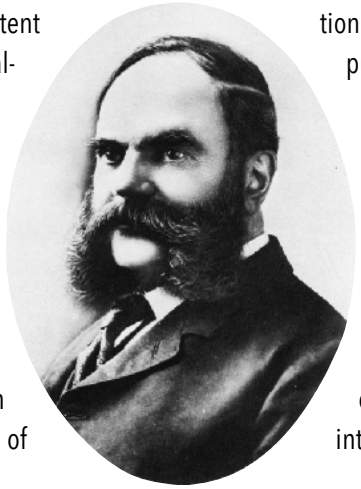
William Robinson and the track circuit

Description © 2022 by Jon R. Roma <jonroma@gmail.com>

A century and a half ago – August 20, 1872 – the United States Patent Office granted a patent 130,661 titled "Improvement in Electric Signaling Apparatus for Railroads." This prosaic description doesn't capture the essence of the invention described in the dry, technical description of the patent application.

The invention embodied in U. S. patent 130,661 was the track circuit – specifically the closed-circuit track circuit used worldwide today to provide train separation. In modern times, there are hundreds of different types of track circuits consisting of coded and non-coded DC and AC energy, some using insulated joints, and others jointless. Regardless of the specific technology used, every closed-circuit system of signaling can trace its ancestry to William Robinson's groundbreaking 1872 invention.



William Robinson, Ph.D.

Born November 22, 1840, County Tyrone, Ireland
Died January 2, 1921, Brooklyn, New York

On November 22, 1910, the third annual report of the Block Signal and Train Control Board to the Interstate Commerce Commission made the following statement:

> Perhaps no single invention in the history of the development of railway transportation has contributed more toward safety and despatch in that field than the track circuit. By this invention, simple in itself, the foundation was obtained for the development of practically every one of the intricate systems of railway block signaling in use today wherein the train is, under all conditions, continuously active in maintaining its own protection.
>
> In other words, the track circuit is today the only medium recognized as fundamentally safe by experts in railway signaling whereby a train or any part thereof may retain continuous and direct control of a block signal while occupying any portion of the track guarded by the signal.

The Signal Section of the American Railway Association, later the Association of American Railways, published a book describing and honoring Robinson's work in 1922, the year following his death. The signal section is now the Communications and Signals group of AREMA – the American Railway Engineering and Maintenance-of-Way Association.

The ARA history describes the track circuit as "the fundamental unit which made possible our present automatic block signaling and interlocking systems." To be sure, automatic block systems (ABS) and centralized traffic control (CTC) would be unknown without Robinson's pioneering work to develop and perfect the track circuit.

Even automatic train protection systems including subway trip stops, automatic train stop, and automatic train control systems depend on the "fundamental unit" invented by Robinson. Many positive train control or communications-based train control systems still depend on track circuits for train detection.

Early life

William Robinson was born in 1840 in the small town of Coalisland in County Tyrone, in what is now Northern Ireland. Details about his early life are skimpy, but he is believed to have immigrated to New York with his family at age 4. Robinson spent most of the remainder of his life as a resident of Brooklyn, which in 1898 would become a borough of New York City

Robinson obtained a Bachelor of Arts degree from Wesleyan University in Middletown, CT in 1865. Following his graduation, he was employed as school principal at various locations, while simultaneously working on a master's degree, again at Wesleyan. Robinson was also involved in the oil business in Pennsylvania.

The open circuit system

In 1867, a year short of finishing his master's degree, Robinson's attention was drawn to railroad accidents which lacked an effective means of prevention. He seized upon collisions caused by the era's inadequate means of separating trains from one another, and he began to conceive the idea of an automatic form of signal system to prevent these accidents.

Robinson's first train detection system was demonstrated using a model at an 1869 exposition. Like many of the other systems explored during this era, Robinson's initial scheme was an open circuit system; the wheels of a passing train actuated a treadle-like lever that closed a circuit.

This type of design mimicked the existing principles of manual block, wherein station staff would request by telegraph permission to forward a train to the next station, also reporting the train's arrival to the preceding station, to allow that station to request passage for a following train. In essence, what was being automated was the reporting of a train's arrival.

Robinson's early open circuit prototype worked roughly as follows: The arrival of a train at a short detection circuit at the station would cause a relay to energize. The relay would remain energized until released by the passage of the train over a second detection circuit located some distance beyond the initial detection circuit. This principle would today be called a "stick circuit," which describes a circuit that energizes a relay through one set of conditions, and causes that relay to "stick" in that position till another condition were satisfied, causing release.

