reaching the upper floors. Elevator operators were common in public buildings, particularly high-rise buildings with high-pressure hydraulic systems that required some muscle as well as skill to operate. Otis sold hydraulic elevators for use in skyscrapers into the early twentieth century.

### Electric Elevators

Thomas Edison had demonstrated the practicality of electric power in 1882, through the successful operation of his Pearl Street Central Station in New York City. Electricity thereafter gradually altered the elevator industry that had relied upon steam engines and hydraulic motors. Stationary electric motors were installed in factories and warehouses to furnish power for operating belt-driven freight elevators. Sometimes electric pumps drove hydraulic plants. In such instances, electric motors simply replaced other power sources without substantially modifying the elevator system.<sup>23</sup> Some early electric systems used a steam engine to drive an electric generator that supplied the electric energy to operate the elevator motor. That electric generator could also power electric lighting in the building. In time, it became possible to obtain electric current from utility lines, which eliminated the need for a power plant within the building. Access to electricity not generated on site enabled elevators to be used in “less important buildings” where the installation of a power plant would be prohibitively expensive.<sup>24</sup>

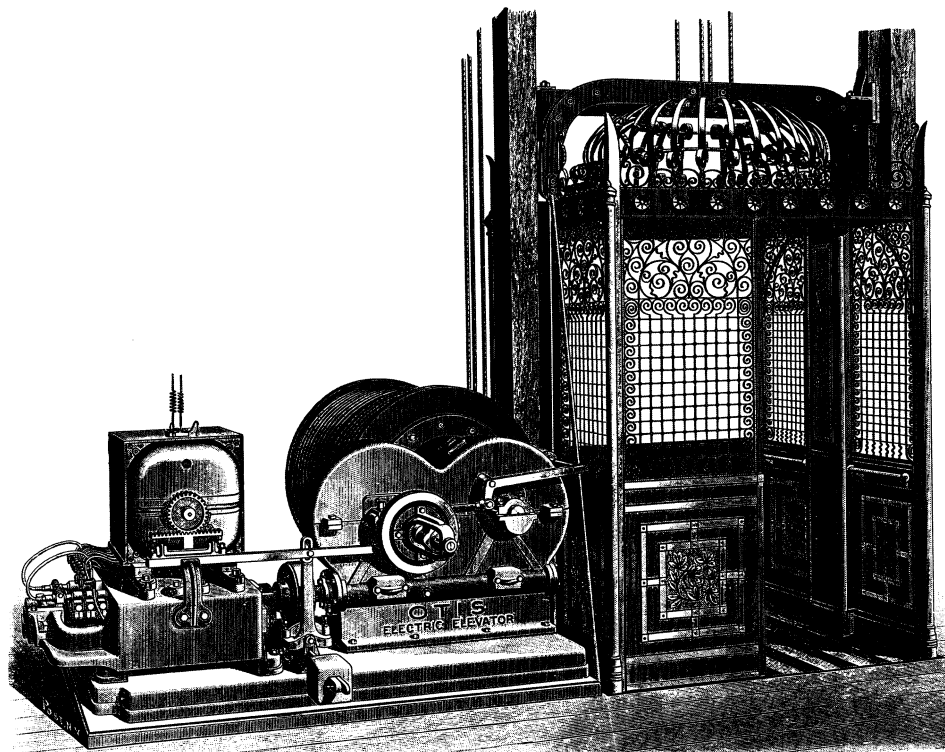
The direct-drive electric elevator took advantage of the increasing availability of electricity in a manner similar to the hydraulic elevator moving into cities with municipal waterworks. Otis Brothers sold its first electric elevators in 1889. That year it installed two worm-gear machines in the Demarest Building at 33rd Street and Fifth Avenue in New York City. Initially, Otis bought electric motors from Rudolf Eickemeyer, a German immigrant, inventor, and manufacturer. Otis described Eickemeyer’s “very ingeniously constructed Motor” in a sales brochure: “This Motor, when so combined with the Elevator, stops and starts with a gradual movement, and consumes power only in proportion to its load.”<sup>25</sup> At the world’s fair or Columbian Exposition in Chicago, the company displayed an electric elevator designed by Norton Otis, R. C. Smith, and Eickemeyer.



The Otis Elevator Works and the Otis Electric Company were neighbors in Yonkers, New York, as shown in this 1896 photo. The electric company is the L-shaped building to the right. (*United Technologies Archive*)

In 1892 Otis Brothers and the young General Electric Company organized the Otis Electric Company.<sup>26</sup> Otis was the majority stockholder, and General Electric held nearly 50 percent interest. Both partners transferred patents, good will, and future inventions related to electric elevators to the Otis Electric Company. The same year, Eickemeyer and his assistant Charles Steinmetz joined General Electric. Eickemeyer's other assistant, John Ihlder, joined the Otis Electric Company. By 1896, that electric elevator company employed about 100 people at its plant next to the Otis Brothers factory in Yonkers.<sup>27</sup> In comparison, Otis Brothers then employed about 500 in its factory and 150 in the field.

Compared to hydraulic motors and steam engines, the electric motor was compact and efficient. Still, the earliest electric elevators were not seen as competition for hydraulic elevators, but as "a valuable adjunct adapted to small buildings, where space is limited, and where the cost of operation of a hydraulic plant would be abnormally high."<sup>28</sup> Most early electric elevators used worm gearing to turn a drum, which limited the height of the lift, because the gearing was not suitable for high speeds and the drums did not hold enough rope for high rises. Hydraulic elevators therefore remained popular in commercial and public buildings.



—THE OTIS—  
DOUBLE SCREW ELECTRIC ELEVATOR.

OTIS BROTHERS & CO.,  
36 & 38 PARK ROW,  
NEW YORK,  
Sole for America.

Electric elevators of the 1890s, like this Otis model, had worm gears and a drum appropriate for low-rise and low-use applications. (*United Technologies Archive*)

# OTIS AUTOMATIC ELECTRIC ELEVATOR FOR USE IN RESIDENCES

is an addition to the comfort of every member of the household; and at the same time increases the value and salability of property more than cost of installation. No house of pretension should be without one. We frequently install elevators in houses already built. It is not as much of an undertaking as one might think to thus bring an old house up-to-date. Write for blanks and specifications.

