Protection Methods for Railway Switches in Snow Conditions

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Research and Development programs conducted on several different methods of overcoming the problem of railway switches failing in the presence of snow and ice are outlined. The most common method at present is the application of heat by the combustion of fossil fuel. By the application of forced convection heat transfer switch protection under reasonably severe environmental conditions is possible. A novel combustion heater based on the valveless pulse jet engine has been applied to railway switches. A non-thermal method employing a horizontal air curtain has been developed to prevent the deposit of snow in critical areas. Two switches have been designed and developed for field evaluation. Both switches are capable of operation in snow and ice conditions.

The fact that railway track switches fail to function properly in the presence of snow and ice is well known in the railway industry. The switch that is in general use throughout the world with only minor variations is the moving point type. The outside rails are standard in design and diverge from the point or apex to the rear or heel of the switch. Within the fixed outer or stock rails two machined rail sections are positioned that are hinged at the heel end and move in unison to provide for straight-through or turning traffic. The machined rails or point rails swing transversely on slide plates and at the apex the points of these rails must fit closely to the head and the base of the stock rail. In operation one point is closed and one is open and in transferring the open and closed points are exchanged. The switch transfer can only be accomplished providing that no foreign material is lodged in the open point between the moving rail and the fixed rail. Although freshly fallen snow can be compressed by a sizeable ratio, a standard railway switch can be rendered unserviceable by as little as .6 cm(¼-in.) snowfall.

At one time it was common practice to clean switches with brooms and shovels and in fact Figure 1 is from a newspaper publication of January 1976 showing that currently it is still in use in some locations. Solutions to this problem have been sought for over a century as was indicated by a patent search disclosing that alternate switch designs were considered more than a hundred years ago and switch heating had been used in the New York and London metropolitan transit systems in the 1890 era.

The advent of Centralized Traffic Control on the railways required that all switches and signals be operated from remotely controlled dispatcher locations. In some cases the switches and signals may be 320 km (200 miles) from the control point. Obviously if a switch is to be controlled by a dispatcher some miles distant it is essential that the switch be capable of operation in all weather conditions. It was the application of CTC to rail operation that has necessitated the development of equipment to protect switches from failure due to snow or ice.

In Canada the two major transcontinental railways had by the late 1960s invested several million dollars in various types of heaters developed in both Europe and North America that were intended to protect a switch from snow failure. The heaters had been developed to satisfy requirements in somewhat more moderate climatic areas; however, when installed in locations with somewhat more severe ambient conditions the equipment had proven to be inadequate. Through an NRC Associate Committee on Railway Problems the Low Temperature Laboratory was asked to look at the problem, to set up standards and to investigate various methods of solving the problem.

Defining the Problem

In cooperation with the CNR and the CPR, arrangements were made to evaluate three of the heaters that the railways had in use in the 1960s. A winter field test was arranged at the Divisional Railway Laboratory. It was a successful field trial inasmuch as all three heaters failed a number of times with different modes of failure, and two of the heaters experienced explosions, fortunately without significant damage. The unit that had not exploded was subsequently investigated further in the laboratory.

In order to evaluate both the problem and possible solutions under controlled conditions it was arranged to install a full scale main line switch in the large cold chamber of the Low Temperature Laboratory. This chamber is 15 meters (50 ft) long and switches of 6.6 meters (22 ft) and 11.7 meters (39 ft) nominal length have been installed at different times for tests. Most of the research and development work was carried out with the 6.6 meter

(22-ft) long switch.

Snow making had been carried out for a considerable period of time prior to the railway switch work; however, for this test program the snow making equipment was modified to allow for different conditions. An overhead air-water multiple nozzle array was installed to supplement the normal snow making nozzles that are mounted on wind chill fans. With three sets of snow making nozzles a maximum snowfall rate equivalent to 12.5 cm (5 in.) per hour could be produced.

The railway track switch was installed in the cold chamber complete with ties, crushed stone ballast and approximately 30 cm (1 ft) of subgrade material. While evaluation of the one heater remaining from the field test was carried out, development of a test standard in cooperation with the railways was pursued. Ultimately it was agreed that the laboratory test standard to be employed for either evaluation of new heaters or for research and development programs should be a snowfall rate of 2.5 cm/h (1 in. per hr), a wind velocity of 32 km/h (20 mph) and an ambient temperature of -17.7C (0°F). It was appreciated that all three conditions could be exceeded in nature at a number of locations; however, the chance of all three being exceeded simultaneously was low as indicated by climatic data.