Robinson sent leaflets describing his system to several railroad officers. One recipient who was intrigued was William A. Baldwin of the Philadelphia & Erie (later a part of the Pennsylvania Railroad). Baldwin, a former telegrapher had the vision to recognize the potential of Robinson's invention.

In 1870, Baldwin quickly arranged for Robinson to make a prototype installation on the Philadelphia & Erie, at Kinzua, PA. The town no longer exists: Around 1960, it was displaced by the building of a dam and reservoir.

Robinson's installation worked flawlessly, and pleased the officers of the Philadelphia & Erie. Nonetheless, Robinson wasn't satisfied: Being a harsh critic of his own work. Robinson found flaws in his design, which were also inherent to every other open-circuit type of train detection then known.

The first defect Robinson identified resulted from a common scenario in the days before the Janney coupler and automatic brakes – that of a break-in-two.

Robinson realized that the first part of a divided train's arrival at the second treadle would cause the circuit to be released, allowing a following train to receive a false "All Clear" indication in spite of the second portion of the train at a dead stop in the section.

Second, Robinson realized that his invention didn't protect trains operating in the opposite direction. Because they activated the respective treadles in the wrong sequence, they were not effective in preventing a collision on bidirectional track.

Third, Robinson observed that a battery failure, line wire break, or tampering would also cause a false "All Clear."

Recognizing this as unacceptable, Robinson moved quickly to to address these defects, and to meet what he felt were basic requirements of reliability. In doing so, Robinson implemented what we know now as the fail-safe principle – before that term had even been coined.

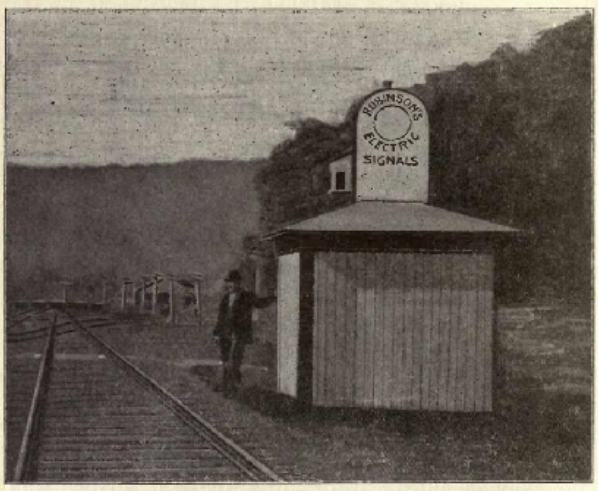
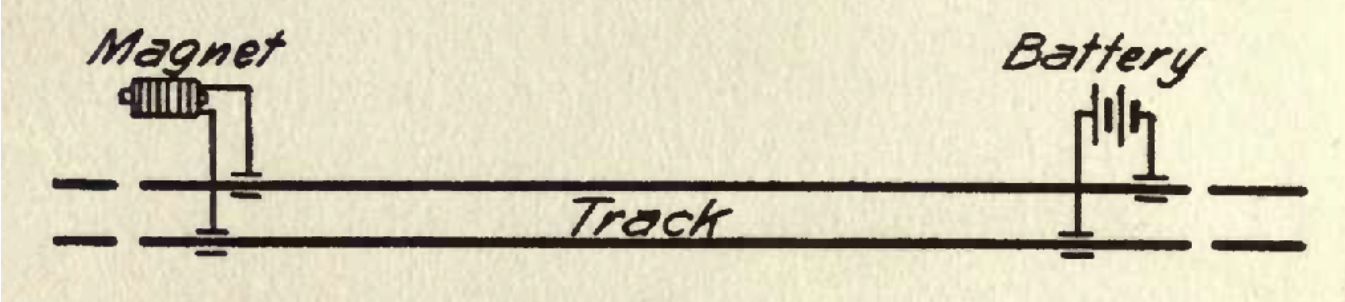


Fig. 1.
Robinson's Closed Rail Circuit System.
Philadelphia & Erie Railroad, 1872.

