A Brief History of Lift Safety Devices 1835-1935

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Abstract. The history of lift technology is, essentially, the history of lift safety devices. Passenger safety has always been a primary focus of the lift industry and all aspects of lift technology are typically designed with regard to safety. For over 175 years the invention of safety devices has followed a developmental pattern predicated on an assessment of risk, the needs of different lift types, lessons learned from actual lift operation, and changes in lift systems and technologies. Critical safety concerns have included rope failure, overspeed, access to lift cars and shafts, automatic door operation, and leveling. This paper will offer a chronological outline of the development of lift safety devices and will, when possible, link the appearance of a given safety device to a specific cause, determining factor, perceived problem, or change in use. This paper examines the first 100 years of lift safety devices and will reveal that the development of these systems followed both logical and (occasionally) somewhat illogical paths.

1 INTRODUCTION

The following outline of the history of lift safety devices from 1835 to 1935 touches on some of the key developments that occurred in England and the United States during the period under investigation. The primary materials examined for this study include the American patent record and scholarship produced by the author over the past twenty years. This paper does not attempt to present a comprehensive history of lift safeties. The goal is to provide an outline that highlights key moments in this important story.

2 1835: THE TEAGLE

The design of William Strutt's North Mill at Belper, England, built in 1803/04, included the installation of one of the first mechanized lift systems [1]. The machine, which became known as a "Teagle," was a belt driven platform lift used for transporting goods and workers in the five-story mill. A description of the lift published in 1835 revealed that between 1804 and 1835 several safety systems were added to the original lift. These included a shaft safety gate and safety stops. The safety gate was designed to prevent the gate from being opened if the lift platform was not present at the landing. The safety stops were balls placed on the shipper rope such that, if the car passed the upper or lower landing it would strike a ball, which would move the shipper rope and stop the lift's movement (Fig. 1). The origin of these safeties is unknown. They were likely developed in response to lift accidents that occurred in the mill.

3 1854: SAFETY HATCHES

The first patent for a lift safety device appeared in 1854 and concerned a design for automatically operating shaft hatches, which were located at each floor [2]. Invented by Daniel Tallcot, the safety was designed to ensure that unwary factory or mill workers could not fall down the lift shaft. As the lift platform moved through the shaft it encountered a cam and spring system that opened and closed the hatches (Fig 2.) In his patent text Tallcot reported that, although many lifts employed shaft doors, these were often left open and thus accidents occurred.

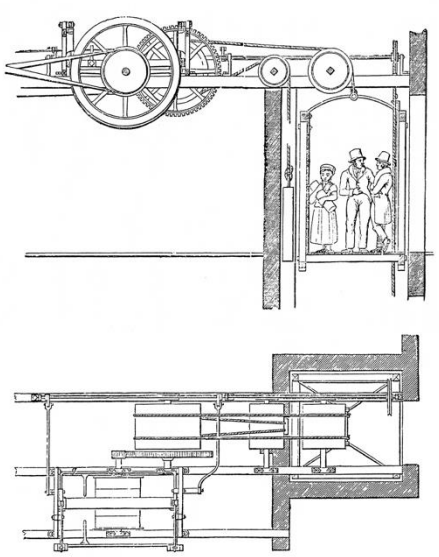

Figure 1 The Teagle, William Strutt's North Mill, Belper, England (1835)

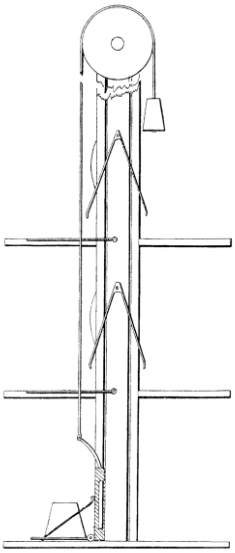

Figure 2 Safety Hatch, Daniel Tallcot (1854)

4 1854: THE RATCHET & PAWL SAFETY DEVICE

In 1854 Elisha Graves Otis exhibited his ratchet & pawl safety device at the New York Crystal Palace (Fig. 3) [1, 3]. Otis was the first to propose integrating a safety into the design of the lift platform. His device was intended to ensure that the platform would not fall if the hoisting rope failed. His exhibition also marked the first (and possibly only) public exhibition of the operation of a lift safety device. Although he initiated the process to patent his design in 1854, Otis later withdrew this application [1].

