John L. Sprague

Frank J. Sprague invents

the constant-speed dc electric motor

ON A MISERABLY COLD SPRING day in 1998, it became necessary to clean out a little-used storage barn in Williamstown, Massachusetts, so that it could be sold. The barn was part of the estate of Robert C. Sprague, who had died in 1991. Although the winter snow was mostly gone, a misty drizzle made the muddy walk down to the barn's entrance slippery and treacherous. Once used to house riding horses, the stalls were long gone and the building was almost completely filled with rotting wet hay and broken pieces of equipment, along with seemingly useless files that once belonged to electrical inventor Frank Julian Sprague, Robert's father. The inventor had died in 1934, nearly 60 years before his son, and it seemed impossible that the barn could still hold anything of value. The building was sagging, and, once inside, broken light bulbs and wooden supports from Frank Sprague's failed late 1920s programmable electric sign business made moving around nearly impossible and dangerous. With its stagnant hay and years of collected rodent droppings, the space reeked, and it seemed best to get a front loader, empty out the structure, take the contents to the dump, and hope for a buyer who could see more value than was apparent.

However, over in the far southeast corner there was a small room with a broken door, which contained a table covered with the remnants of a metal lathe and miscellaneous, mostly unrecognizable,

The "History" column in the November/December 2015 issue of *IEEE Power & Energy Magazine* was about the remarkable life and career of Frank Julian Sprague, the accomplished inventor and electrical engineer. That article, authored by Frank's grandson, John L. Sprague, focused on Sprague's multiple unit control system, still in wide use today, chiefly in railway applications. This issue's article, also authored by John L. Sprague, delves even deeper into Frank Sprague's career, centering on his pioneering work on dc motors. His inventions, still in use, include constant-speed motors, which are nonsparking and fully self-regulating under changing load conditions, and the design of advanced railway motor trucks.

Born in 1930, John L. Sprague holds an A.B. degree in chemistry from Princeton University and a Ph.D. degree in chemistry from Stanford University. He served as a line officer in the U.S. Navy during the Korean War, including two years in naval electronics. He joined the Sprague Electric Company in 1959 as a research scientist and retired as CEO in 1987. Since then, Sprague has headed a small consulting firm, John L. Sprague Associates, now headquartered in Williamstown, Massachusetts. John, an IEEE Life Member, has authored or coauthored more than 20 articles, primarily in technical journals, and holds six U.S. and three foreign patents. He coauthored "A Frank Sprague Triumph: The Electrification of Grand Central Terminal," which appeared in the "History" column of the January/February 2013 issue of this magazine. John's first book, *Revitalizing U.S. Electronics: Lessons from Japan*, was published by Butterworth-Heinemann in 1993. He edited *The Birth of Electric Traction, the Extraordinary Life and Times of Inventor Frank Julian Sprague*, a book written by Frank Rowsome and published in 2014 by the IEEE History Center Press. More recently, John authored *Sprague Electric, An Electronics Giant's Rise, Fall, and Life After Death*, a book published this past April by the IEEE History Center Press.

We are honored and pleased to welcome John Sprague back as our guest "History" author for this issue of *IEEE Power & Energy Magazine*.

—Carl Sulzberger
Associate Editor, History

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figure 1. The restored 1884 Sprague dc motor in the museum display. (Photo courtesy of Jeff Hakner, Shore Line Trolley Museum, operated by the Branford Electric Railway Association, East Haven, Connecticut.)

pieces of rusting metal. Centered on the table was also something of substance covered with grime and cobwebs. Wiping away the dirt on its name plate revealed a startling date, "1884." Clearly, the front loader would have to wait until the identity of this unexpected object could be determined.

Following a call for help to the Shore Line Trolley Museum in East Haven, Connecticut, a team was soon on the scene and tentatively concluded that it could be a demonstration model of one of Sprague's early electric motors, possibly the only one still in existence. Gleefully offering to take the object back to the museum to see if it could be brought back to life, the team left with the motor and several of the files. Then the front loader came, emptied out what was left in the building, and headed for the town dump. Although now gone from the barn, Sprague's memory lives on in Connecticut where, a year later, the motor was running again, lovingly worked on by Fred Sherwood. Today the motor (see Figure 1) sits on display as part of the museum's permanent exhibit, "Frank J. Sprague: Inventor, Scientist, Engineer," which opened on 15 May 1999 at a private reception with many Sprague family members present, including the author.

Finding this motor seems especially appropriate since the largest percentage of the inventor's 95 patents dealt with electric motors: how to make them (the constant speed motor), how to use them (urban railways and elevators), how to control them [elevators and multiple unit (MU) control systems], and how to make the vehicles that used them safe (Sprague Safety Company).

figure 2. Frank J. Sprague as a cadet-ensign in the U.S. Navy, circa 1878. (Photo courtesy of John L. Sprague.)