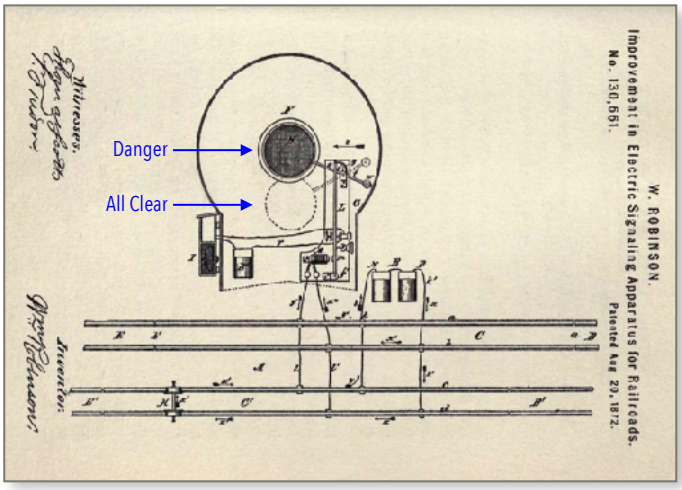


This drawing accompanied William Robinson's 1871 patent application. Patent rights were granted in France in February 1872, and in the United States in August of the same year. The apparatus labeled as "Magnet" is, of course, what we know today as a track relay. This drawing envisions traffic moving from left to right.

The closed circuit principle

Robinson decided that each and every pair of wheels in a train, acting on every inch of the section, must cause the controlling signal to display "Danger" (*Stop*). Furthermore, he reasoned that the signal should go to danger by gravity, and that only the presence of current should allow the signal to display "Safety" (*Proceed*).

He then set out to design and build such a system. Robinson applied for a patent, and made an exhibition of his new closed-circuit scheme for a track circuit at the state fair in Erie, PA in 1872. Robinson's demonstration rang a gong when the track circuit was occupied. The gong began ringing as soon as the train entered the signaled section, and ceased ringing as soon as the train was completely clear of the section. Of course, the audible signal was for demonstration purposes, but the same principle applies to controlling a visual signal.



With the encouragement of the Philadelphia & Erie's William Baldwin, Robinson made the fairly simple changes needed to convert the prototype installation at Kinzua from his original open-circuit design to the new closed-circuit design. Although the scheme worked as designed, Robinson discovered along the way that reliable operation depended on establishing a good electrical connection through the length of the prototype section, which was roughly one and a quarter mile long.

At this point, Robinson perceived the need for a means to make a reliable electrical connection through the length of the circuit. Thus was the familiar rail bond was born.

Robinson was asked by the Philadelphia & Erie to make a second installation of the closed track circuit system, this being placed in service at Irvineton, PA. This installation included a visual signal as well as a loud gong audible from anywhere on the train. The system included a bell indicator inside the depot, as well as a manual switch at the same location that allowed manually opening the circuit to set the signal to "Danger."

The Irvineton installation was so trustworthy in the eyes of the locomotive engineers that they nicknamed it "the old reliable."

How it works

Robinson's closed circuit system functions by dividing the railroad track into sections roughly a mile long, insulating the rails making up each section from the rails of adjacent sections. The terminals of a battery are connected, one per rail, at one end of the section. At the other end of a section,

a relay was likewise connected to both rails. Current therefore passed through the entire length of the section, energizing the relay within this closed circuit. This relay maintains the signal in its normally-closed position indicating "Safety" – meaning that a train can safely enter the section.

Once a train's wheels enter the section, the wheels and axles connect the two rails, short-circuiting the current from the relay, which de-energizes as a result. This in turn opens the signal control circuit, leading the signal to assume the "Danger" position.

The illustration accompanying the Robinson patent application showed an enclosed disc signal, but it should be evident that the system can be used with any kind of signal, be it electro-mechanical, electro-pneumatic, electrically-controlled gas, or light type signals.

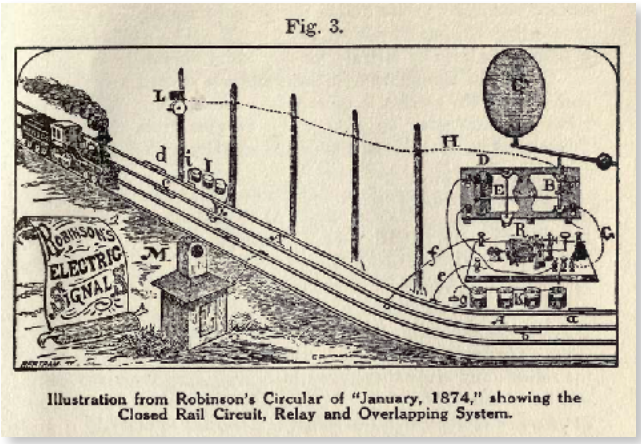


Illustration from Robinson's Circular of "January, 1874," showing the Closed Rail Circuit, Relay and Overlapping System.