5 1856: THE FIRST RATCHET & PAWL SAFETY DEVICE PATENT

In 1856 Hugh Baines, an architect practicing in Manchester, England, received a patent for a ratchet and pawl safety device that resembled Otis' design in its proposed operation, whereby if the hoisting rope broke ratchets would be released and engage racks, thus stopping the lift platform (Fig. 4) [4]. Baines claimed that his invention represented:

> a novel method of stopping or retaining the ascending or descending room, chamber, or box employed in "hoists" in warehouses, mills, factories, pits, etc., for conveying persons and goods from one floor or height to another, in the event of the rope breaking, or the occurrence of any other equivalent accident, which would cause or allow the room or chamber to fall to the bottom of said shaft, thereby endangering life and property [4].

While the inventor's rationale focused on the most common cause of lift accidents – rope failure – he also alluded to other unspecified causes of accidents.

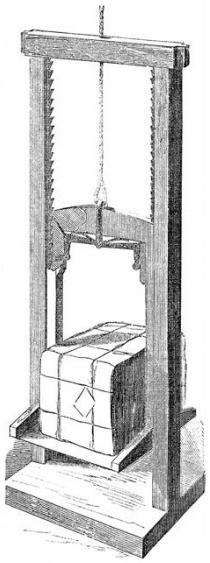

Figure 3 Elisha Graves Otis safety exhibited at the New York Crystal Palace (1854)

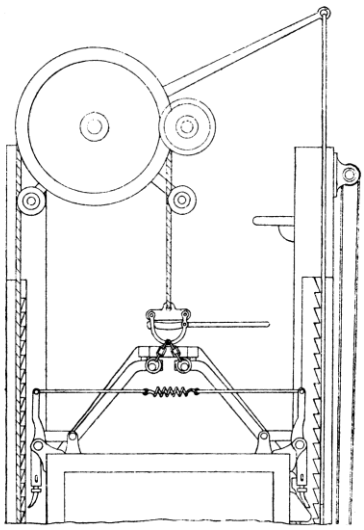

Figure 4 Hugh Baines, Ratchet and pawl safety patent (1856)

6 1857: THE FIRST SAFETY DEVICE TEST ACCIDENT

In addition to receiving the first patent for a ratchet and pawl safety device, Baines has the unfortunate distinction of beging the first to be involved in a safety test accident [5]. In April 1857 he had his

safety installed on an existing lift in Pender & Co.'s Warehouse in Manchester. The lift, carrying four passengers (including Baines), was raised to the top floor, and the hoisting ropes were "disconnected." The safety failed to act and the car fell 60 feet to the bottom of the shaft, resulting in one fatality, two serious injuries, and the inventor receiving a "severe laceration of one foot" [5]. The cause of the safety's failure is unknown (Baines alleged that previous tests had been successful). This tragic event reveals an aspect of safety development that remains unexplored: the history of lift safety testing.

7 1859: THE FIRST AIR CUSHION SAFETY DEVICE

In 1859 Albert Betteley patented the first "air cushion" safety device [6]. The lift platform featured a tapered "parachute" like structure that, when it entered a reservoir at the base of the shaft would compress the air in the reservoir, which would be slowly released around the edges the platform (Fig.5). Betteley's rationale was that there was a clear need to supplement existing rachet and pawl safeties because of their "inefficiency in preventing the fall of the car in many cases, as for instance when some part of the machinery gives way beyond the rope, or where, as may be the case, the rope breaks and is subject to sufficient friction to keep the pawls from falling into the rack until the car acquires such a momentum as to destroy the racks and pawls when they act" [6].