**OTIS ELEVATOR COMPANY,**  
New York Office, 17 Battery Place

*Branch Offices throughout the Country*



At the turn of the century Otis advertised its popular automatic electric elevator for use in residences. Automatic meant pushbutton control. (*United Technologies Archive*)

In the matter of control, electric elevators rendered possible the elimination of the hand rope used in nearly all hydraulic elevators. Yet the hand rope—manipulated manually or via a wheel or lever—could be and was used in electric elevators; for example, with the Otis installation in the Demarest Building. In the 1890s Otis Brothers introduced a new product specially designed for residences—an electric elevator with push-button control. The push-button control meant that any passenger could operate the elevator without the assistance of an attendant. “A child can operate the Otis elevator,” boasted one advertisement.<sup>29</sup> As explained at the International Engineering Congress of 1904, “[t]he electric elevator is eminently suitable to push-button (automatic) control, enabling attendants to be dispensed with, and therefore is peculiarly suited to private and apartment houses, and similar light service.”<sup>30</sup>

A residential installation of the 1890s and early 1900s consisted of:

- an electric motor—to drive the winding machine,
- a bank of push buttons in the elevator car—to select the desired destination,
- a call bell at each floor—to call the elevator to that floor,
- a controller—to open and close the electric circuits,
- a floor controller—to stop the car at the desired floor,

and an ornamental car of wood or iron, hoisting ropes, and, of course, safety devices. Such an elevator, Otis advertised, could increase “the value and salability of property more than [the] cost of installation.”<sup>31</sup>

### The Elevator Trust

When the electric elevator was still a new product, Otis Brothers & Company formed ties with the Whittier Machine Company of Boston, the Crane Elevator Company of Chicago, and Stokes & Parrish of Philadelphia. Otis was already associated with the Hale and Hydraulic elevator companies of Chicago. The relationships evolved. In the beginning, for example, Whittier simply wanted to buy some Otis equipment. Charles Whittier sent Otis Brothers a telegram to that effect in 1889. The Otis board of trustees responded by adopting the following resolution:<sup>32</sup>

That the request of the Whittier Machine Co. to purchase elevator-machinery be declined, and the President be instructed to write the Whittier Machine Co. to this effect, and to say to it that this Company might entertain a proposal for the sale of two machines for the Museum of Natural History on the execution of an agreement that the said Whittier Machine Co. will withdraw all offers for our type of vertical machines, and will not offer or sell such machines hereafter during the life of our Patents.

Within months, Otis was negotiating the acquisition of Whittier’s elevator business. State laws then did not permit Otis Brothers to hold Whittier stock, so the officers of Otis purchased shares of Whittier stock. When state laws changed, Otis Brothers bought the stock from its officers. That was in 1895.

There emerged an elevator trust, a group of elevator companies cooperating to limit competition and control prices. Whittier, to continue the example, advertised horizontal hydraulic elevators, vertical hydraulic elevators, plunger hydraulic elevators, electric elevators, and belt-driven machines; and it sold Otis and Stokes & Parrish equipment.<sup>33</sup> In 1895 the magazine *Electricity* printed an "exposé" of "the big five": "the Otis Co. and its allies, the other members of the Elevator Trust."<sup>34</sup> The four Otis allies mentioned in the article were Hale, Crane, Whittier, and Stokes & Parrish. All five were known for their hydraulic elevators. Unable to obtain sufficient electric patents to stifle competition from makers of electric elevators, the five—according to the magazine writer—resorted to unfair business practices. He accused Otis of having a "rule or ruin policy" regarding other elevator companies, particularly small companies that could be overwhelmed by lawsuits. As antitrust sentiments grew, so did the Otis trust. Yet Otis Brothers itself had few stockholders—only seven when the trustees voted to merge into a new Otis Elevator Company.<sup>35</sup>

In 1898 Otis Brothers & Company merged with Hale, Crane, Whittier, Stokes & Parrish, and other elevator companies. The result was the Otis Elevator Company, organized as a holding company under the laws of New Jersey. It had a board of directors instead of a board of trustees. William D. Baldwin, long a trustee and officer of Otis Brothers, became president of the new company. Norton Otis became chairman of the board, a position he held until his death in 1905 (at which time he was a member of the U.S. House of Representatives). Classified as a "lesser" trust by industry chronicler John Moody, the Otis Elevator Company soon controlled 65 percent of the industry and kept growing by acquiring other elevator firms, including electric elevator companies.<sup>36</sup> Otis thus participated in the merger movement that swept American industry at the turn of the century. As explained by one business historian, "the predominant process was horizontal consolidation—the simultaneous merger of many or all competitors in an industry into a single, giant enterprise."<sup>37</sup> In addition to Otis, during that period American Can, DuPont, Eastman Kodak, International Harvester, International Paper, and Pittsburgh Plate Glass acquired major market shares through mergers.

