How the promising PCC car was prematurely derailed

The U.S. electric streetcar industry failed to reap the rewards of its 1930s research, aimed at producing a revolutionary trolley car

Oct. 1, 1936, dawned cool and damp in New York City, another unmemorable day in the Great Depression, except for one event that at first glance appeared to be routine. Mayor Fiorello H. La Guardia snipped a blue ribbon strung across a section of trolley tracks at the Manhattan end of the Brooklyn Bridge to mark the start of service by a new generation of streetcars—the PCC car.

The PCC streetcar, so named because it was the product of a research team formed by the Presidents Conference Committee of the American Electric Railway Association, was the world's first trolley designed under the probing, patient system known as the scientific method. It took five years to develop.

At first the new vehicle was a hit; passengers liked its smoother ride and responded with increased patronage. About 5000 PCC cars were built in the United States over the next 16 years. But political and financial pressures slowly brought the U.S. streetcar industry to its knees. And in the end the PCC streetcar could not overcome its biggest obstacle: the U.S. public's new love affair with the automobile.

Today, except for historical references, the PCC is a forgotten vehicle in the United States [Fig. 1]; it remains uncommemorated in the annals of mass transportation. In Europe, however, variations on the basic PCC car continue to carry millions of passengers every day.

A streetcar not desired

The heyday of the U.S. streetcar spanned three decades: from the 1890s until the 1920s. By the early 1920s, however, much of the equipment was nearing obsolescence. The cars were uncomfortable; they clattered, lurched, and made their starts and stops in a series of frenetic jerks that tested the resilience of the human spine. Of the fleet of roughly 74 000 electric railway passenger cars operating in the country at that time, half were more than 20 years old [see "From shake, rattle, and jolt to smooth riding," p. 50]. As service became unreliable, the profits of streetcar manufacturers and operators began to slip.

The American Electric Railway Association, a group of executives from the major companies in the business, tackled the problem head-on at its 1929 convention in Atlantic City, N.J. The convention directed Charles Gordon and Thomas Conway Jr., as a "committee of two," to plan a research effort aimed at improving the trolley car. Gordon was managing director of the association, and Conway had already built a reputation for rescuing failing electric railroad companies. Several months later, the association's advisory council met in Chicago and approved the plan drafted by Conway and Gordon.

It called for the formation of the Electric Railway Presidents Conference Committee, which ultimately included representatives of almost all the major players in the U.S. streetcar industry—28 electric railway operating companies and 25 manufacturing companies. The goal was to develop a new streetcar to pull the industry out of its doldrums. Each participating company agreed to put up a percentage of the funds for research. In all, $630 000 was subscribed—a modest sum for building a large research program from the ground up.

The first major step by the presidents committee was to appoint Clarence F. Hirshfeld, then head of research at the Detroit Edison Co., as chief engineer of the program. Hirshfeld had not worked with an electric railway system before, but his background included electrical and mechanical engineering and extensive research experience in industry. Together, Conway and Hirshfeld devoted a year to "planning the details of an elaborate scientific investigation," Conway told an audience at the 1931 convention of the railway association.

"The scientific method permits no shortcuts," he said. "It is like the siege of a great fortress which goes on grimly and remorselessly day and night over a long period of time, the victory being attained, if at all, as the culmination of a carefully planned and executed campaign."

Scaling the fortress walls

Although the presidents committee aimed to create a more comfortable streetcar, Hirshfeld pointed out in the first bulletin published by the group: "We speak rather glibly of riding quality and attempt to judge by personal sensations between the virtues of different cars" yet "we do not know what a human being finds comfortable and uncomfortable respectively, and we do not know how to produce with certainty what we now call good riding qualities."

To quantify "comfort," the committee funded two studies, one at the University of Michigan and another at Purdue University. The first determined the optimum acceleration for starting a streetcar with the least discomfort to standing passengers. For the first time, it was recognized that such discomfort resulted from the rate of change in the rate of acceleration. The second study analyzed the range of vibrations that passengers could tolerate.

As the university investigators explored what conditions made a ride comfortable, a 30-man research team commanded by Hirshfeld began an analysis and test program at laboratories in Brooklyn, made available by the Brooklyn & Queens Transit Corp. The research group had four basic goals:

- To develop a radically new control and braking apparatus for smooth and rapid starts and stops.
- To design a new assembly for the motor and wheels (called the truck) using rubber connections, instead of metal ones, between the truck and the car body.
- To develop the essential features of a resilient wheel.
- To design the essential features of an attractive, comfortable, modern car body.