Early Years

Frank Julian Sprague was born on 25 July 1857 in Milford, Connecticut, but grew up in North Adams, Massachusetts, when, in 1864, his mother died and his father left to find his fortune in the West, shipping Frank and his younger brother, Charley, to live with their Aunt Ann in North Adams. The Sprague family had originally arrived in the New World in 1629 from Upwey in Dorset, England, when Ralph Sprague and his family disembarked from the *Lion's Whelp* in Salem, Massachusetts. They first settled in Charlestown and then spread out across New England. While they were substantial, good, hard-working citizens, none showed the creative genius that would blossom in eight-year-old Sprague some 235 years later. Although Sprague was physically unimpressive, as he was small, wiry, with sandy hair and eyes that glittered with intelligence, he quickly demonstrated that he was no one to take lightly.

In North Adams he attended Drury Academy, where he excelled in mathematics and science, and then won a competitive exam for the U.S. Naval Academy in Annapolis, Maryland (surprising since he thought the exam, taken in Springfield, Massachusetts, was for West Point!), entering as a plebe in 1874. His technical skills and fascination with electricity blossomed at Annapolis, and he graduated in 1878 with honors in mathematics, physics, and chemistry (see Figure 2).

In 1881, while serving on the training ship USS *Minnesota*, at the time stationed in Newport, Rhode Island, inventive and influential Prof. Moses Farmer at the Torpedo Station became his mentor. Encouraged by Farmer, Sprague created his first electric device, a unique inverted-type dynamo, designed such that the relationship between the magnetic field and armature circuits became the basis for series-parallel controllers used on direct current (dc) railway motors to this day. Filed 4 October 1881 and issued 26 August 1884 (assigned to the U.S. Navy), this was Sprague's first patent, U.S. 304,145: "Dynamo-Electric Machine." Farmer then helped Sprague gain assignment to the 1882 Crystal Palace Electrical Exhibition in London where he served as secretary to the awards jury. His "Report on the Exhibits at the Crystal Palace Electrical Exposition" won him considerable notoriety (and saved him from certain court martial since its preparation caused him to be six months AWOL). It also led to his 1883 resignation from the Navy to take a job working for Thomas Edison on electrical distribution systems for lighting.

Although he was initially enthralled by the opportunity to work for the "Wizard of Menlo Park," it wasn't long before tensions flared between the two men. Sprague made an important early contribution by developing a mathematical approach for calculating the values and locations of the electrical street mains for new electric lighting installations. It replaced a tedious and inaccurate modeling approach and, in the process, reduced the time required for the exercise from weeks to hours. As a uniquely competent and intuitive inventor, Edison always seemed uncomfortable when technically trained engineers, such as Sprague, found ways to solve problems other than by pure experimentation. Also, Edison wanted electricity primarily for lighting purposes while Sprague viewed it as a new motive power for transportation. Only 11 months after joining Edison, following an angry exchange of letters, Sprague departed, to continue his motor work begun at the Torpedo Station and form his first company, the Sprague Electric Railroad and Motor Company (SERM), incorporated in late November 1884.

Early dc Electric Motors

Although he arguably developed the first truly useful electric motor, Sprague was the first to admit he certainly didn't invent the electric motor. Actually, the foundation for the electrical revolution began in 1831 when English scientist Michael Faraday discovered that electricity could be generated by the movement of a conductor in a magnetic field. Then in 1834 Vermont blacksmith Thomas Davenport developed a crude electric motor followed two years later by a small 2-ft (0.61-m) diameter electric model railroad. Motor work accelerated around the world, in Russia, Scotland, Britain, the United States, Italy, and elsewhere. However, the electric power for all these different devices came from storage batteries, making them impractical for most applications.