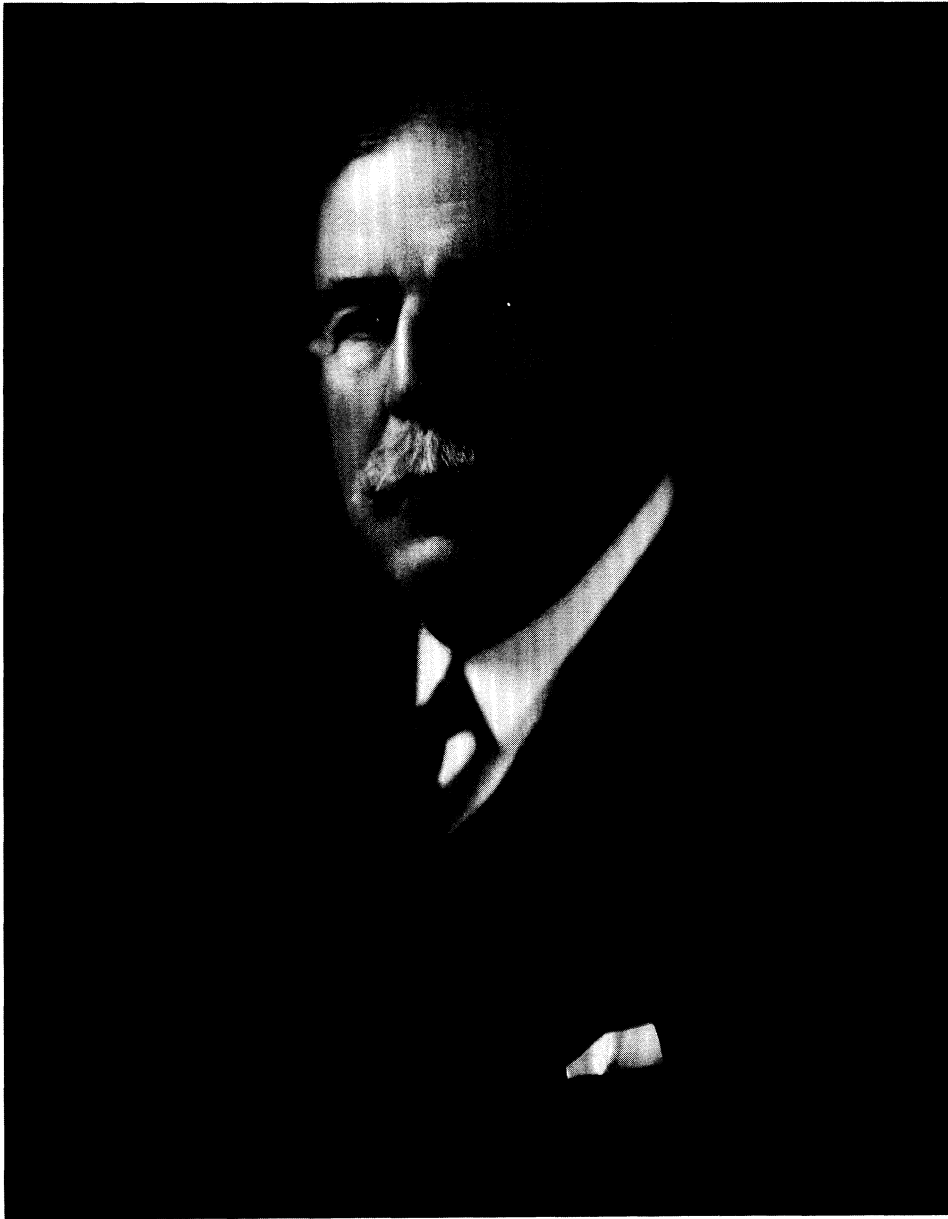
Federal antitrust proceedings helped shape Otis. In 1906 the United States sued the Otis Elevator Company, twenty-seven other companies, and three individuals, and charged them with violation of the Sherman Antitrust law. According to the U.S. Attorney General, "in order to make the combination effective the Otis Elevator Company has acquired the whole or a majority interest in the businesses of all the other defendants, although said defendants are still being operated as apparently separate and independent concerns."<sup>38</sup> As a result of this antitrust action, Otis submitted to a consent decree banning objectionable practices,<sup>39</sup> that is, not to hinder trade, not to fix prices, and not to divide territory. The subsidiary companies were dissolved or merged out of existence. Otis concentrated the once far-flung manufacturing operations into several factories. As of 1910, the company had seven plants and about 6500 employees in the United States.<sup>40</sup> The company's products included the Escalator brand of moving stairway and the increasingly popular electric elevator, as well as hydraulic products.<sup>1</sup>



Norton P. Otis (1840–1905) and William E. Baldwin (1856–1930) led the Otis Elevator Trust. (*United Technologies*)

### **Technical Competition**

The electric elevator eclipsed the hydraulic early in the twentieth century. Baldwin, in a report to stockholders, described the transition within Otis. Regarding the company, he said:<sup>41</sup>



Norton P. Otis (1840–1905) and William E. Baldwin (1856–1930) led the Otis Elevator Trust. (*United Technologies Archive*)

. . . up to the year 1903, a very large proportion of its business was in the manufacture and installation of hydraulic elevators. This type of elevator required for its operation a number of articles of different lines of manufacture which could not be produced in our shops to advantage and were purchased by us from other manufacturers.



Since that time, owing to the great development in the distribution and use of electricity, as well as the perfection of electrical apparatus, the demand for the electric elevators made by us has constantly increased, and each year has shown a larger percentage of sales of the electric type, all parts of which have been manufactured in our own shops, not only resulting in an increased demand upon our manufacturing facilities, but also substantially changing the character of the work.

For the industry as well as Otis, by 1905, the number of electric elevators being manufactured exceeded the total number of all other types of elevators combined.<sup>42</sup> This was due to the large number of small electric machines, like the residential elevator.