Distant signals

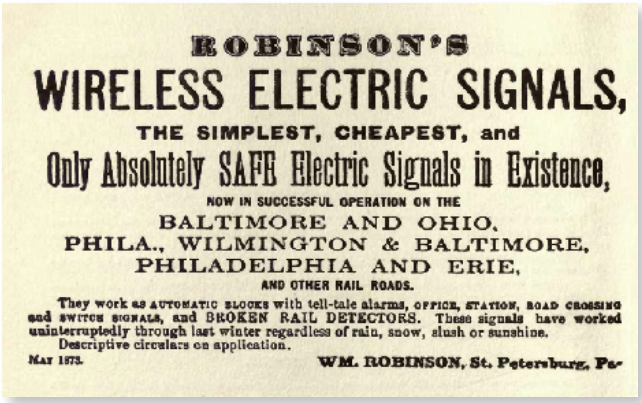
One of Robinson's early circulars (see illustration above) describes a so-called "overlapping" system. Home signal C is operated by the track relay R, and the overlapping or distant signal L is controlled directly by the position of the signal C through line circuit H. Again, Robinson followed the fail-safe principle. He described the behavior of these signals in the circular dated January 1874.

> When it is desired to operate a secondary signal … a line wire H is used, attached to the primary signal C in such a way that the secondary signal cannot possibly operate unless the primary signal C is first exposed, thus closing circuit on the wire H.

In this instance, exposing the signal refers to the withdrawal of the red cloth disc from the signal's aperture, which produces an "All Clear" (*Proceed*) indication. Robinson's description is significant: The distant signal is prevented from displaying "All Clear" until the home signal has been proved to be displaying the same indication.

This foreshadows the principle of indication locking, whose function is to protect against mechanical or electrical failure. Indication locking requires that a device be proved to be in the intended position before other dependent devices are permitted to operate. In this instance, the operation of the distant signal is controlled not simply by the state of the track circuit, *but by the position of the home signal itself*.

It is striking that Robinson had the intuition to grasp this concept in the infancy of electrical signaling. This realization is an indication of genius: Long before mechanical interlocking gave way to relay-based logic, Robinson understood the essentials that needed to be part of electric signaling. He got it right, and he did so at the very beginning.


ROBINSON'S
WIRELESS ELECTRIC SIGNALS,
THE SIMPLEST, CHEAPEST, and
Only Absolutely SAFE Electric Signals in Existence,
NOW IN SUCCESSFUL OPERATION ON THE
BALTIMORE AND OHIO,
PHILA., WILMINGTON & BALTIMORE,
PHILADELPHIA AND ERIE,
AND OTHER RAIL ROADS.
They work as AUTOMATIC BLOCKS with tell-tale alarms, OFFICE, STATION, ROAD CROSSING and SWITCH SIGNALS, and BROKEN RAIL DETECTORS. These signals have worked uninterruptedly through last winter regardless of rain, snow, slush or sunshine.
Descriptive circulars on application.
MAY 1873. WM. ROBINSON, St. Petersburg, Pa.

Robinson's circular went on to say

> The following functions may be embraced in the signals of a single section. Block signaling, both automatic and manipulated, switch, drawbridge, bridge, road crossing, and station-approach signaling, and broken rail detecting.
>
> Since the signal is [operated] mechanically, any tampering with the rails or connections, or failure of the battery, will invariably result in exposing the signal; any error therefore which may occur from

any cause will be in behalf of safety. *It is impossible to show safety when the danger exists which the signal is designed to avert.* [Emphasis in original.]

Inspection by PRR officers

On October 24, 1873, several officers of the Pennsylvania Railroad rode an inspection train over the Philadelphia & Erie. William Baldwin was part of the group, as was A. J. Cassatt, PRR general manager at the time. Cassatt would later become one of the Pennsylvania's most legendary presidents.

Robinson joined the inspection party as it traveled over the Philadelphia & Erie. The special train stopped at several locations to examine Robinson's closed circuit signal system. According a letter written by Robinson to his brother, "Mr. Baldwin could not say enough in favor of the signals" and that the PRR officers "were all much pleased with the signals." The inventor noted that the officers were surprised by the the method of operation, and expected they might take some time to fully comprehend the importance of the closed track circuit concept.