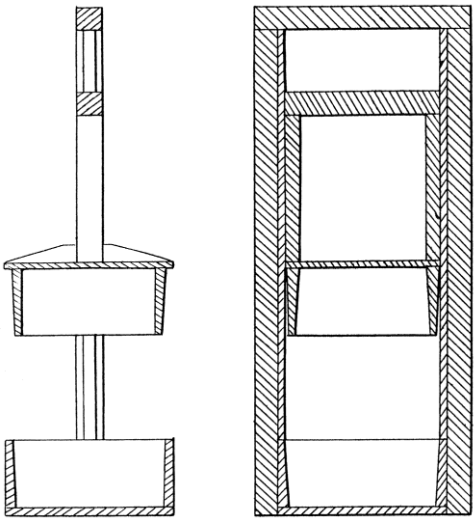

Figure 5 Albert Betteley, Air cushion safety device (1859)

8 1859: THE VERTICAL RAILWAY

In 1859 Otis Tufts patented his "vertical railway" elevator that replaced hoisting ropes with a screw-shaft that extended the height of the building with the car traveling along the shaft (Fig. 6) [7]. His goal was to avoid the "extreme and ordinary dangers of suspension upon chains, ropes, or cords of any kind, in the safety of which, every additional experience has led me to place less and less reliance" [7]. In addition to eliminating hoisting ropes, Tufts provided other safeties, including a speed governor, an automatic safety stop (located at the top of shaft) and a buffer (located at the bottom of shaft). He was also the first lift designer to propose using an enclosed car to carry passengers (in order to ensure their safety), and he was one of the first to place the controller or shipper rope inside the car.

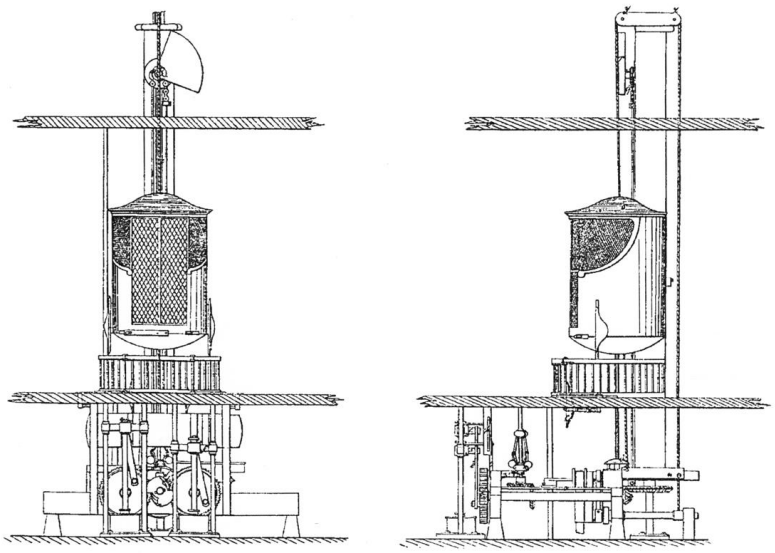

Figure 6 Otis Tufts, Vertical railway elevator (1859)

9 1859: THE FIRST INTERLOCK DOOR SAFETY DEVICE

In 1859 Albert Betteley patented the first interlock door safety system that featured interlocking shaft and car doors [8]. It employed a device operated by a series of cams and springs such that, when the car door was open, the safety automatically "grasped" the shipper rope and prevented its use, thereby holding the car stationary (Fig. 7). Betteley's use of ordinary hinged-doors followed the established door-type used on lifts at this time.

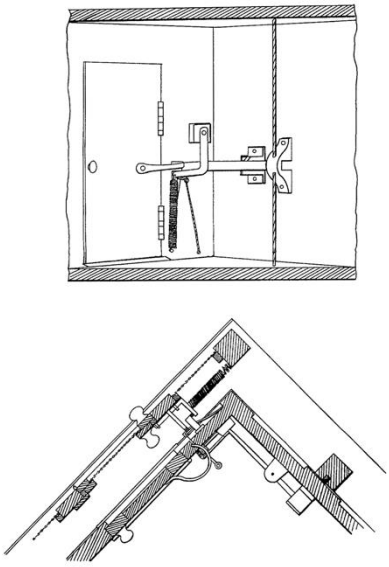

Figure 7 Albert Betteley, Interlock door safety device (1859)

10 1859: THE FIRST SAFETY LIFT

In a December 1859 advertisement for his lift company, Elisha Otis stated that "not a single" accident had occurred to one of his "improved safety elevators" [9]. This marked the first use of the phrase

"safety elevator" in the United States. From this date forward, most manufacturers referred to their products as "safety elevators" or "safety lifts."