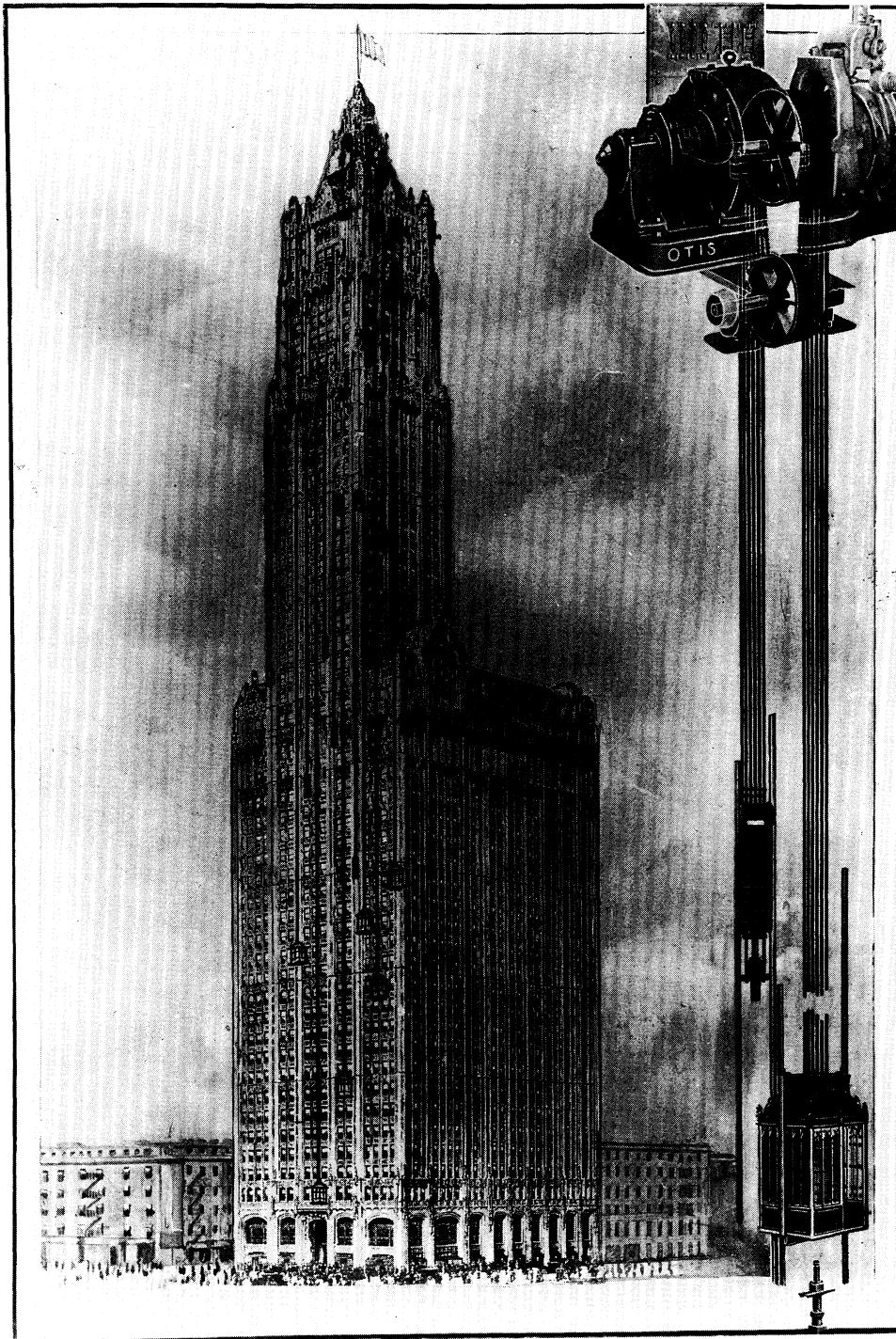
Hydraulic elevators remained briefly competitive for high-rise buildings. Already popular in Europe, the hydraulic plunger elevator competed successfully for commercial buildings, like the John Wanamaker stores in New York and Philadelphia, but Otis stayed with its rope-gear products.<sup>43</sup> George A. Fuller, a building contractor known for high-rise construction, selected Otis hydraulic elevators for his 20-story office building in New York City. Completed in 1902, the Fuller Building quickly became known as the Flatiron Building due to its shape. Otis supplied six rope-gear machines. The installation included two water supply tanks on the roof and an auxiliary pressure tank in the subbasement next to three steam pumps. The pumps could raise water to the tanks on the roof or place water under pressure in the auxiliary tank. The elevators were geared 6:1, six feet rise of the car to one foot movement of the vertical piston. The operating valves were six inches in diameter. Cars traveled at the speed of 600 feet per minute. A few years after the Flatiron Building opened, the Metropolitan Life Insurance Company remodeled and expanded its building in New York City. Otis installed a large, high-pressure hydraulic plant to power nearly fifty elevators in the 11-story office block, but Otis selected electric traction machines for the new 45-story tower.

Otis introduced the gearless traction electric elevator in 1904–1905. This type of electric elevator soon dominated the high-rise market.<sup>44</sup> The gearless traction machine had a simple cable drive, no gearing and no drum. Simply stated, the traction elevator system consisted of an electric motor, a traction driving sheave, and a brake pulley. Of course, it also had hoisting ropes (made of steel), a car, a controller, and safety devices. As a direct-drive system, the traction elevator had no gearing between the motor and the driven component, which was either the car or the counterweight. The traction sheave replaced the drum of earlier electric models. The traction elevator could accommodate high rises, as Otis proved with installations in the Singer, Metropolitan Life, and Woolworth buildings in New York City. The world's tallest building when it opened in 1913, the 60-story Woolworth Building was called "The Cathedral of Commerce."<sup>45</sup> Original equipment included 26 Otis gearless, traction, electric elevators.

Typical control systems—for operation by hand rope, by car switch, or by single push button—became inadequate as buildings reached higher and demands for service grew. An electrical engineer explained in 1907, "The development of the electric elevator has no doubt been largely retarded by the difficulties attendant upon the design of satisfactory controlling devices."<sup>46</sup> Otis used a patented system of control in the more than one thousand automatic residence elevators it had installed



Completed in 1902, the twenty-story Flatiron Building had six Otis rope-gearred hydraulic elevators. (*United Technologies Archive*)



In 1913 twenty-six Otis traction elevators carried passengers and freight in the new sixty-story Woolworth building, dubbed "the Cathedral of Commerce." (*United Technologies Archive*)

throughout the world by 1910. The control was an “automatic continuous non-interference system.”<sup>47</sup> The noninterference feature limited applications of push-button elevators. Noninterference meant that a person could call the elevator and ride it to the desired floor without interference from anyone in the halls wishing to use the elevator; that is, the elevator handled one call at a time. In other words, a person could “call” the elevator only if it were not in motion and not occupied. The elevator did not take calls in sequence and did not stop for additional passengers along a run. By 1918, Otis had installed over two thousand push-button controlled elevators in residences—the “finest residences”!<sup>48</sup>—where use was low, and the non-interference feature posed little inconvenience.