The Brooklyn program ran from 1931 to 1936. One of the first

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Fred W. Schneider 3rd

[1] New York Mayor Fiorello H. La Guardia cut the ceremonial ribbon at the Manhattan end of the Brooklyn Bridge in 1936 to inaugurate service by PCC streetcars.

steps was to compile a list of the characteristics of existing streetcars. The research team recorded such details as car size and weight for more than 610 cars built by 14 different companies. With those data, the members sketched the characteristics of a composite car, including the best technology the industry could offer. With this idealized car as a guide, the team selected four relatively new streetcars for experiments on ventilation, lighting, vibration, acceleration, and braking.

Acceleration and braking tests, for example, were run at night on the Gravesend Avenue (now MacDonald Avenue) line in Brooklyn. A crew in an experimental car would follow the last scheduled car in service at 10:00 p.m. and would return ahead of the first car in service the next day, around 5:00 a.m. Since 2 hours were needed to get ready for the testing and 2 more to clean up in the morning, the crew worked about 11 hours each shift.

Executing the battle plan

The research team created two prototype streetcar trucks and a set of specifications for a motor controller. The Westinghouse Electric & Manufacturing Co. and the General Electric Co. each developed a motor controller that matched the researchers' criteria. The control technology they developed may have been the greatest electrotechnical contribution of the program.

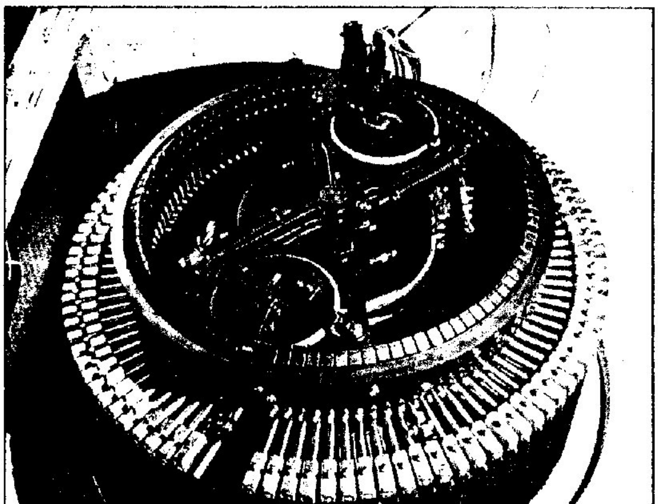
Before this, motor control had been achieved by a nonautomatic system introduced in 1888 by Frank J. Sprague, who later founded Sprague Electric. This system was still in use on most streetcars in the 1920s. It had eight or nine predetermined acceleration steps, but only two—full and half speed—could be used for long periods. An air brake valve adjusted the air pressure through pipes and cylinders for deceleration. Since both acceleration and braking were done manually, the result was a jerky ride, even with an experienced motorman operating the controls.

To meet the performance criteria established for the PCC car, Westinghouse and General Electric turned to an existing, though previously uneconomical, technology: the rheostat.

Rheostats changed the resistance of the motor circuit by removing or inserting wire coils, or metal resistors, into the circuit to control the current to the motor. The rheostat wasted much electric power dissipated by the resistors in the form of heat. Consequently, it had not been deemed economical to use the rheostat for heavy loads.

The rheostatic control for the PCC car, however, could provide many resistance steps and thus precisely maintain the desired current value during acceleration and braking, to provide a smoother ride. Consequently, although rheostatic control tended to be more costly than traditional motor controls, it was the only technology that would enable the manufacturers to meet the specifications laid out by the research team.

General Electric's controller was marketed under the trade name Floating Control. It had a stationary commutator divided by notches into segments that were connected to resistors. An air engine drove a brush arm that rotated around the commutator and cut out resistance as it passed from one notched section to the next. One continuous movement of the brush arm over the commutator surface cut out 130 sections of resistance. In this scheme, however, the commutator resistance was used twice during the acceleration or braking cycle, providing 260 steps. In later models, the air engine was replaced by an electric motor.