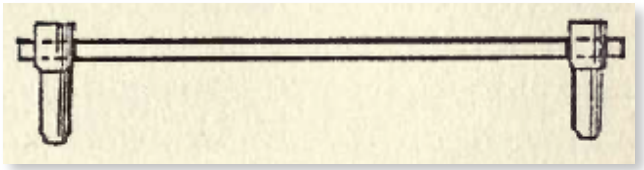
Other inventions

A later Robinson invention was a pole-changing device that presaged the later practice of pole-changing a distant signal's line circuit to select *Caution* or *Proceed* indications.

In 1876, Robinson was involved in making several signal installations in New England, and began to conceive of building switch protection into his system, which eventually became known as "automatic block signaling" or ABS. The track sections containing switches functioned like regular closed circuit blocks, but with an addition: The switches were connected to the track circuit so that each switch had to be closed and locked for the main line in order to display the "All Clear" indication. An unlocked or mispositioned switch thus caused a "Danger" signal to be displayed to an approaching train in the same way as if the track were occupied. This was effected by apparatus that short circuited the track circuit if the switch were not in the proper position.

In a similar fashion, Robinson made an installation on the Old Colony (later to become part of the New Haven) in Massachusetts that included a drawbridge.

Robinson designed the scheme so that withdrawing any of the bridge lock bolts would cause the signal to display "Danger" until the bridge locks were restored to their normal position, allowing train movements to proceed with safety.



An early plug-style of rail bond.

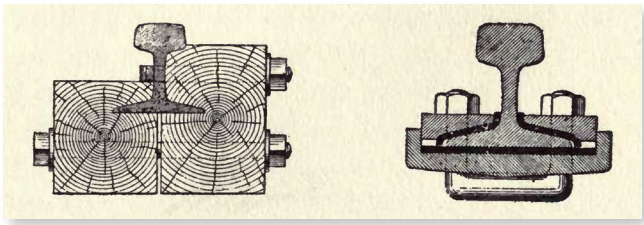
Rail bonds

Robinson recognized that rust at the rail ends and in the tie plates made a poor connection, and would result in a high enough electrical resistance to prevent reliable passage of current from reaching the track relay. He experimented with different type of rail bonds.

Robinson first used plug bonds that were driven into holes drilled in the rail, thus insuring an electrical connection impervious to rust or other impurities. He also envisioned welded bonds, but this process was at first impractical until advances in welding technology changed the picture later.

Insulated joints

Signaling also requires insulated joints. Robinson's earliest I-joints consisted of wooden bars to separate the rail sections. As early as 1876, he had conceived of an insulated joint using vulcanized fiber placed between rail ends.



Two types of insulated joint used in Robinson's experiments are depicted above.

Epilog

In 1878, Robinson organized the Union Electric Signal Company. Robinson was sole owner until approximately 1880 when he sold a controlling interest in the company to George Westinghouse and associates.

In 1881, the company was reorganized and renamed to the Union Switch & Signal Company. US&S became the sole owner of Robinson's closed circuit signaling system until his patents expired. Over time, US&S became one of the titans of the North American signal industry. The company's headquarters and factory were located in the Pittsburgh suburb of Swissvale, PA. Today, US&S is a subsidiary of the global firm Ansaldo.

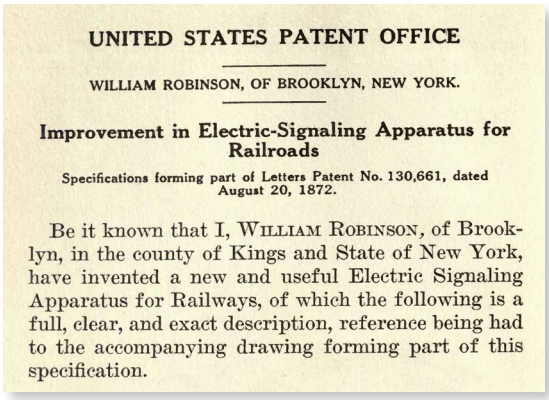
As for William Robinson, he earned a Ph.D from Boston University in 1907 in electrical and mechanical engineering at the age of 67. Dr. Robinson continued to work in electrical and mechanical engineering, as well as telephony, fluids, and turbine engines. One of Robinson's telephonic experiments included conducting a telephone conversation through the medium of the two rails comprising a closed circuit signal block.

Robinson never married, and had no children. He died in Brooklyn, NY on January 2, 1921 at the age of 80. Dr. William Robinson was buried in Green-Wood Cemetery, Brooklyn, NY.