By 1918, however, the automatic Otis push-button elevator was also widely in use in other buildings where intermittent service prevailed—in buildings of moderate size, from three to eight stories. These small commercial installations included apartment houses, like Westminister Apartments in San Francisco; banks, like Boatmen’s Bank in St. Louis; churches, like the Latter Day Saints Temple in Salt Lake City; businesses, like the Peerless Motor Car Company in Cleveland; colleges, like Williams College in Williamstown, Massachusetts; hospitals, like Hartford Hospital in Hartford; stores, like the J. L. Hudson Department Store in Detroit; and other buildings, like the Y.W.C.A. Building in Duluth, Minnesota. Some customers used dual-control elevators—an operator working a car switch during busy hours and passengers activating the push buttons during periods of limited traffic.

Otis experimented with control systems for large commercial applications, the traction installations. For the Woolworth Building, for example, Otis replaced the starter with a dispatcher.<sup>49</sup> In commercial buildings with a bank of elevators, the *starter* (a person) would typically signal the operator in an elevator car when to start a run. Based on the model of railroad dispatching, the elevator *dispatcher* monitored the location of elevators on an indicator panel. The dispatcher could cut or transfer a call signal and could communicate with each elevator operator by megaphone, buzzer, and push button. An operator worked a lever inside the car in accordance with the schedule of service, call signals received, and instructions from the dispatcher. The control levers in the cars were connected to controllers, usually located with the hoisting engines above or below the serviced floors. Installation by installation, Otis acquired experience with resistance control, field regulation, group and unit control, multivoltage control, and other control features.

In 1924 the company introduced Signal Control for commercial applications when it installed Signal Control elevators for the first time in the Standard Oil Building in New York City. Signal Control meant push-button control and more. The operator no longer controlled elevator speed and no longer manually stopped the elevator. Instead, the car operated automatically in response to signals from the call buttons in the halls and the selector buttons in the car. The operator pressed selector buttons for boarding passengers and closing the car doors. As explained in the *Scientific American* magazine, the Signal Control gave elevators “electric brains.”<sup>50</sup>

Otis eliminated the need for operators in public buildings with the 1950 installation of Autotronic—Without Attendant—Elevating in the Atlantic Refining Company in Dallas, Texas. Autotronic combined automatic and electronic technology. The system included automatic, push-button controls; self-leveling, automatic terminal



In 1925, the *Scientific American* magazine announces that Signal Control gave elevators "electric brains." (*United Technologies Archive*)

stops; speed regulation and variable speed; power-operated doors with electronic proximity detectors; load-weighing device to identify full loads; and scheduled operation of an entire bank of cars. The self-service elevator, introduced in private homes in the 1890s, finally moved to busy commercial and public buildings.

## Conclusion

Otis had sold residential electric elevators from the 1890s until the company converted to defense production for World War II. In 1991 Otis began market testing its first residential model since 1942—a model purchased from an independent elevator maker. The current home elevator is hydraulic, not electric, and today hydraulic means oil, not water. One hundred years after the hydraulic elevator dominated the high-rise market and the electric elevator cornered the low-rise market, hydraulic elevators are used for low rises and low use, and electric elevators are used for high rises and high use.

From the establishment of the Otis elevator works in 1853, into the twentieth century, the Otis company acquired technology through purchase and merger. Elisha Otis and his sons purchased steam engines and other steam equipment for elevators. The brothers moved into hydraulic technology by acquiring patents and a hydraulic elevator company. Elisha Otis and his sons, all master mechanics, began a lasting tradition of in-house development, but the acquisition of technology developed outside the company proved decisive in the major technological competition between elevator systems—as illustrated by the transition from hydraulic to electric elevator systems. Otis participated in trust and merger arrangements to gain access to technology and territory—initially hydraulic technology and markets, but later electric technology and markets. Otis thereby gained dominance in the elevator business.

## Notes

1. Thomas P. Hughes, *Networks of Power, Electrification in Western Society, 1880–1930* (Baltimore, Md.: Johns Hopkins Univ. Press, 1983), p. 5.
2. Jeff MacNelly, “Shoe,” *Hartford Courant*, Sunday, June 16, 1991, comics section.
3. Letters Patent No. 31,128, “Improvement in hoisting apparatus,” E. G. Otis, January 15, 1861.
4. E. Graves Otis, calling card, photo no. R-570, ca. 1857; and Union Elevator Works, advertisement, photo no. HP-100, 1855. All Otis documents cited in this chapter are in the Otis Record Group at the Archive and Historical Resource Center, United Technologies Corporation, East Hartford, Conn. HP numbers refer to photographic copies of the respective documents.
5. The quoted terms in this and the next sentence are from Otis Brothers & Co., *Patent Safety Hoisting Machinery, Illustrated Descriptive Catalogue and Price List* (New York, 1869), p. 42. Regarding the palace car, see also Otis Brothers & Co., “Sole manufacturers of Otis’ patent safety hoisting machinery,” advertisement, 1868. The customers are listed in Otis Brothers & Co., “Otis safety steam passenger elevators,” foldout advertising brochure also for W.E. Hale & Co. and American Elevator Company, New York [ca. 1884]. See also Ada Louise Huxtable, “Store for E.V. Haughwout & Company—1857,” *Progressive Architecture*, February 1958, 4 pp. Hotels were an important early market for passenger elevators, as discussed in Jefferson Williamson, *The American Hotel*, 1930 (reprinted New York: Arno Press, 1975, pp. 64–66).
6. “Science, industry and invention,” *New-York Daily Tribune*, May 30, 1854. The *Tribune* reporter alluded to “an Elevator, or machine for hoisting goods, (exhibited by Mr. E. G.