Thermal Protection

In due course it was established from the cold chamber test program that to protect a switch under the previously noted conditions a thermal system should distribute the heat by forced convection to the critical areas of a switch and with a good duct system a thermal capacity of 62,500 kilocalories (250,000 BTU) per hr was required for a 6.6 meter (22-ft) long switch. Three manufacturers eventually developed heaters that produced this quantity of heat and used forced convection distribution ducts to direct the heat to the critical areas. The conventional forced convection combustion heaters that were developed had a number of serious design deficiencies, e.g. dirty combustion, inadequate air inlet systems, excess electrical power consumption.

The laboratory undertook to develop an advanced design forced convection combustion heater that would eliminate or alleviate these specific problem areas. To ensure clean combustion a cyclone burner combustion chamber with a conical re-entrant outlet was chosen. By careful design of the air inlet, the combustion chamber by-pass, the cross duct and the distribution ducts and by application of a higher efficiency fan the electrical power consumption was reduced to approximately 50% of a commercial model. The air inlet was designed with a low velocity re-entrant system to eliminate almost all snow ingestion. This had been a serious problem with all previous heaters. Prototypes of the cyclone combustion heater have been field tested(1) and arrangements completed to place this heater in production.

The forced convection combustion heater for railway switches can be applied at any location with sufficient single phase electrical power; however, the power demand of one to two kilowatts has ruled out the use of this heater where it has not been economically feasible to bring in power lines to switch locations. The CPR outlined a requirement for a forced convection combustion heater that would have an electrical demand of under 100 watts. While consideration was given to engine-driven or engine generator units for the conventional heater, another means of producing forced convection combustion was pursued.

One of the developments resulting from World War II was the pulse jet engine used to power the German V 1 missile. This simple device produced thrust with only an air flapper valve as the single moving part. Post war developments led to the so-called valveless pulse jet engine which in fact employed an aerodynamic valve based on a tuned length re-entrant tube. It was considered possible that a forced convection combustion heater might be developed using a valveless pulse jet as the combustion chamber with the thrust from the engine to produce the forced convection heat transfer means. As reported earlier (2) the pulse jet combustion heater was successfully developed to meet the railway requirements for a unit capable of producing 62,500 kilocalories (250,000 BTU) per hr and distributing this through a duct system to the switch. Figure 2 shows a unit in a field evaluation location approximately 96 km (60 miles) from Ottawa. This heater is extremely simple in concept although there are several critical design aspects that required major development. Figure 3 shows a cross section of a typical switch heater installation. One of the major disadvantages of the pulse jet heater is the noise level produced by this combustion process. It will produce a sound pressure exceeding 120 db "A" scale. Originally this was not considered a disadvantage in view of the intended use in remote locations where power line costs were prohibitive. Subsequently, however, a request was received to install units in areas where the noise would be a problem. The pulse jet design was modified and the units were installed in sound insulated metal bungalows complete with a silencer air inlet while a Maxim type exhaust muffler was installed in the cross duct. This treatment reduced the source noise level to 80 dB "A" scale.

While the pulse jet was under development there were parallel developments by commercial interests of propane engine driven forced convection heaters, and in addition heater installations incorporating an engine-generator to provide electrical power to a standard forced convection switch heater. The combination of a combustion heater, an engine-generator together with a control system housed in a metal bungalow results in a fairly expensive solution to the snow and ice problem with railway switches.

The thermal method of protecting switches is an energy intensive means since the snow is melted and some is vaporized for disposal. The efficiency of this energy application even with a good distribution duct system is quite low since a large portion of the heat is dissipated to the atmosphere except under the more severe snowfall conditions. With the rising cost of hydrocarbon fossil fuels the heating of track switches for a winter season is becoming prohibitively expensive. There are recorded cases where the cost of heating a switch for a winter season has exceeded $1,000.00.