This changed dramatically when, in 1861, Italian physicist Antonio Pacinotti

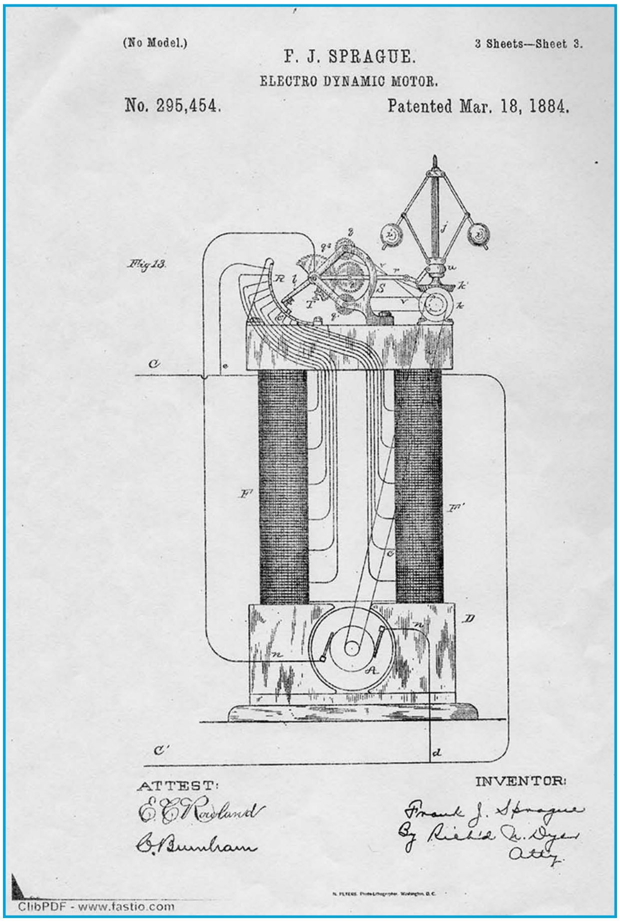
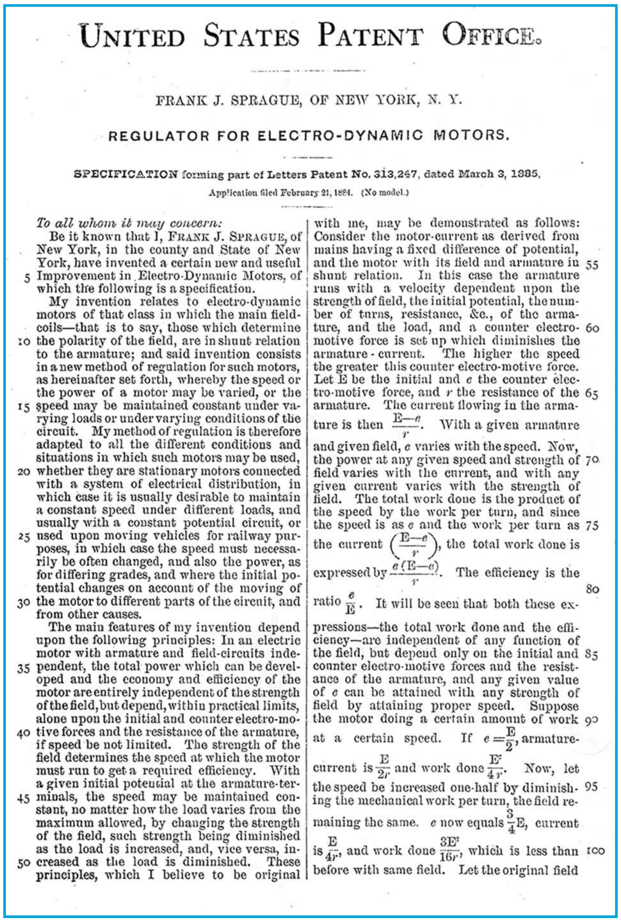


figure 3. A drawing for the Sprague electro dynamic motor patent U.S. Patent 295,454, issued to Sprague on 18 March 1884. (Photo courtesy of John L. Sprague.)



UNITED STATES PATENT OFFICE.

FRANK J. SPRAGUE, OF NEW YORK, N. Y.

REGULATOR FOR ELECTRO-DYNAMIC MOTORS.

SPECIFICATION forming part of Letters Patent No. 313,247, dated March 3, 1885.

Application filed February 21, 1884. (No model.)

To all whom it may concern:

Be it known that I, FRANK J. SPRAGUE, of New York, in the county and State of New York, have invented a certain new and useful Improvement in Electro-Dynamic Motors, of which the following is a specification.

My invention relates to electro-dynamic motors of that class in which the main field-coils—that is to say, those which determine the polarity of the field, are in shunt relation to the armature; and said invention consists in a new method of regulation for such motors, as hereinafter set forth, whereby the speed or the power of a motor may be varied, or the speed may be maintained constant under varying loads or under varying conditions of the circuit. My method of regulation is therefore adapted to all the different conditions and situations in which such motors may be used, whether they are stationary motors connected with a system of electrical distribution, in which case it is usually desirable to maintain a constant speed under different loads, and usually with a constant potential circuit, or used upon moving vehicles for railway purposes, in which case the speed must necessarily be often changed, and also the power, as for differing grades, and where the initial potential changes on account of the moving of the motor to different parts of the circuit, and from other causes.