Westinghouse Transportation Division

[2] The accelerator devised by Westinghouse Electric & Manufacturing Co. was the most widely used motor control in PCC streetcars. It was based on a rheostatic mechanism and provided smooth acceleration and braking. Resistors were mounted along the outside edge of the drum. Ninety-nine spring-mounted fingers, or buttons, lined the inside of the drum and were electrically connected to the resistors. In the middle of the drum was a rotating arm with rollers at each end. The rollers pressed on the buttons, activating and deactivating specific resistors. The arm and rollers were powered by a 32-volt electric motor.

The most widely used controller, however, was Westinghouse Electric's ABS Accelerator. The heart of this new control was a drum-shaped accelerator [Fig. 2]. Some Westinghouse accelerators had more than 100 speeds.

The PCC car achieved smoother braking through a combination of three mechanisms. Primary braking power was supplied by the car's electric motors, in a system called dynamic braking. Air-activated friction brakes, used as the principal brake prior to the PCC car, became the secondary braking mechanism, aided by magnetic track brakes, which brought the car to a halt.

The three braking mechanisms operated together. The motorman selected the rate of deceleration; the equipment determined when each system was activated.

Dynamic braking was based on the principle that a motor can act as a generator when its shaft is mechanically rotated. When the motorman pressed his foot on the brake pedal, the motor shut off. Resistance was then placed across the motor circuit, absorbing energy and slowing the wheels.

At approximately 10 miles an hour, the air-operated friction brake took over. When the car reached approximately 2 miles per hour, the magnetic track brake brought the car to a halt.

The PCC car's brake design changed over the next few years. Eventually the magnetic brake was used only as an emergency holding brake. With the introduction of the "all electric car" in St. Louis in 1939, the air friction brake was abandoned, being replaced by an electric braking system.

By 1934 the work was winding down. The new rheostatic control was paired with the smoother braking mechanisms, the car motor was lighter and more efficient, the truck was redesigned to shield the passengers from vibration (in part by use of rubber springs), and the car body was redesigned with comfortable seats, improved ventilation, and better internal lighting.

Five years after the start of the research program, four PCC cars were displayed at the 1934 convention of the American Electric Railway Association.

Winning the battle

The work of the Presidents Conference Committee was not yet over, however. Selling the car was the next task. The Brooklyn & Queens Transit Corp. placed the first order, for 100 PCC cars, with the St. Louis Car Co. in June 1935. After the transit company began regular service with the PCC cars in October 1936, revenues went up. In Brooklyn, for example, gross revenues on the Smith-Coney Island line increased 33 percent from the introduction of the new trolleys in October 1936 to September 1937.

The new cars reduced travel time by 14 percent in comparison with the old cars on the same line, and since they could also carry more passengers, fewer cars were needed. The traveling public was also impressed with the comfort of the cars. Eventually about 25 U.S. cities were using PCC streetcars.

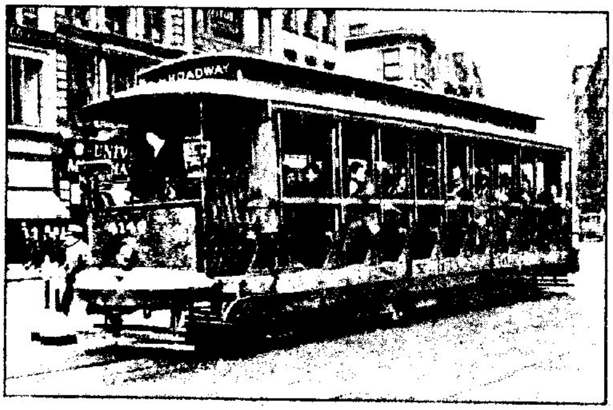
Its work finished, the Presidents Conference Committee disbanded and transferred its assets to the Transit Research Corp., incorporated in New York City on Nov. 22, 1935. This nonprofit company intended to continue research and development of the PCC car with funds from patent royalties and licensing agreements acquired from the presidents committee.

The onslaught of World War II, however, diverted work from nonmilitary activities, including the PCC. Although some research continued, the main concern of the nonprofit firm was to maintain the PCC streetcars serving wartime centers, like the Brooklyn Navy Yard, and to develop substitutes for products, such as rubber, that were critical to the war.