Significance of Robinson's invention

Dr. William Robinson's legacy was described in the 1922 Signal Section tribute, which outlines Robinson's accomplishments regarding his invention of automatic electric signaling. An abbreviated summary follows.

- The invention was "of incalculable value to the human race in the wholesale saving of life and property" and defied others' skeptical viewpoint that it could not possibly work. The invention had humanitarian benefits for countless rail passengers by preserving life and limb.
- The closed circuit track circuit had no precedent; it was an entirely new concept never before known or used. Along with the principle of interlocking, first installed in the United States around the time of Robinson's patent, the design of the track circuit was one of the key elements underpinning the concept of fail-safe design and vital hardware, which remain critical elements of railway signaling today.
- Robinson's invention was unique in that it was conceived, tested, and placed in service, and perfected by its original inventor.
- The invention made it possible to run trains at increasingly higher speeds while doing so with safety.
- The automatic block signal system used in the New York subway made it possible to increase the capacity of the New York subway by at least threefold, allowing the subways to carry four times the number of riders they otherwise would have been able to carry..
- The creation of the track circuit helped establish the new industry of railway signaling, thus creating new opportunities for employment in that industry.
- The invention increased the railroads' capacity without sacrificing safety, allowing railroads to carry more traffic, and in turn increase income. At the same time, the system reduces expensive damage to equipment and lading that results from collisions.
- The invention of an adjunct – the humble rail bond – made it possible for electric railroads to use the rails as the return path for propulsion current.