- Otis of Yonkers, N.Y.) which attracts attention both by its prominent position and the apparent daring of the inventor, who, as he rides up and down upon the platform occasionally cuts the rope by which it is supported." See also Robert M. Vogel, "Hoisting," in *1876, a Centennial Exhibition*, ed. Robert C. Post (Washington, D.C.: National Museum of History and Technology, Smithsonian Institution, 1976), pp. 46–47. Regarding steam power in general, see Louis C. Hunter, *A History of Industrial Power in the United States, 1780–1930*, Volume Two, *Steam Power* (Charlottesville, Va.: Univ. Press of Virginia, for the Hagley Museum and Library, 1985).
7. Otis Brothers & Co., *Patent Safety Hoisting Machinery, Illustrated Descriptive Catalogue and Price List*, pp. 61 and 65; and Otis Brothers & Co., "Hoisting machinery," advertisement printed by Livesey Brothers, photo no. HP-105, ca. 1876.
  8. Letters Patent No. 30,241, "Oscillating engine," E. G. Otis, October 2, 1860. See also photo no. HP-014.
  9. Otis Brothers & Co., "Hoisting machinery," photo no. HP-105. See also Otis Brothers & Co., *Description and Price List of Otis' Metropolitan Steam Safety Elevator, for Stores, Etc.* (New York, 1872). The "Metropolitan" engine was an internal-gear type, and the "New York" an external-gear type. For examples of the brothers' contributions to steam technology, see Letters Patent No. 30-240, "Improvement in oscillating engines," Charles R. Otis, October 2, 1860; Letters Patent No. 51,076, "Improved steam hoisting apparatus," Charles R. Otis and Norton P. Otis, November 21, 1865; and Letters Patent No. 68,783, "Improvement in valves for steam engines," Charles R. Otis and Norton P. Otis, September 10, 1867. Regarding later steam elevators, see Otis Elevator Company, *Otis Elevators*, catalog, New York, 1905, pp. 43–45.
  10. Robert M. Vogel, *Vertical Transportation in Old Back Bay, a Museum Case Study, the Acquisition of a Small Residential Hydraulic Elevator*, Smithsonian Studies in History and Technology, No. 50 (Washington, D.C.: Smithsonian Institution Press, 1988), p. 8. Vogel presents a brief history of elevators in this booklet and a longer review in his *Elevator Systems of the Eiffel Tower, 1889*, United States National Museum, Bull. 228 (Washington, D.C.: Smithsonian Institution, 1961). A general overview also appears in George R. Strakosch, *Vertical Transportation: Elevators and Escalators*, 2nd ed. (New York: Wiley, 1983), pp. 1–25.
  11. Regarding Elisha and Charles Otis, see their respective entries in *The Dictionary of American Biography*, vol. 14 (New York: Scribner's, 1934), pp. 93–94. Regarding Norton Otis, see *The National Cyclopaedia of American Biography*, vol. 11 (New York: James T. White, 1909), p. 120; and U.S. Congress, *Norton P. Otis, Memorial Addresses Delivered in the House of Representatives*, 58th Congress, 3rd session (Washington, D.C.: U.S. Government Printing Office, 1905). See also *A Genealogical and Historical Memoir of the Otis Family in America*, compiled by William A. Otis (Chicago, 1924).
  12. Otis Brothers & Co., Minutes of Trustees' and Stockholders' Meetings, 1867–1898, two manuscript volumes, Otis Record Group.
  13. Entry of November 7, 1869, in New York Vol. 374, p. 51, R.G. Dun & Co. Collection, Baker Library, Harvard University Graduate School of Business Administration, Boston, Mass. Before Hubbard, J. M. Alvord was a partner of the Otis brothers, as listed in the same source, same page, in an entry dated July 13, 1866.
  14. Otis Brothers & Co. and Tufts Elevator Works, "The Union Elevator Company," pp. 1–2 of the 9-page printed prospectus, 1873; and Tufts Elevator Works to Otis Brothers & Co., March 12, 1873, transcribed on pp. 1873 (1–3) in "The Annals of Vertical Transportation," typed notes prepared by Donald Shannon, 1953.

15. The quotation is from minutes of the special meeting of the board of trustees, January 27, 1879, in *Minutes of Trustees' and Stockholders' Meetings*, Vol. 1, p. 68.
16. "John L. Hubbard, plaintiff and appellant, against Charles R. Otis and Norton P. Otis, defendants and respondents, papers on appeal from order granting defendants' motion for bill of particular," New York Supreme Court, General Term, First Department (New York: Charles S. Hamilton, 1883).
17. Charles R. Otis to William E. Hale, in Cha[rle]s R. and N. P. Otis Private Letterbook, 1870–1882, May 6, 1882, pp. 111–113; see also the brothers' offer in Norton P. Otis and Cha[rle]s R. Otis to William E. Hale, January 28, 1882, pp. 104–110, in the same letterbook. Regarding the consultancy agreement, see particularly minutes of the meeting of the trustees, September 4, 1882, in *Minutes of Trustees' and Stockholders' Meetings*, Vol. 1, pp. 112–117. Hubbard's departure appears in the minutes of the meeting of the trustees, November 6, 1880, in Vol. 1, p. 77. Charles and Norton Otis resigned at the special meeting of the trustees, May 31, 1882, in Vol. 1, pp. 83–85. William Frank Hall was president of the company for one month during the transition of power in 1882; see minutes of the trustees' meetings of June 24 and June 30, 1882, in Vol. 1, pp. 103 and 108. Hall then became vice president of the company and handled the European business for years.
18. Baldwin (1856–1930) and Mills (1844–1929) became trustees at the meeting of April 5, 1883, per *Minutes of Trustees' and Stockholders' Meetings*, Vol. 1, p. 141. See "William Delavan Baldwin," *The Americana, a University Reference Library, Biographies* (New York: Americana Company, 1911), pp. 148–149 plus portrait. Mills formerly worked for the U.S. Treasury Department; see "Bismarck of baseball," *Otis Bulletin*, No. 415, April–May 1949; pp. 17–19 and "In Memoriam, Abraham G. Mills," *Spalding Official Base Ball Guide* (New York, 1930), p. 348; and the Abraham Gilbert Mills Papers, 1793–1929, at the New York Public Library.
19. Both quotations in this paragraph are from Otis Brothers & Co., "The Otis standard hydraulic elevator," advertisement, pp. 1 and 2 of 4, New York [1882]. The customers mentioned in the paragraph came from a list on p. 4 of this advertisement.
20. Otis Brothers & Co., "The Otis standard hydraulic elevator," p. 4. An overview of hydraulic elevators in Kansas City appears in B. F. Jones, "Hydraulic elevators and motors," *Sci. Am. Suppl.*, No. 392, July 7, 1883. Westinghouse began to make electric motors and controls for elevators in the 1890s and started manufacturing elevators in the early 1900s; see "Transportation," *Westinghouse Engineer*, Vol. 10, pp. 98–104, March 1950.
21. Regarding the Otis technology, see F. Reuleaux, translated from the German by P. Jensen, *Opinion on the "Otis" Hydraulic Elevator*, London: Otis Elevator Company, Limited [1886]; see pp. 2–5 for how the elevator worked. See also Otis Brothers & Co., *Directions for Taking Care of the Otis Hydraulic Elevator*, New York [ca. 1890]. Also, see the series on "Vertical hydraulic elevators," in Otis Elevator Company, *The Indicator*, vols. 3–4, July 1910–March 1911.
22. The quotation is from Otis Brothers & Co., "The Otis standard hydraulic elevator," p. 1.
23. Joseph Sachs, "Electric elevators," pp. 387–388; and "Electric elevators," *Electrical World*, vol. 19, pp. 447–450 and 475–476, April 3 and April 10, 1897. Regarding Edison, see Hughes, *Networks of Power*, Chap. 2. The early history of electric elevators is covered in Joseph Sachs, "Electric elevators," *Cassier's Magazine*, vol. 8, pp. 387–408, Aug. 1895; and Thomas E. Brown, "Passenger elevators," *Trans. ASCE, International Engineering Congress, 1904*, pp. 133–205, 1904.
24. Brown, "Passenger elevators," op. cit., p. 203. See also "The evolution of the electric elevator machine," *Indicator*, Vol. 2, No. 2, February 1909, pp. 11–12.