New York jumps the tracks

The PCC cars were also running into nontechnical problems. In the 1920s the U.S. government had decided to put much effort

From shake, rattle, and jolt to smooth riding



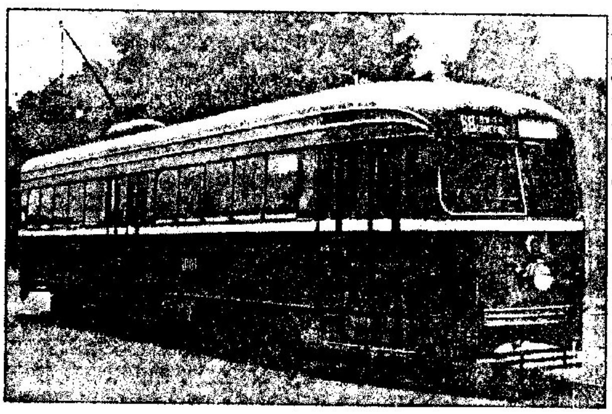
Charles Duncan

Typical pre-PCC car

Average acceleration rate	0.5 to 1.0 mph/s
Average braking rate	1.5 mph/s
Maximum operating speed	20 mph
Length	37 feet
Width (measured from the outside edges)	7.5 feet
Weight (unloaded)	29 000 pounds
Seating capacity	40 people

Before the advent of the PCC streetcar—a vehicle commissioned by the Presidents Conference Committee of the U.S. electric railway industry—trolleys used to shake, rattle, and jolt their passengers. Acceleration hinged on nine predetermined steps of the motor, of which only two could be used for long stretches.

In 1935 the New York Railway Corp. was operating a fleet of such archaic streetcars in Manhattan.



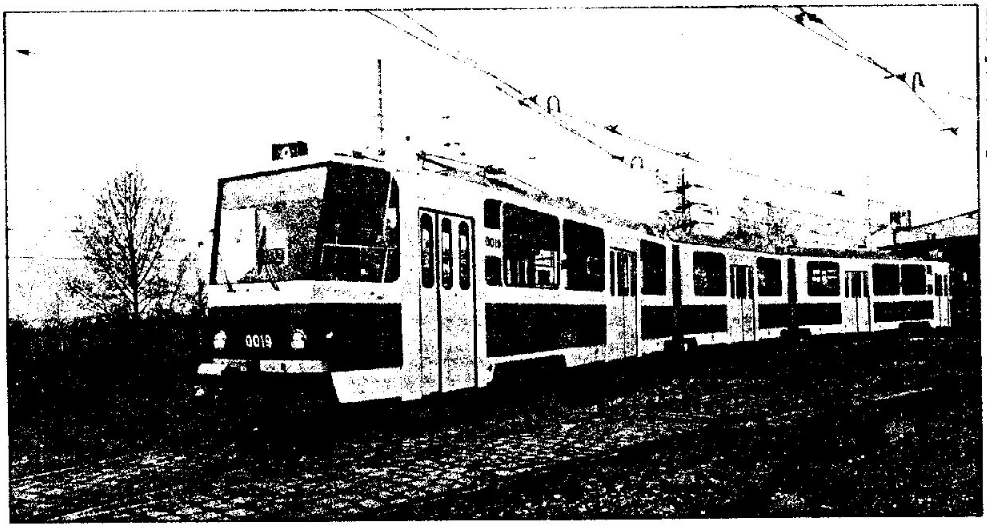
Donald Harold Collection

First PCC car

Average acceleration rate	4.00 mph/s
Maximum acceleration rate	4.75 mph/s
Service braking rate	4.75 mph/s
Maximum braking rate	9.00 mph/s
Maximum safe operating speed	50 mph
Length	46 feet
Width (measured from the outside edges)	8.28 feet
Weight (unloaded)	33 360 pounds
Seating capacity	60 people

The first PCC car put into service in New York City was a vast improvement. Designated car No. 1001 by the Brooklyn & Queens Transit Corp., it ran on the Smith-Coney Island line in Brooklyn, N.Y. The key to the PCC trolley's smoother ride was rheostatic control of the motors.

The tables here compare the performance of the PCC and an older streetcar under good track conditions.