The main features of my invention depend upon the following principles: In an electric motor with armature and field-circuits independent, the total power which can be developed and the economy and efficiency of the motor are entirely independent of the strength of the field, but depend, within practical limits, alone upon the initial and counter electro-motive forces and the resistance of the armature, if speed be not limited. The strength of the field determines the speed at which the motor must run to get a required efficiency. With a given initial potential at the armature-terminals, the speed may be maintained constant, no matter how the load varies from the maximum allowed, by changing the strength of the field, such strength being diminished as the load is increased, and, vice versa, increased as the load is diminished. These principles, which I believe to be original with me, may be demonstrated as follows: Consider the motor-current as derived from mains having a fixed difference of potential, and the motor with its field and armature in shunt relation. In this case the armature runs with a velocity dependent upon the strength of field, the initial potential, the number of turns, resistance, &c., of the armature, and the load, and a counter electro-motive force is set up which diminishes the armature-current. The higher the speed the greater this counter electro-motive force. Let E be the initial and e the counter electro-motive force, and r the resistance of the armature. The current flowing in the armature is then $\frac{E-e}{r}$. With a given armature and given field, e varies with the speed. Now, the power at any given speed and strength of field varies with the current, and with any given current varies with the strength of field. The total work done is the product of the speed by the work per turn, and since the speed is as e and the work per turn as the current $\left(\frac{E-e}{r}\right)$, the total work done is expressed by $\frac{e(E-e)}{r}$. The efficiency is the ratio $\frac{e}{E}$. It will be seen that both these expressions—the total work done and the efficiency—are independent of any function of the field, but depend only on the initial and counter electro-motive forces and the resistance of the armature, and any given value of e can be attained with any strength of field by attaining proper speed. Suppose the motor doing a certain amount of work at a certain speed. If $e=\frac{E}{2}$, armature-current is $\frac{E}{2r}$ and work done $\frac{E^2}{4r}$. Now, let the speed be increased one-half by diminishing the mechanical work per turn, the field remaining the same. e now equals $\frac{3}{4}E$, current is $\frac{E}{4r}$, and work done $\frac{3E^2}{16r}$, which is less than before with same field. Let the original field

figure 4. The first page of the Sprague regulator for electro-dynamic motors patent, U.S. patent 313,247, issued to Sprague on 3 March 1885. (Image courtesy of John L. Sprague.)

developed the first dynamo, where one or more wire coils rotating in a magnetic field created an alternating electric current in each one. When the ends of the coils were connected to terminals, electrical circuits could be designed such that a direct current was created. Rapidly improved upon by scientists around the world, in 1870 Belgium-born Frenchman Zénobie T. Gramme demonstrated the first truly practical continuous current self-exciting dynamo-electric machine. Then in 1873 at the Munich Exhibition, Gramme and Hippolyte Fontaine of France stunned the rest of the world by jointly demonstrating what was called "reversibility of function." Using one dynamo to generate electricity and a second one to transform this electricity back into mechanical power, they laid the foundation for all modern electric power transmission.

Now there was a practical replacement for storage batteries, and only 42 years after Faraday's initial observation, an explosion of activity to improve control of motors and dynamos began, including Sprague's inverted dynamo design. Surprisingly, while nine years later at the 1882 London Crystal Palace Electrical Exposition there were numerous exhibits of different power-generating dynamos, there were still no practical electric motors. This was because up to that point none could maintain constant power under a changing load. An electric motor-driven railway engine pulling a load up a hill slowed down while just the reverse occurred on a downgrade. While this was impractical, it could become exciting, especially down a steep grade. Sprague and others were about to change this.

The Self-Regulating Nonsparking dc Electric Motor

The dc electric motor field that Sprague and SERM were entering in the early 1880s was already crowded, with major players such as Edison, Siemens, Esmond, and Deprez. Former furniture manufacturer Thomas J. Van Depoele was especially prolific with some 243 issued patents between 1881 and 1894, with the majority covering inventions in electric motors and electric railway transportation. It is impossible to directly compare all the competitive patent claims with those of Sprague since many are almost identical. However, the patent content is dramatically different. As we shall see, rather than hide exactly how his motors worked, in many of his patents Sprague reveled in supplying detailed information that he referred to as "Sprague laws." Since his years at Annapolis, Sprague had repeatedly argued that almost any action in the electrical field, or any other technical field for that matter, could be explained using scientific first principles; hence the beginning of his laws.

Reviewing his patent notebooks provides fascinating insight into how his mind worked and the process involved in the development of his self-regulating dc electric motor, a process that took place almost entirely in 1884. In one notebook entry he describes the derivation of a series of "Sprague laws" that interrelate E (initial emf), e (counter emf), m (magnetic moment of the main shunt coil), and u (magnetic moment of the differential series coil). Several examples of specific laws are shown in the patent discussions that follow. In a notebook discussion of self-regulation of one of his motors, one finds an entry headed "Suggestion," which proposes

> We know that to get a constant current with a variable external resistance (R or load) in a dynamo-electric generator, and to get a constant speed with constant potential in a motor with varying load, it is necessary to have identically the same windings (in each). If so, it is probable that if a dynamo generator can be wound to give a constant potential at its terminals under a varying external load, if it is then used as a motor it will maintain a constant speed under constant current with varying loads. So we'll first try the generator ….

Pages of calculations, curves, circuit diagrams, and measurements follow.