11 1861: THE SECOND RATCHET & PAWL SAFETY DEVICE PATENT

In 1861 Elisha Otis finally patented his ratchet and pawl safety device (Fig. 8) [10].

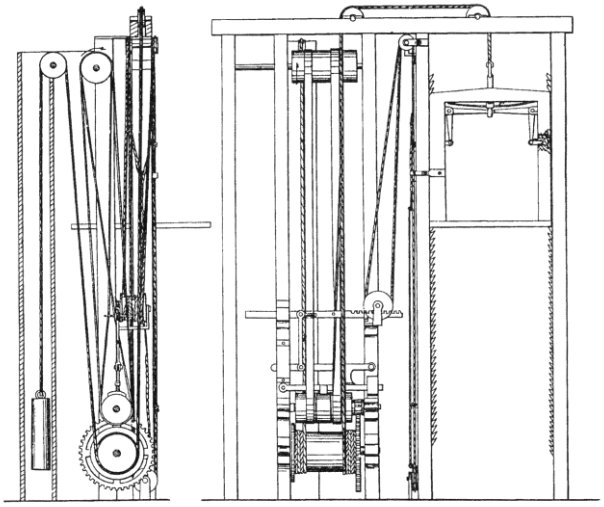

Figure 8 Elisha Otis, Ratchet and pawl safety device patent (1861)

12 1861: AN EARLY OTIS ELEVATOR ACCIDENT

On February 1, 1861 an accident occurred involving one of Otis' improved safety elevators [11]. Following routine maintenance (which involved replacing the hoisting rope) on an Otis lift in Struelens & Palmer's factory in New York, the lift traveled to the fifth floor here it was loaded with goods. As the lift began to descend the hoisting rope, which had not been properly secured, came loose and the car fell. The safety did not engage until the lift reached the second floor. The resulting "force of concussion" killed an employee on the lift and injured Nazaire Struelens, who had been standing near the second-floor lift entrance [11]. Following an investigation, Elisha Otis reported that the car's framework "had been racked out of shape in such a manner as to prevent the operation of the safety spring" [12]. Otis also stated that he had "never warranted elevators to be *perfectly safe*, as their safety depends in some measure upon their reasonable care and usage by the operator, over whom I can have no control" [12]. This was one of the first public acknowledgements that safe lift operation was not solely dependent on the efforts of lift manufacturers. The tragedy of this accident was compounded in March 1861 when Struelens, while reaching for the shipper rope, slipped and fell down the unguarded shaft to his death [13].

13 1864: THE FIRST OVERSPEED SAFETY (DIRECT ACTION HYDRAULIC LIFT)

In 1864 Easton, Amos & Sons designed a speed regulator for use on the direct-action hydraulic lift installed in the Brighton Hotel (Fig. 9) [14]. The regulator was described as:

> a cast iron box or chamber, through which the water passes on its way to and from the cylinder, and in which is suspended on a center a brass quadrant, the face of which fits accurately the face of both the inlet and outlet passages … When the velocity of the water, in either direction, does not exceed that decided upon, the swinger hangs

> in a vertical position without moving, but the instant the velocity increases beyond that point … the swinger rises and closes the passage to such an extent as to reduce the speed to the normal velocity [14].

The safety was unusual in addressing the possibility of overspeed in a hydraulic lift. This device was also the first to address overspeed in the "up" direction.

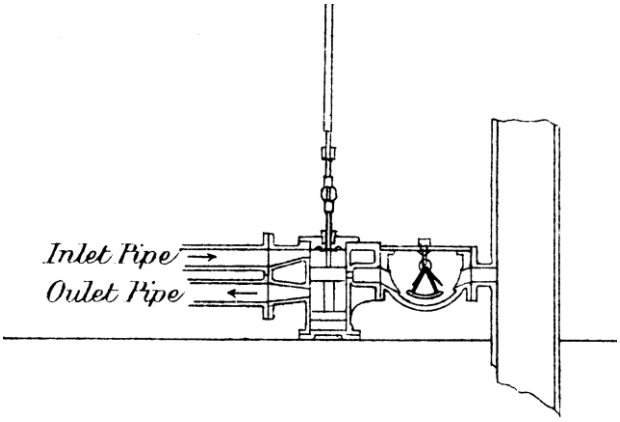

Figure 9 Easton, Amos & Sons, Overspeed safety for a direct-action hydraulic lift (1864)