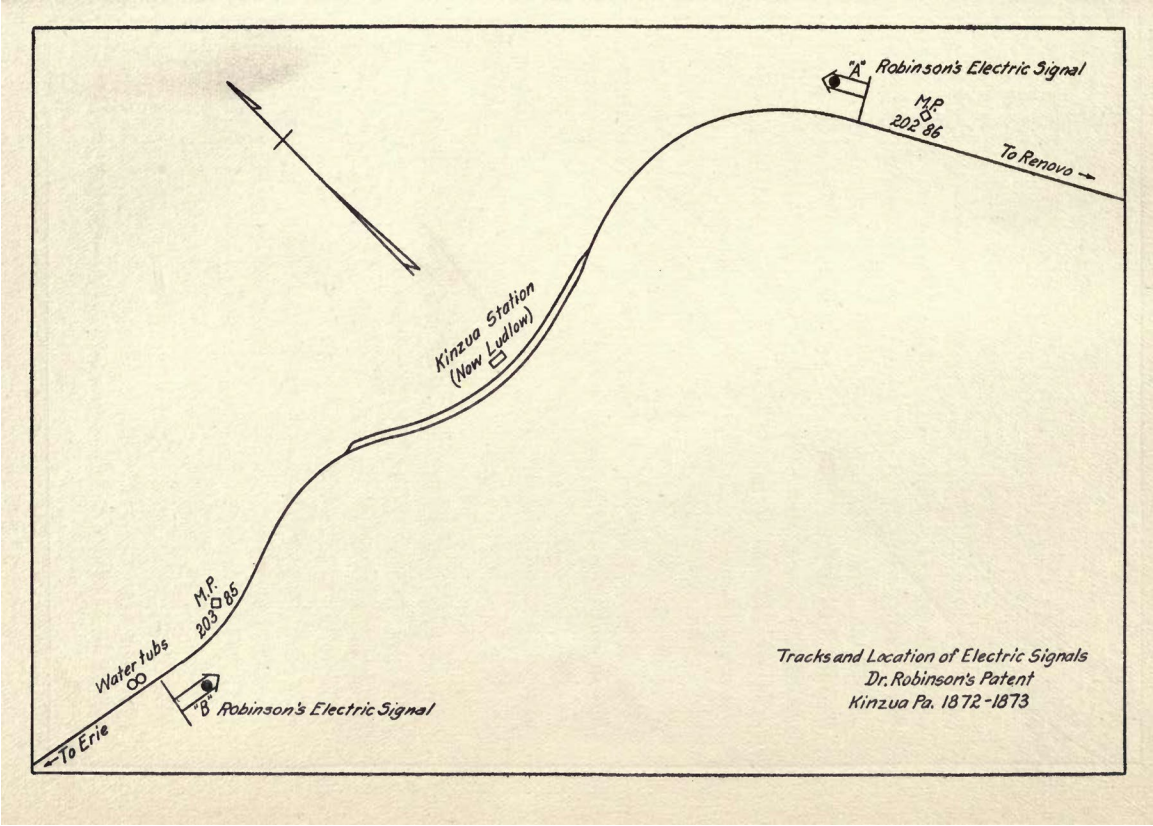
UNITED STATES PATENT OFFICE

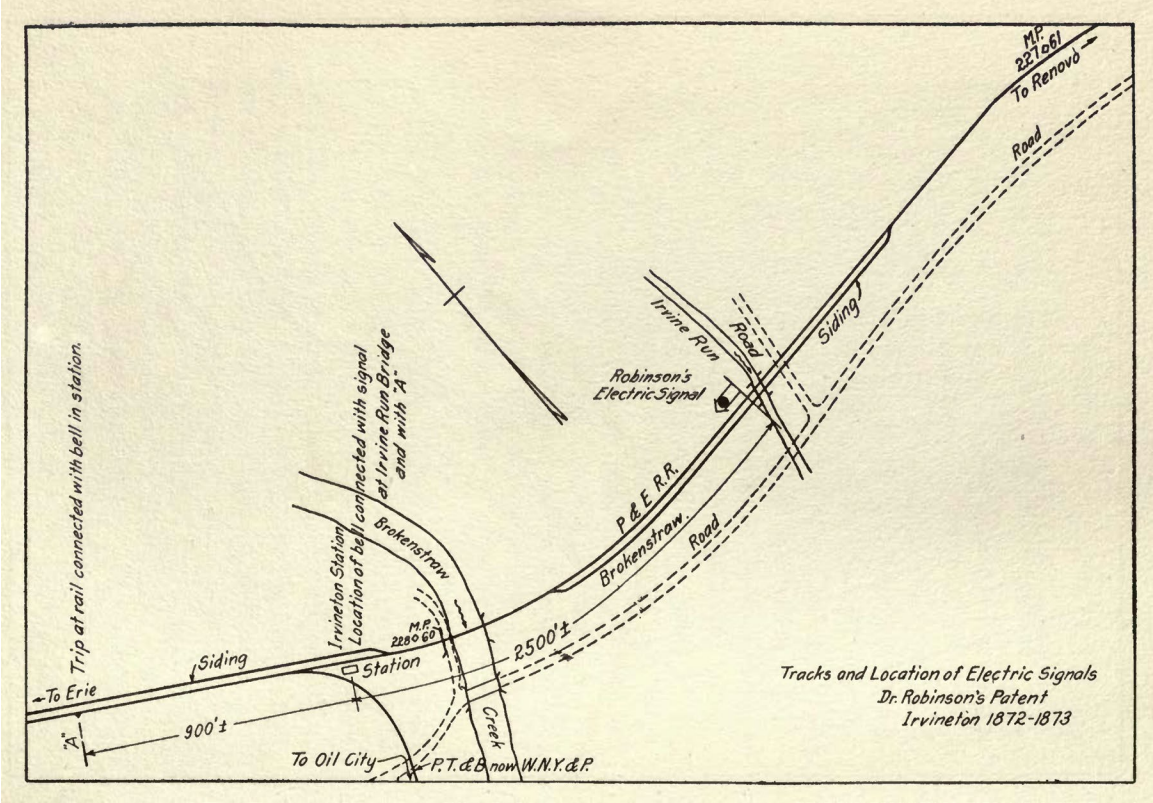
WILLIAM ROBINSON, OF BROOKLYN, NEW YORK.