This is a perfect example of how his mind worked in solving complex problems such as creating a constant speed motor. Using first principles and prior experience, he developed a theory or law. He then went about making dynamos or motors according to the law, measured their performance, and modified the theory as necessary. As we shall see, development of his self-regulating nonsparking dc motor was an iterative process covering a little over a year.

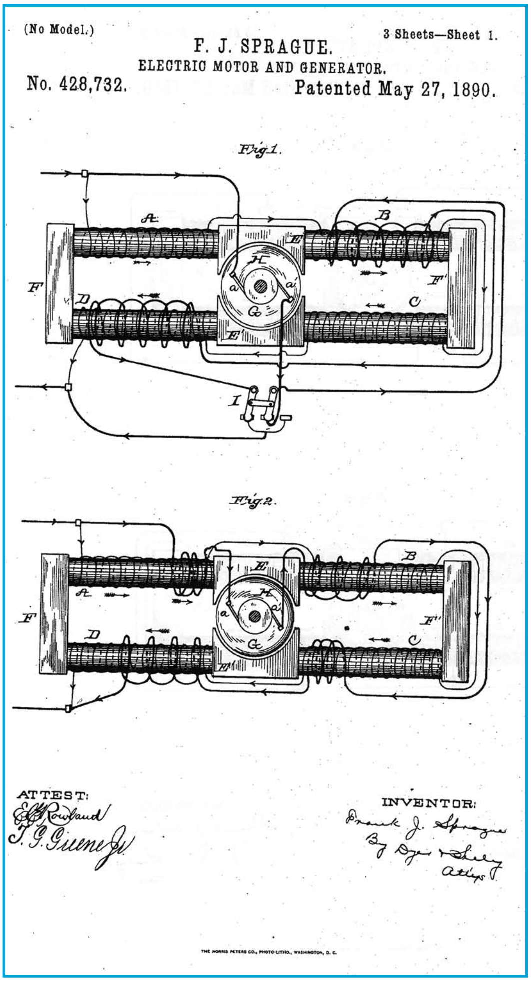


figure 5. A drawing for the Sprague electric motor and generator patent U.S. Patent 428,732, issued to Sprague on 27 May 1890. (Photo courtesy of John L. Sprague.)

Key Sprague dc Motor Patents

Of his some 30 electric motor patents, the following are some of the most important ones related to this motor. U.S. Patent 295,454, "Electro-Dynamic Motor," was filed 2 May 1883 and issued 18 March 1884. Following steam engine practice, speed control is maintained "using a mechanical centrifugal governor attached to the axle of the armature which, as speed of rotation changes with varying loads, through a secondary apparatus, changes the position of the switch that controls the relation of the armature and field circuits in such a way as to compensate for changes in the axle rotation" (see Figure 3). Sprague was never very happy with it because it was mechanical, crude, and above all, inelegant. But it worked and was a start.

U.S. Patent 313,247, "Regulator for Electro-Dynamic Motor," was filed 21 February 1884 as an improvement on U.S. Patent 295,454. The mechanical regulator is still present, but the motor control is improved by adding a small auxiliary motor between the governor and the commutator switch. Also, for the first time there is a "Sprague law" describing how the control system works. An excerpt of the law is shown in Figure 4. It theorizes that in a motor with armature and field coils in shunt relationship, power, economy, and efficiency depend upon the initial and

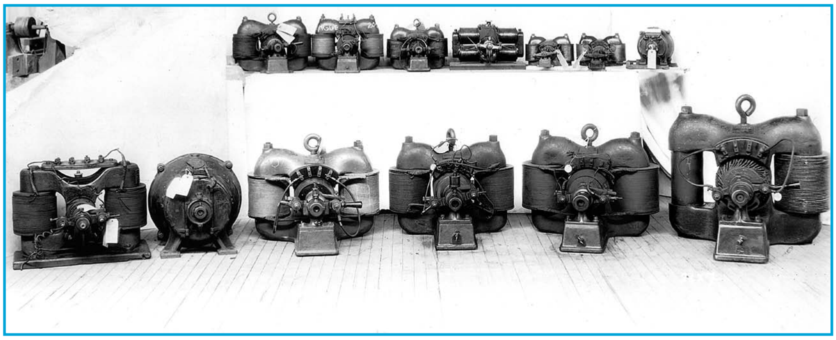


figure 6. A group of constant-speed motors manufactured by the Sprague Electric Railroad and Motor company, circa 1884. (Photo courtesy of John L. Sprague.)

counter emfs and the resistance of the armature. Speed and/or power can be increased by weakening the magnetic field and decreased by strengthening it.

The pace of filing and complexity of the motor accelerated with U.S. Patent 315,179, "Electro Dynamic Motor," filed 30 April 1884 and issued 7 April 1885. To improve speed and power regulation even further, a second centrifugal governor is added to modify the electric field of an additional series of field coils. And for the first time, Sprague addresses the problem of automatic regulation of the brush position to minimize sparking by adding a solenoid in the armature circuit as a control device.