14 1865: THE FIRST OVERSPEED SAFETY (STEAM POWERED LIFT)

In 1865 Charles R. Otis patented the first overspeed safety designed for use on steam powered, winding drum lifts (Fig. 10) [15]. The design employed a safety drum located at the top of the shaft, which used a flyball governor to control the action of a brake. The safety was attached to car such that the car's speed determined the governor's rotational speed. If the car exceeded a predetermined speed the governor would activate the brake. Charles Otis, acknowledging earlier criticisms of his father's original safety device, stated that the overspeed safety was needed in the event of an accident where the action of the falling car failed to trigger the ratchet and pawl safety.

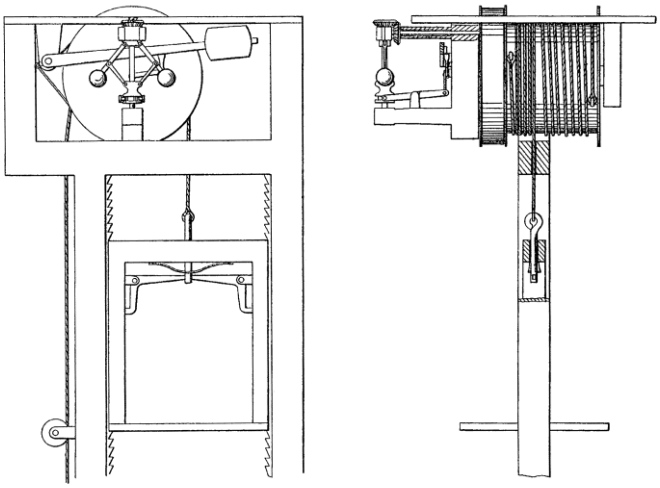

Figure 10 Charles R. Otis, Overspeed safety for a steam powered lift (1865)

15 1879: THE SECOND AIR CUSHION SAFETY DEVICE

In 1879 Albert C. Ellithorpe patented the second "air cushion" safety device (Fig, 11) [16]. His rationale and design were similar to Betteley's, with the primary difference between the two designs being the addition of an automatic air valve that opened to admit air into shaft as car ascended and closed as the car descended. Ellithorpe also recommended the use of sliding doors to keep the shaft as "air tight" as possible. The critical difference between these inventions was the fact that, unlike Betteley, Ellithorpe was able to successfully market his safety device across the United States.

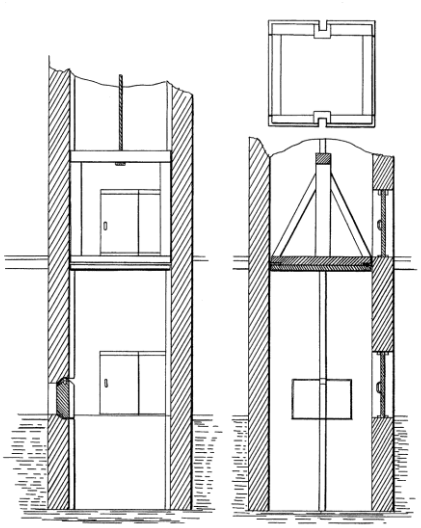

Figure 11 Albert C. Ellithorpe, Air cushion safety device (1879)

16 1884: (ANOTHER) OVERSPEED SAFETY

In 1884 Adolphe Gallinant patented an overspeed safety that consisted of a series of fan blades attached to a mechanism mounted at the of the shaft (Fig. 12) [17]. The mechanism was attached to the top of the car via a rope such that the car's movement caused the fan blades to rotate. The blades were designed to close as the car ascended and open as it descended, and chains were used to prevent the blades from opening too far. The car's speed was allegedly controlled by moving the blades on their supports. Nothing is known about Gallinant other than the fact that he immigrated to the United States from France in 1872/73 and that he apparently had no connection to the vertical transportation (VT) industry. This safety is representative of hundreds of devices patented during the 19th century by people outside the VT industry. These patents represent another unexplored topic: in spite of their idiosyncratic and often impractical nature, they serve as an important indicator of the public's general awareness of the need to ensure safe lift operation.