The thermal protection method has both advantages and disadvantages. The major advantage with this method is that a switch that is completely covered in snow can be restored to service by the application of heat. The disadvantages resulting from the switch heater include the following. Overheating can result in ignition of the creosote impregnated wooden ties. With a forced convection duct system supplying air, all of the ties in a switch can be burned out resulting in an unsupported switch assembly. This has occurred on several railways with various heaters, and currently protective devices to shut down the heater in the event of overheat are required. Although the heat is directed primarily at the rails and the slide plates, the operation of a switch heater for extensive periods does result in thawing of the ballast. Traffic movement over soft ballast can force the rails and ties below the normal level requiring the application of shims to restore rail level. The maximum allowable shim application of 2.5 cm (1 in.) can be exceeded depending on heater use and the grade of ballast. The melt water resulting from a switch

Figure 1. Manual switch cleaning January 1976, courtesy Toronto Globe & Mail.

Figure 2. Pulse jet switch heater at Perth, Ontario.

Figure 3. Cross section of pulse jet switch heater installation.

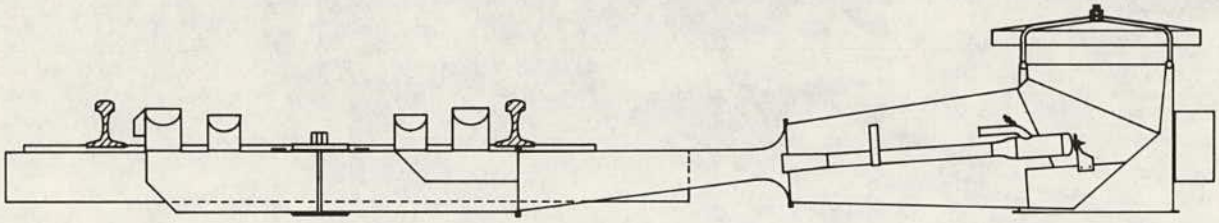

Figure 4. Horizontal air curtain switch protector.

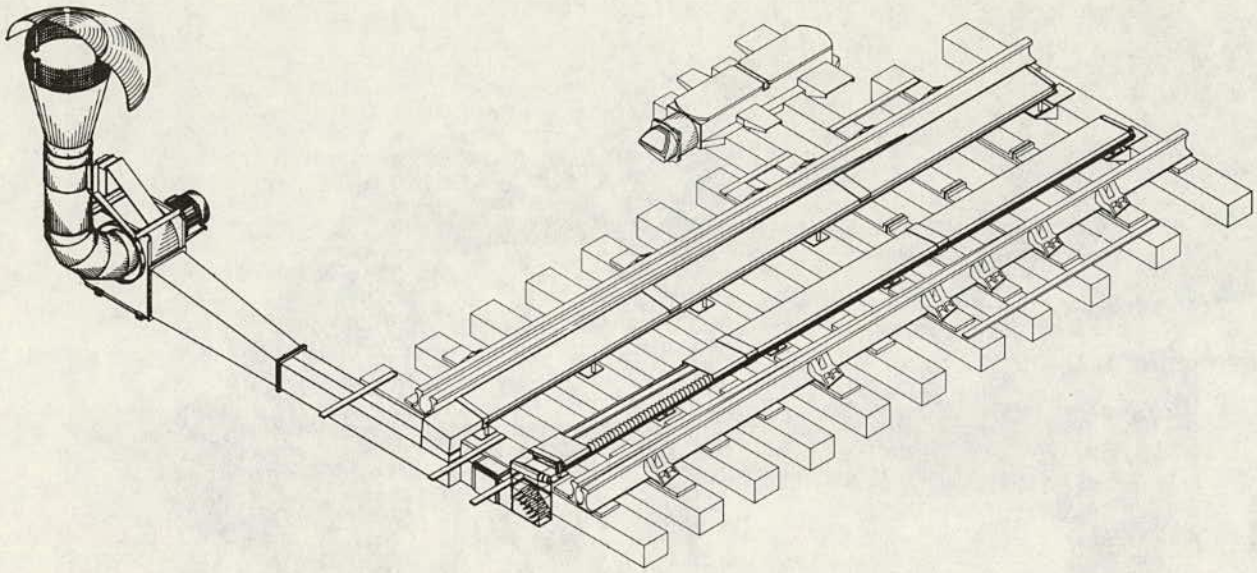

Figure 5. Horizontal traverse switch.

heater operation during snowfall runs down into the ballast and in areas where the ballast is frozen it subsequently turns to ice. It is not uncommon for a switch heater to cause the formation of an ice dam in the ballast around a switch. If the snowfall and low temperature are of sufficient duration the ice dam may grow to such an extent that melt water accumulates in the crib spaces. On heater shutdown this turns to ice and in some cases it renders the switch unserviceable by freezing in the throw rods from the switch machine.