Frustrated by the complexity of the latest version and by still having to use a mechanical centrifugal governor to move switches, he rationalized that, since a change in load causes changes in the current flow and magnetic effects in a motor, the motor could be designed such that these changes are automatically compensated within the motor itself. Using intuition, detailed analysis, and experimentation, he was finally able to determine the required relationships between the motor's different magnetic windings for self-regulation. So on 19 July 1884, Sprague filed U.S. Patent 315,181, "Electric Motor and Generator." Issued 7 April 1885, this patent contains the most complex and important of his laws. For what he refers to as a "differential" motor (one with two sets of field coils, the so-called "governing coil" in series with the armature and the second shunting the armature) the law states that, "if the number of turns in the shunt coil bears the same ratio to the number of turns in the series coil as the resistance of the shunt coil bears to the sum of the resistances of the series coil and the armature, then the motor will be perfectly self-regulating." Other configurations are also discussed. The earlier cumbersome centrifugal governors and their auxiliary motors are gone, and the control device for self-regulation of speed and power is a simple solenoid in the armature circuit.

Filed 19 July 1884, the same date as U.S. Patent 315,181 (but because of extensive patent interference actions not issued until 27 May 1890), U.S. Patent 428,732, "Electric Motor and Generator," closed the loop, covering the last link in the truly self-regulating nonsparking dc electric motor (see Figure 5). The design of the motor is such that, rather than automatically shifting the nonsparking point as the load changes, the position of the nonsparking points is always the same so that the position of the brushes never has to be changed. Simple and elegant, the motor has field-magnet cores extending in different directions from the pole pieces, on one set of which there are uniform windings, while the other set is wound so that it exerts a greater influence on diagonally opposite parts of the magnet than it does on other parts. As a result, a compensating force is generated as the main magnetic field changes, and the nonsparking point remains stationary.

SERM

In the fall of 1884, SERM's new constant-speed motors (see Figure 6) were introduced at the International

Electrical Exhibition in Philadelphia, Pennsylvania, to almost uniformly rave reviews, including a particularly handsome one from an unexpected source, Thomas Edison. The "Wizard" applauded, saying, "A young man named Sprague, who resigned his position as an officer in our Navy to devote himself to electrical studies, has worked the matter up in a very remarkable way. His is the only true motor; the others are but dynamos turned into motors. His machine keeps the same rate of speed all the time, and does not vary with the amount of work done, as the others do." But as Sprague soon learned, inevitably each new application required major redesign of his motors, especially when used in the demanding weather environment of rail transportation.

figure 7. An example of the steep and muddy grades on which the Richmond City Railway had to operate, circa 1888. (Photo courtesy of John L. Sprague.)

Somehow during this flurry of activity, Sprague met, wooed, and, in the spring of 1885, married a beautiful southern belle named Mary Keatinge. Over time she was unable to deal with Frank's frantic work habits, and they were amicably divorced in 1895. Their only child, Desmond, was born in 1888 and grew up to become a fine Cornell-trained engineer. He worked for his father on several projects, including MU train control when he was only ten, and of Frank's three sons by two marriages, Desmond was his favorite.

Richmond, Virginia

After repeated failures in trying to interest New York City's Manhattan Elevated Railroad to use his new motors, in the spring of 1887 SERM signed a seemingly impossible contract to electrify Richmond's 12-mi (19.3-km) horse-drawn street railway, a system with up to 10% grades, tight turns, and an uncertain muddy track (see Figure 7). Further, SERM had to accomplish this electrification within 90 days. Sprague brought his new motors, the concept of an overhead "trolley" source of power, a new "wheelbarrow" motor truck design (see Figure 8), (which is used to this day on street railways, elevated

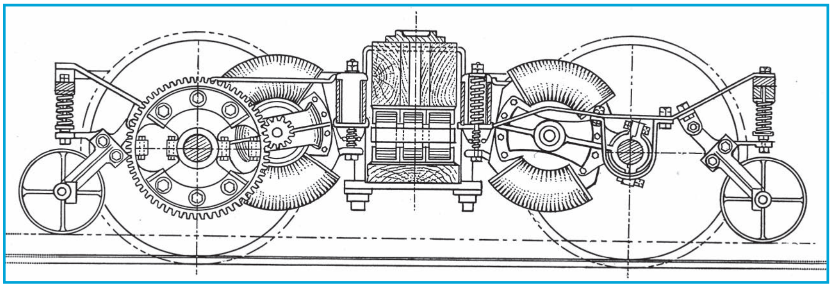


figure 8. A drawing of the Sprague "wheelbarrow" dc railway motor truck design. (Image courtesy of John L. Sprague.)

railways, and other urban rail systems), a small but extremely talented team, his own indomitable spirit and skills, but no experience whatsoever in executing a project of this magnitude.