25. Otis Brothers & Co., *The Otis Electric Elevator*, New York [ca. 1891]. Regarding Eickemeyer (1831–1895), see *Dictionary of American Biography*, Vol. 6 (New York: Scribner's, 1931), pp. 59–60; and Charles Proteus Steinmetz, "Rudolf Eickemeyer," *Elec. World*, March 16, 1895, pp. 331–332. Regarding Eickemeyer's motors, see J. H. Bunnell & Co., *Eickemeyer Dynamos and Electric Motors, Patented Feb. 22, 1887, and Feb. 14, 1888*, New York [ca. 1888], Otis Record Group; and Ronald Kline, "Science and engineering theory in the invention and development of the induction motor, 1880–1900," *Technol. Cult.*, Vol. 28, April 1987, pp. 283–313.
26. See minutes of trustees' meeting, May 3, 1892, in *Minutes of Trustees' and Stockholders' Meetings*, Vol. 2, pp. 225; and resolution passed at meeting of stockholders and incorporators of the Otis Electric Company, November 30, 1892, typescript copy, Otis Record Group. Baldwin summarized the history of the electric company in W. D. Baldwin to F. P. Fish, April 11, 1922, General Electric File, Otis Patent Department, Otis Record Group; and the "consolidation" of interests with General Electric is mentioned in Steinmetz's obituary of Eickemeyer.
27. Charles Elmer Allison, *The History of Yonkers*, 1896 (reprinted Harrison, N.Y.: Harbor Hill, 1984), p. 350; the employment of Otis Brothers is given on p. 348.
28. William Baxter, Jr., "The electric versus the hydraulic elevator," *Eng. Mag.*, June 1896, pp. 478–485; the quotation is from p. 479.
29. Otis Brothers & Co., "A child can operate the Otis elevator," advertisement, photo no. HP-108, 1890s. An early description of the push-button control appears in Patent No. 471,100, "Electrically controlled elevator," A. M. Coyle, March 22, 1892. See also "Electric elevators—VIII, Otis electrically operated elevators," *Elec. World*, Vol. 19, May 29, 1897, pp. 684–685. In rare cases, electric control was applied to hydraulic elevators, mostly dumbwaiters; see "Electric control of hydraulic elevators," *Indicator*, Vol. 5, No. 11, November 1912, pp. 85–86.
30. Brown, "Passenger elevators," *op. cit.*, p. 203.
31. Otis Elevator Company, "Otis automatic electric elevator for use in residences," advertisement, photo no. HP-109 [ca. 1900]. See also "The Otis automatic residence elevator," *Indicator*, Vol. 5, No. 1, January 1912, p. 3; Otis Elevator Company, *Otis Electric Elevators* (New York, 1905); and Otis Elevator Company, *Otis Residence Elevators* (New York [ca. 1910]).
32. Minutes of special meeting of the board of trustees, May 22, 1889, in *Minutes of Trustees' and Stockholders' Meetings*, Vol. 2, p. 156. See also the minutes of February 4, 1890, p. 169; June 7, 1890, p. 189; and April 1, 1895, p. 255—all in Vol. 2.
33. Whittier Machine Co., *Whittier Machine Co., Manufacturers of Hydraulic, Electric, Steam and Belt Elevators* (Boston [ca. 1895]).
34. *Electricity*, "Attempted elevator monopoly," June 12, 1895, pp. 297–299.
35. The stockholders were N. P. Otis (1502 shares), W. D. Baldwin (1500 shares), A. G. Mills (600 shares), R. T. Crane (1823 shares), Nash Spaulding & Co. (365 shares), John A. Roebling's Sons Co. (200 shares), and Henry R. Reed (10 shares); see minutes of the special meeting of Otis Brothers & Co., December 3, 1898, p. 1, second document inserted after p. 336, in *Minutes of Trustees' and Stockholders' Meetings*, Vol. 2.
36. John Moody, *The Truth about the Trusts, a Description and Analysis of the American Trust Movement* (New York: Moody Publishing Company, 1904), pp. 265–266. See also Eliot Jones, *The Trust Problem in the United States* (New York: Macmillan, 1926), pp. 40–42.