Czechoslovak Embassy

[3] In Czechoslovakia, the most modern streetcar in use today—the No. 0019 car built by CKD Tatra Smichov Works in Prague—is a derivative of the PCC. Tatra signed a licensing agreement with the Transit Research Corp. in the United States in 1947 to use the PCC design. Four prototype cars were completed in 1951. By the end of 1984, Tatra had exported over 15 850 streetcars, primarily to the Soviet Union and other Eastern European countries.

into creating a national highway network. A family of industries, including cement, gasoline, and car manufacturing, were encouraging the construction of highways and the abandonment of streetcars.

In New York City, where almost 40 percent of the streetcar market was concentrated, there was growing sentiment against the trolley for a variety of economic and political reasons. Public transportation in New York primarily consisted of subway lines, elevated railways—or Els—and streetcar lines operated by various companies. In early 1938 the Brooklyn & Queens Transit Corp., the first company to buy PCC cars, applied to the Federal Reconstruction Finance Corp. for a loan to buy 500 more. In May 1938 the Federal agency made a conditional commitment of $5.6 million to cover 70 percent of the cost.

But city officials had already decided to unify the subway lines and to end the El and streetcar operations. On Sept. 27, 1938, the Reconstruction Finance Corp. issued a press released that stated: "Upon receipt of a copy of Mayor La Guardia's letter of July 26th to W.S. Menden, president of Brooklyn & Queens Transit Corp., which stated that the purchase of the cars did not meet with the approval of the city, the commitment was canceled."

PCC cars continued to run in the city until the mid-1950s, when their gradual replacement by buses was completed.

In other cities financial speculators moved in to take over faltering streetcar companies. One notorious example after World War II was the fiscal manipulation of assets of the Twin City Rapid Transit Co. in Minneapolis-St. Paul by a new management. In the hope of making a fast dollar, the management liquidated the company's street railway plant. The action resulted in criminal prosecution and prison for a principal in the scheme, but this came too late to preserve the company's assets.

In the 16 years during which PCC streetcars were manufactured in the United States, the basic vehicle was continuously refined. But by 1959 the Transit Research Corp. finally halted all work to develop the car more fully.

Although the PCC car largely disappeared from the U.S. streets, Europeans picked up the technology and built nearly 30 000 PCC cars under license from the Transit Research Corp. Italy's Cia. Generale di Elettricita of Milan (a subsidiary of the U.S. General Electric Co.) was the first non-U.S. licensee, completing its initial PCC car in 1942. By the 1950s, companies in Australia, Belgium, Czechoslovakia, Great Britain, Italy, Japan, Poland, and Spain were building streetcars based on the PCC design. Today the leading streetcar manufacturers in the world are BN Constructions Ferroviaires et Metalliques S.A. in Belgium and CKD Tatra Smichov Works in Czechoslovakia [Fig. 3], and their output bears the earmarks of PCC design. (The Presidents Conference Committee had anticipated refinements in the design.)

So, in a sense, the PCC trolley car never died. Changing political and financial conditions forced the U.S. industry to phase out the more capital-intensive rail systems used by the PCC car. But the research project that gave birth to the PCC succeeded in an industry where companies were unaccustomed to cooperating. And that research effort could serve as a model for any large-scale industry project.

To probe further

The Electric Railway Presidents Conference Committee published five bulletins between September 1931 and February 1933 that describe some of the research that preceded the PCC car. The bulletins are available at the Engineering Societies Library at 345 E. 47th St., New York, N.Y. 10017.

Another key library for transportation literature is the Municipal Reference Library of New York City. Many states have local museums on electric streetcars, including museums that are located in Old Lyme and Branford, Conn.; Kingston, N.Y.; Baltimore, Md.; Hopkins, Minn.; Boston, Mass.; Chicago, Ill.; and Rio Vista Junction, Calif.

Interurban Press, based in Glendale, Calif., has published several books on the PCC, including *PCC, The Car That Fought Back* (1980), by Stephen P. Carlson and Fred W. Schneider 3rd, and *An American Original: The PCC Car* (1986) by Seymour Kashin and Harre Demoro.

Finally, among the books covering the history of the last U.S.-built PCC car, is *From Horse Cars to Streamliners, an Illustrated History of the St. Louis Car Company*, by Alan R. Lind, Transport History Press, Forest Park, Ill., 1979.

About the authors

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Illustration on p. 48: from *An American Original: The PCC Car*, by Seymour Kashin and Harre Demoro.