The high cost of fuel is forcing the railways to look to the automatic operation of switch heaters using local condition snow sensors. The units used to date are heated moisture sensors and while they do detect snow some of them may also detect any other foreign conducting material.

While work was being conducted on thermal protection methods, some thought was given to other means of solving this problem since it was considered that heating, in view of the principal disadvantages, i.e. the high operating cost and the consumption of fossil fuel, was unacceptable except as an interim answer.

Non-Thermal Protection

In another field the Low Temperature Laboratory was investigating snow removal from surfaces by non-contact methods. One method under investigation was removal of deposited snow from a surface by the use of high speed air jets. While conducting these tests it was observed that an air jet propelled the airborne snow a considerable horizontal distance before fallout of the particles. This raised the question of whether a railway switch might be protected by an air jet that would prevent snow from depositing in the critical areas. Some preliminary calculations indicated that the energy required appeared to be within reasonable and acceptable limits. The initial mathematical model of the concept was rather crude but served to show the order of magnitude on energy considerations. To investigate further an experiment was set up immediately with an available blower to which a longitudinal duct with a slit nozzle was fitted. This assembly was placed adjacent to an experimental track and subsequently tested under natural snowfall conditions. The initial test verified that a horizontal air curtain could maintain an area free from snow deposit and accumulation.

The horizontal air curtain switch protector is premised on the idea of adding a horizontal velocity component to the existing vertical velocity component of falling snow particles such that the resulting velocity vector will cause the snow particles to be deposited on an area outside of the protected area (3,4,5). The terminal velocity (the vertical velocity component) of falling snow particles has been measured by previous observers. The area of a switch that must be protected against snow deposit includes that between the open point and the adjoining stock rail, the slide plates within the switch, and the top of rail in order that snow does not fall from here into the critical zones.

The duct and nozzle design that ultimately resulted was that of two outward directed longitudinal nozzles to clear snow from within the switch area to deposition zones outside the stock rails. In order to get the jet close to the point and stock rails a double duct system evolved with two longitudinal nozzles. The configuration of the MK III Horizontal Air Curtain Switch Protector is shown in Figure 4. It consists of a low velocity re-entrant design air inlet so that the upward velocity at the entry is less than the terminal velocity of snow particles. This supplies air to a centrifugal fan discharging air to the distribution system at the specified flow and pressure. The duct system is composed of a cross duct, elbows and two longitudinal ducts with slit nozzles.

The MK III Horizontal Air Curtain has subsequently been superseded by a production model, the MK IV, that incorporates various modifications found necessary for field installations. This method of protecting a switch consumes much less energy than the thermal method, e.g. 5 kw electrical energy compared with 62,500 kilocalories (250,000 BTU) per hr of fuel. Several of the problems resulting from operation of switch heaters are eliminated. It has the disadvantage that it is a non-recovery device, i.e. it must be in operation at the beginning of a snowfall since it cannot remove already deposited snow. With the use of snow detectors this method offers a more economical means of protecting existing switches from snow blockage.

There is one other protective method that must be mentioned in discussing this problem and that is housing the switch. The problem with this solution is how long to make the house so that snow does not block a significant length from the end openings. This approach to this problem has been applied by Quebec North Shore and Labrador Railway to one switch. The building is 75 meters (250 ft) in length and unfortunately the problem has not been solved completely by this method. Ore trains moving through the switch and shelter drag along dry snow into the switch. Some improvement resulted by narrowing the building cross section at the switch area so that the higher local velocity would keep the snow moving. The enclosure has resulted in a new secondary problem. Under certain conditions with snow on the roof, moisture condenses and drips to form ice deposits along the track including the switch.

The ultimate answer to the snow problem with railway switches is to redesign the switch so it will not fail from ice or snow. Numerous inventors have outlined various schemes that supposedly overcame this problem and in the Mechanical Engineering Division at NRC we have designed and developed two switches both of which do not fail from ice and snow. One of these switches employs vertical hinged point rails moving in opposition. The other switch is a horizontal hinged assembly in which both the point and stock rail are one swinging beam hinged at the heel end. The switch has been tested in the field for two winters and has not failed due to ice or snow. Figure 5 shows a locomotive crossing the operating switch in winter. Whether these switches are adopted by the railway industry is a question. We do believe, however, that a new switch design will be the long range answer to the snow and ice problem with the existing switch.

References

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