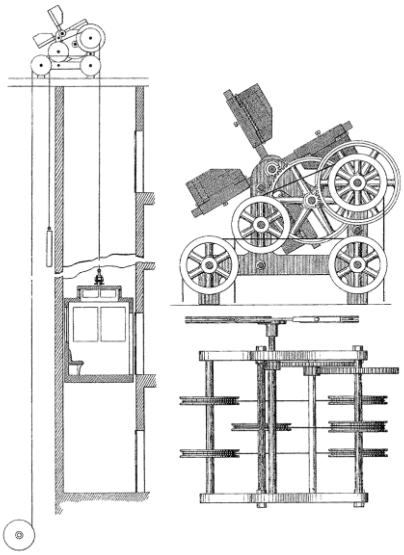

Figure 12 Adolphe Gallinant, Overspeed safety device (1884)

17 1897: THE FIRST UNDER-CAR OVERSPEED SAFETY

In 1897 Charles R. Pratt patented one of the first under-car overspeed safety devices [18]. Pratt's design was, in many ways, made possible by the development of modern steel guide rails in the early 1890s [19]. Earlier car mounted safeties were typically located atop the car and were designed to engage wooden guide rails. The presence of narrow steel guide rails allowed Pratt to propose using spring activated clamps that grasped the sides of the rails (Fig. 13). The action of his safety was controlled by a flyball governor whose speed was determined by the car's movement.

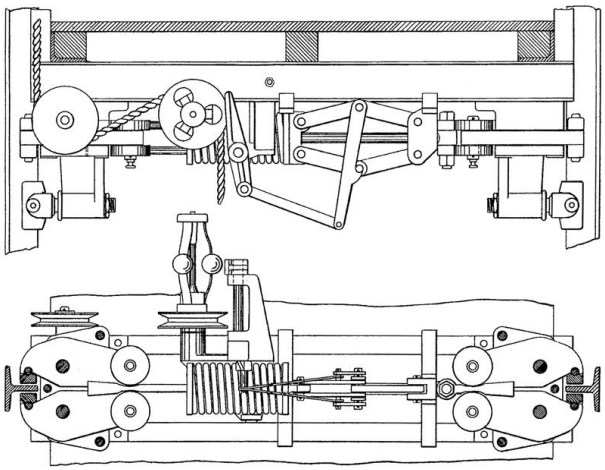

Figure 13 Charles R. Pratt, Under-car overspeed safety device (1897)

18 1899: THE FIRST IN-CAR COMMUNICATION SYSTEM

The Park Row Building in New York, completed in 1899, utilized the first lift cars that employed an in-car communication system; the cars were equipped with telephones that allowed lift operators to immediately report operational problems to the building's engineer [20].

19 1903: (ONE OF) THE FIRST ELEVATOR THRESHOLD SAFETY DEVICES

The absence of automatic elevating systems inspired inventors to devise safety devices to help passengers enter and exit cars that were not perfectly level with their landings [21]. Once such safety, developed by George Hail, involved placing lights either inside the car or on the landing that were directed at the threshold to help passengers to see if the car was level (Fig. 14) [22, 23].

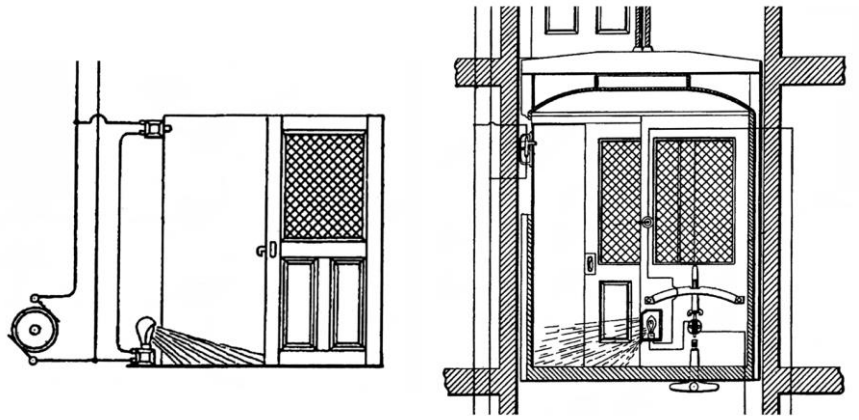

Figure 14 George Hail, Elevator threshold safeties (1903)