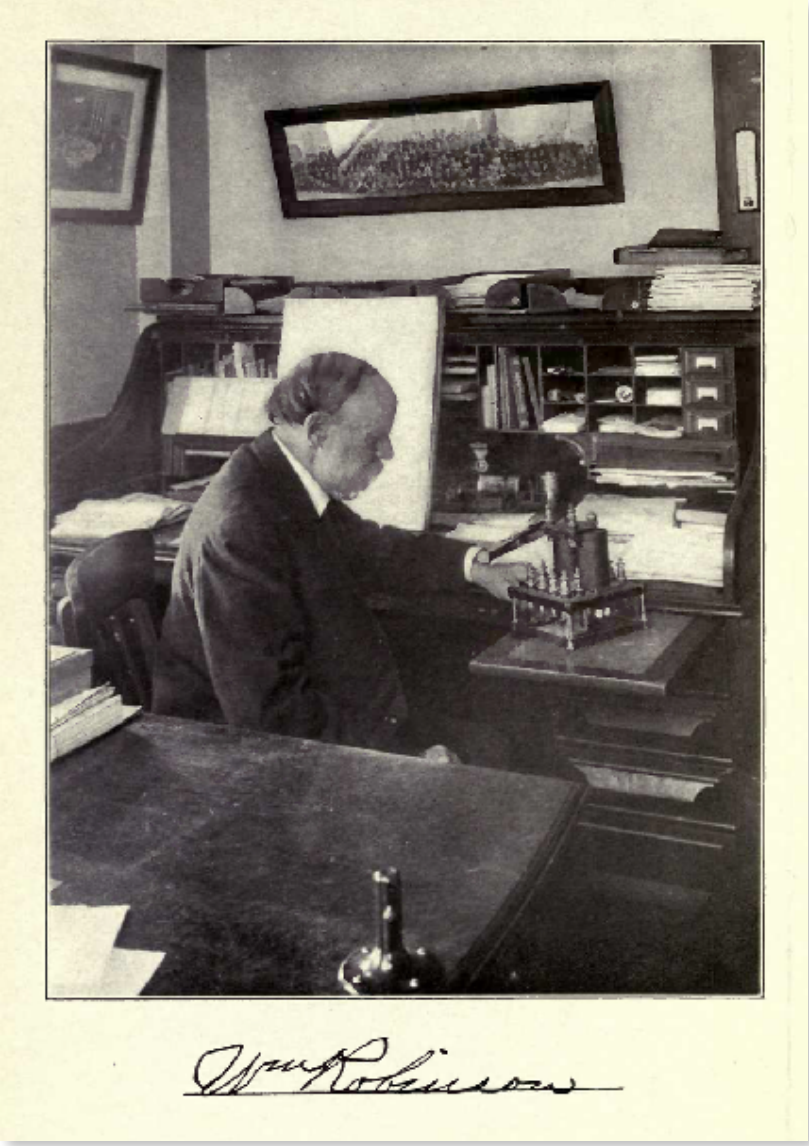
Improvement in Electric-Signaling Apparatus for Railroads

Specifications forming part of Letters Patent No. 130,661, dated August 20, 1872.

Be it known that I, WILLIAM ROBINSON, of Brooklyn, in the county of Kings and State of New York, have invented a new and useful Electric Signaling Apparatus for Railways, of which the following is a full, clear, and exact description, reference being had to the accompanying drawing forming part of this specification.


"A" Robinson's Electric Signal
M.P. 202.86
To Renovo
Kinzua Station (Now Ludlow)
M.P. 203.85
Water tubs
"B" Robinson's Electric Signal
To Erie
Tracks and Location of Electric Signals
Dr. Robinson's Patent
Kinzua Pa. 1872-1873


M.P. 227.061
To Renovo
Road
Irvine Run
Road
Siding
Robinson's Electric Signal
Trip at rail connected with bell in station.
Location of bell connected with signal at Irvine Run Bridge and with "A"
Irvineton Station
Brokenstraw
P & E R.R.
Brokenstraw Road
M.P. 228.060
2500'±
Siding
Station
To Erie
"A"
900'±
To Oil City
Creek
P.T. & B. now W.N.Y. & P.
Tracks and Location of Electric Signals
Dr. Robinson's Patent
Irvineton 1872-1873



Dr. William Robinson examines a signal relay in his office during his twilight years. Robinson founded the company that became US&S in 1881, and which became a dominant force in signaling for much of the twentieth century.

Citations

"A Memorial for Dr. William Robinson," Railway Signal Engineer, vol. 14, no. 4, p. 126, April 1921. Simmons-Boardman Pub. Co., Chicago, IL, USA.

American Railway Association Signal Section. The Invention of the Track Circuit: The History of Dr. William Robinson's Invention of the Track Circuit. New York, NY, USA: 1922.

"Dr. William Robinson" Find-A-Grave.com. https://www.findagrave.com/memorial/194887672/william-robinson (accessed Feb. 1, 2009).

"Dr. William Robinson" Find-A-Grave.com. https://www.findagrave.com/memorial/58362243/william-robinson (accessed August 13, 2022).

"In Memoriam – Dr. William Robinson," Railway Signal Engineer, vol. 14, no. 1, p. 24, January 1921. Simmons-Boardman Pub. Co., Chicago, IL, USA.

Third Annual Report of The Block Signal and Train Control Board to the Interstate Commerce Commission. November. 22, 1910.

Wm. Robinson, "Improvement in Electric Signaling Apparatus for Railroads," U.S. Patent 130,661, August 20, 1872.