It was a nightmare from the start and financial disaster when completed (although sales in the motor part of the enterprise kept SERM from bankruptcy); his beautiful motors kept burning out, commutators pitted and failed, and brushes had to be continually changed (until carbon finally replaced a variety of different metals and alloys). Still, he and his team prevailed, and when the contract completion was finally accepted by the city of Richmond in mid-May 1888, Sprague and SERM had done the seemingly impossible. Not only had they completed the world's first commercially successful electric street railway system, they had started a worldwide revolution in urban transportation. By 1890 there were more than 200 trolley lines running or being built in the United States, either by or under license to SERM. The Richmond City Railway was named an IEEE Milestone in Electrical Engineering in 1992, having been nominated by the IEEE Richmond Section.

Edison General Electric, Thompson-Houston, and General Electric

The euphoria of success lasted only briefly given the realities of the marketplace. Undercapitalized SERM soon found itself facing heavy competition from Edison General Electric (EGE), Westinghouse, and a relative newcomer, Thomson-Houston (T-H, after founders Elihu Thomson and Edwin J. Houston) of Lynn, Massachusetts. T-H was headed by tough, aggressive Charles Coffin. Forced to sell SERM to EGE in late 1889, only a year and a half after success in Richmond, Sprague found himself reduced to a consultancy and a relative outsider in his own company. Thomas Edison's earlier brief support had long since evaporated, and he did everything he could to both undermine Sprague's influence and attack his reputation. Ever the self-promoter, Edison always had difficulty in sharing credit with others. His final insults included threatening to replace the overhead trolley in street railways with his own impractical pet idea of taking power from the rails, and, even worse, he ordered removal of the Sprague name from any equipment manufactured by EGE.

Then in an ironic twist of fate, when, in the spring of 1892, T-H purchased EGE, the merged company was renamed simply General Electric (GE), leaving out the Edison name and much of the famous inventor's influence. But by then, having resigned in June 1890 to seek other opportunities for his beloved motors, Sprague was on a new, exciting vertical track.

Sprague Electric Elevator Company

As far back as 1884, a Sprague stationary electric motor had been used to power a freight elevator in the Pemberton Mills in Lawrence, Massachusetts, believed to be the first practical everyday electric elevator in the world. However, when Sprague, Charles Pratt, and Ed Johnson incorporated the Sprague Electric Elevator Company (SEEC) in November 1891, it was to capitalize on Pratt's unique screw-type elevator that was suffering a variety of problems, including burnt-out motors.

At Sprague's suggestion, cast iron grids (resistors in the motor control system) solved the motor problem and, throwing caution to the winds, in October 1891, SEEC signed a contract to install two express and four local elevators in New York City's new 14-story Postal Telegraph Building (see Figure 9). The terms were even more onerous than the Richmond contract and included guaranteed performance superior to that of well-established hydraulic companies, such as Otis, at a fraction of the cost. During construction, Sprague continued to improve the motors and designed most of the control systems, including one for control of multiple elevators from a single location, the forerunner of his MU control system. The Postal Telegraph installation was successfully completed in April 1894, and others followed. But by the end of 1898, the elevator interests of SEEC had been sold to Otis so that Sprague could concentrate on the Sprague Electric Company (SEC), incorporated in the spring of 1898 to capitalize on the MU train control system.

The MU Train Control System

As urban railway systems began to use electricity for their motive power, the impracticality of using locomotives dictated that distributed power was required. But how to control this distributed power from single different locations throughout the train remained the key unsolved problem. Sprague was the first to intuit it (in the Postal Telegraph Building elevator installation) and first to install a successful operating system, in 1887 in Chicago's "Alley L" elevated railway. Westinghouse and especially GE soon offered competitive approaches, but Sprague's superb

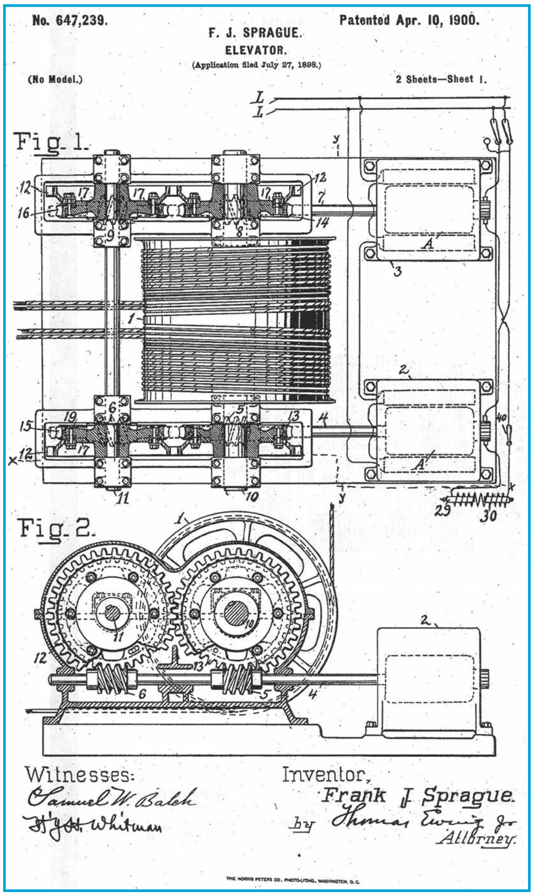


figure 9. A drawing for the Sprague screw-type elevator patent U.S. Patent 647,239, issued to Sprague on 10 April 1900. (Image courtesy of John L. Sprague.)