37. Naomi R. Lamoreaux, *The Great Merger Movement in American Business, 1895–1904* (New York: Cambridge Univ. Press, 1985), p. 1. The examples of consolidated firms, each with 70 percent or more market share, were selected from a list on p. 3.
38. U.S. Attorney-General Moody as quoted in “After the elevator trust,” reprinted from the *New York Sun*, as *Circular No. 2*, issued by Alonzo B. See and Walter L. Tyler, owners of the A.B. See Electric Elevator Co. (New York, 1906), p. 1, in the Gurney Clippings File, Otis Record Group. See also Martin J. Sklar, *The Corporate Reconstruction of American Capitalism, 1890–1960, the Market, the Law, and Politics* (New York: Cambridge Univ. Press, 1988), p. 152; and Jones, *The Trust Problem*, op. cit., pp. 445 and 492.
39. *United States v. Otis Elevator Co.*, pp. 107–113, in *Decrees and Judgments in Federal Anti-Trust Cases, July 2, 1908–January 1, 1918*, compiled by Roger Shale (Washington, D.C.: Government Printing Office, 1918). The decree is dated June 1, 1906. In addition to the Otis Elevator Company, the consent decree covered: Burdett and Rowntree Manufacturing Co., Cahill and Hall Elevator Co., Central Iron Works Co., Crane Elevator Co., D.H. Darrin Co., Eaton and Prince Elevator Co., Electrical Engineering Co., Elektron Manufacturing Co., Gardner Elevator Co.; Geiger, Fiske & Koop; Graves Elevator Co., McAdams & Cartwright Elevator Co., A.J. McNicoll Elevator Co., Moline Elevator Co., Moon Elevator Co.; Morse, Williams & Co.; National Electric Elevator Co., M.J. O’Donnell & Co., Plunger Elevator Co., Smith-Hill Elevator Co., Sprague Elevator Co., Standard Elevator and Manufacturing Co., Stokes & Parish Elevator Co., Sulzer-Voght Machine Co., Warner Elevator Co., Whittier Machine Co., and three individuals—Samuel Burger, W. D. Baldwin (president of Otis), and C. G. Comstock (of the Smith-Hill company and a director of Otis). The government dismissed from its complaint the Bloomsberg Elevator and Machine Co., and it apparently added Darrin and Elektron after the initial announcement.
40. Otis Elevator Company, *Annual Report, 1909* (New York, 1910), pp. 2–3. The plants were in Yonkers and Buffalo, N.Y., Harrison, N.J., Philadelphia, Pa., Chicago and Moline, Ill., and Peru, Ind.
41. Otis Elevator Company, *Annual Report, 1910* (New York, 1911), p. 2.
42. William C. L. Eglin, “The relative efficiencies of electric and hydraulic elevators,” pp. 1–27 from unidentified publication, late 1904 or early 1905, Morse Articles File, Otis Record Group; the figure is from p. 21. Eighty percent of all elevators installed each year in the United States were electric, according to E. R. Carichoff, “Fundamental features of electric elevators,” *Elec. Rev.*, Vol. 46, June 24, 1905, pp. 1006–1007.
43. About plunger elevators, see David Lindquist, “Modern electric elevators and elevator problems,” reprinted from the *J. ASME*, June 1915, pp. 1–16, esp. p. 1; Brown, “Passenger elevators,” op. cit., p. 150; and “Hydraulic vs. electric,” *Otis Bulletin*, No. 411, November 1948, p. 22. For Otis examples, see “The Fuller Building,” *Indicator*, Vol. 3, No. 8, August 1910, p. 1; and “High-pressure elevator equipment of the Metropolitan Life Insurance building, New York,” *Eng. Rec.*, Vol. 55, March 23, 1907, pp. 374–377.
44. “The electric elevator equipment for a tall office building,” *Eng. Rec.*, Vol. 56, September 21, 1907, pp. 309–310; Lindquist, “Modern electric elevators and elevator problems,” *J. ASME*, op. cit., pp. 1–16; “The traction elevator,” *Indicator*, Vol. 1, No. 1, July 1908, p. 3; and “Traction machines, 1:1 and 2:1,” *Indicator*, Vol. 4, No. 9, September 1911.
45. Spencer Klaw, “The world’s tallest building,” *Am. Heritage*, February 1977, pp. 87–99; and Charles E. Knox, “The world’s highest office building,” *Elec. World*, Vol. 62, July 19, 1913, pp. 125–131; see also “The elevator equipment in the Singer building,” *Owners Build. Mag.*, September 1907, p. 27.

46. E. R. Carichoff, "Notes on elevators," *Elec. Rev.*, Vol. 51, September 21, 1907, pp. 464–466; the quotation is from p. 466. See also "Control system[s] for hand rope operation," "Control systems for car switch operation," and "Control systems for single push button operation," *Indicator*, Vol. 3, No. 1, January 1910, pp. 6–7. Basic features of electric controls are described in H. D. James, "Electric elevator control systems," *Am. Elec.*, Vol. 14, November 1902, pp. 515–518.
47. Otis Elevator Company, *Otis Residence Elevators*, [ca. 1905], p. 5. See also, "The Otis automatic residence elevator," *Indicator*, Vol. 5, No. 1, January 1912, pp. 3–4.
48. Otis Elevator Company, *Otis Push Button Controlled Electric Elevators* (New York, 1918), p. 18. The customers listed in the next paragraph of text appear in this trade catalog.
49. Knox, "World's highest office building," op. cit., pp. 125, 129–132. Elevators were sometimes called "vertical railways" because of obvious similarities in passenger service; for example, "The vertical railway," *Harper's New Mon. Mag.*, Vol. 45, November 1882, pp. 888–894.
50. Albert A. Hopkins, "Elevators with electric brains," *Sci. Am.*, October 1925, p. 249. A thorough description of the electric elevator systems appears in *Electric Elevators*, Vols. 1 and 2 (Scranton, Pa.: International Textbook Company, 1931). Regarding self-service elevators, see "Self-service elevators in new office building," reprinted from *Skyscraper Manage.*, August 1950, as Otis sales folder B-2084, 1950. See also "Now it's just touch and go," *Otis Bull.*, No. 437, November–December 1952, pp. 9–12; and George R. Bailey, "New era in elevators," reprinted from *Skyscraper Manage.*, July 1952.