20 1900-1915: AUTOMATIC LEVELING SYSTEMS

Designing an effective automatic leveling system was defined in terms of solving two related problems [24]. The first problem concerned the design of a cost-effective means of automatically slowing the car speed to approximately 15 feet per minute as it approached the landing. The second problem involved designing a means by which the car, now moving at a slow speed, would automatically stop level with a given landing and automatically "inch" back to a landing should it go past level [25]. In 1903 Harold Rowntree patented a design that solved the first problem. He proposed to switch from the main motor to an auxiliary slow speed motor as the car approached a landing [26]. In 1913 August Sundh patented a solution to second problem [27]. His design employed a controller mounted on the car that was connected to a chain that ran from the top to the bottom of the shaft. As the car traveled through the shaft the chain rotated sprocket wheels in the car controller that in turn rotated contact points that governed the flow of current to the hoisting motor and controlled the activation of the brake. The mechanical movements within the controller were determined by the height between individual floors, which was keyed to the number of chain links that passed over the sprockets. If the car traveled past the landing the controller would detect this movement and the car would automatically reverse its motion and level itself.

21 1931: THE FIRST DOOR REVERSAL SAFETY DEVICE

The development of interlocking, automatically operating sliding lift doors in the 1920s created a new safety hazard: the possibility of passengers being injured by the closing doors [28]. In 1931 two Westinghouse engineers, Luther J. Kinnard and James Dunlop, patented an automatic door reversal safety device [29]. They described the need for their invention and its basic operational characteristics as follows:

> In operating an elevator having a power-controlled gate, it is desirable to provide some means for preventing the passengers from being injured by a premature closing of the gate while they are entering or leaving the car. Therefore, we have devised a means for preventing the gate from closing until the doorway, or entrance, to the car is clear. This means comprises … a photoelectric cell and a cooperating source of light …

mounted in the entrance to the car for operating a safety relay, the contact members of which are included in the circuit for the door-operating mechanism [29].

The inventors also stated that it was an "object of our invention to provide for reopening the door or gate and retaining it in such open position for a predetermined length of time when anyone steps into the entrance to the elevator while the door is in the act of closing" [29]. Their design employed two pairs of lights and photoelectric cells, one mounted in the car and one the landings, that could be used to detect passengers' movements in and out of the car (Fig. 15).

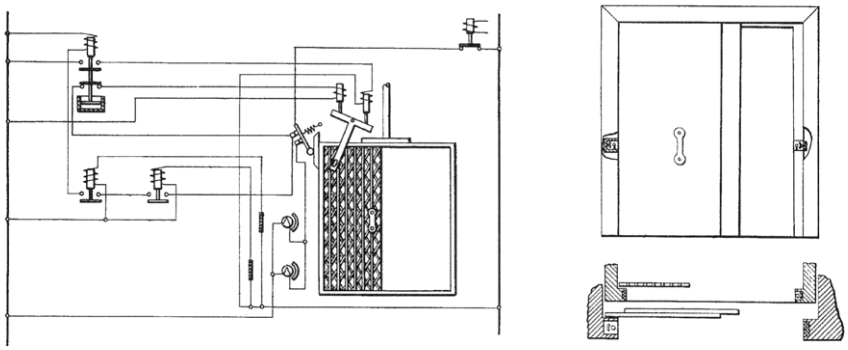

Figure 15 Luther J. Kinnard and James Dunlop, Door reversal safety device (1931)

22 CONCLUSION

This brief examination of the history of safety devices reveals the need for a comprehensive study of lift safeties. Such a study would involve a careful examination of the patent record in the United States and Europe, the relevant technical literature, accident reports, lift codes and regulations, and manufacturer's catalogs. The product of such an investigation would be a comprehensive history of lift development. While several lift histories have appeared over the past 50 years, none of them offers readers a work that encompasses all of the topics referenced above (1, 30, 31).

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BIOGRAPHICAL DETAILS

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