U.S. Patent 660,065 prevailed, forcing GE's combative president, Charles Coffin, to acquire Sprague Electric in May 1902. In the process, Sprague received a consultancy until 1918, which was then renewed, and became a wealthy man.

At almost the same time as this dramatic change in his professional life, his personal life took a new and decidedly improved direction when, in October 1899, he married Harriet C. Jones. She was 20 years his junior, and, while fascinated by his technical world, she also added a whole new dimension to his character, including bringing him into an entirely different social world that included such luminaries as Samuel Clemens (Mark Twain). There was a new summer home in Sharon, Connecticut, more travel together, and three more children, Robert, Julian, and Althea. Robert would go on to found the next Sprague Electric Company, a highly successful manufacturer of electronic components. But Sprague was not about to retire in his mid-40s.

Moving On

While the sale of his MU control systems company marked the high point of his professional life, Sprague was anything but marginalized. He started more companies: Sprague Safety Control and Signal Corporation (1906), Standard Third Rail Company with William Wilgus (1907), and Sprague Signs, Inc. (1929). While none were a commercial success, he always maintained that the Safety Company was some of his best work.

Sprague served as a key member of the Electric Traction Commission that planned the electrification of Grand Central Terminal in the early 20th century and during World War I served on the Naval Advisory Board chaired by Thomas Edison. May 1913 entries in the Sprague guest book, made when Edison and his second wife, Mina, visited Sprague and his wife Harriet in New York City, hint at the complexity of the relationship: *Edison:* Everything comes to those who hustle while they wait. *Mina:* It is only the great hearted who can be true friends. The mean, the cowardly can never know what true friendship means.

Still, if the two men maintained some form of a limited truce during this service,

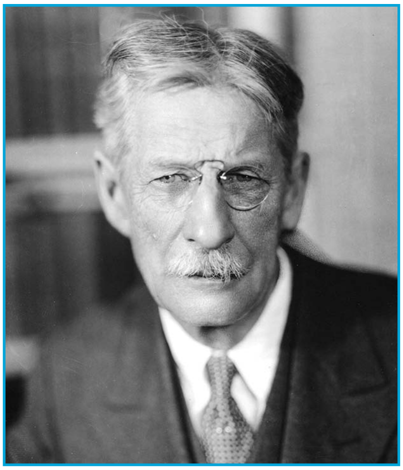


figure 10. Frank J. Sprague on his 75th birthday, 25 July 1932. (Photo courtesy of John L. Sprague.)

they were at it again after the war. Following an interview with Edison, a 10 August 1919 *New York Sun* article credited him with the invention of the street railway system. Recalling his Richmond success, a furious Sprague replied, "Neither of us invented the dynamo-electric machine, whether used as a generator or motor, and except that both were founded on basic principles developed by others, there was no more similarity between the Edison dynamo and the Sprague motor than between a brindle pup and a greyhound." It should be noted that, while Sprague is often found arguing about words someone else has credited to Edison, the "Wizard" seldom, if ever, took issue with their validity.

Another view on where credit is due can be found in a letter T-H cofounder Elihu Thomson wrote in May 1932 to Sprague for the 25 July 1932 celebration of Sprague's 75th birthday (see Figure 10). At the time, Thomson was director of the Thomson Research Laboratory of GE in Lynn, Massachusetts.

> My Dear Sprague,
>
> I remember well the time we first met at the Franklin Institute Electrical Exhibition in Philadelphia in the fall of 1884 when you explained the work in which you were engaged, in the design of advanced types of electrical motors

for direct current work. Now I have been more or less familiar with your subsequent work and career and take this occasion to emphasize the fact of its great importance, especially to the art of electric railway control and propulsion. I think it can be truly said that your trials of the trolley system in Richmond, Virginia were a definitive starting point in the development of trolley systems in the United States. Needless to say, the subsequent electrification of the whole of the street car lines itself followed and created a profound extension of the electric railway systems throughout the country.

Better than all this, I have appreciated our many years of acquaintance and friendship.

Very truly yours,
Elihu Thomson

When Sprague died of pneumonia on 25 October 1934, he richly deserved his mantle as the "father of electric traction."

For Further Reading

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