Operational and Economical Advantages Of a New Style Track Switch Heater

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ABSTRACT

The Massachusetts Bay Transportation Authority, in an effort to improve operational reliability on its Green Line light rail system, has instituted a program of replacing existing direct embedment track switch heaters in pavement with a newly developed type of heater. Track switch heaters provide heat to rail track switches keeping snow and ice during winter months from freezing the switch points. Frozen track switches cannot be operated and light rail vehicles cannot run through them and sometimes are forced to take diverging routes which causes severe delays to service. A buildup of snow and ice can also cause derailments. Existing heaters, generically known as 'Tubular Element style' are constantly being replaced due to very fast burnout rate creating unreliability and high replacement cost. Frequent replacement is not only expensive but time consuming and nearly impossible to undertake during snow and ice storm conditions.

Track switch heaters in general use on transit systems in North America use a circular tube heater with the element encased in a magnesium-oxide insulting powder that can be prone to frequent and complete failure due to moisture ingress from sheath disintegration. Previous attempts to mitigate the problems of accelerated failure and difficult replacement have been undertaken by the Authority but with mixed results. Installation methods ranged from insertion in pipes to direct burial but failures continually occurred and so often that all heaters in stock during a heating season were used so that replacements were not available. The new style of switch heater being implemented has proven superior to the types and methods formally employed and has an extended life over a typical heating season at minimum. This style heater has become the standard for the Authority's in-pavement street switch heater.

This paper explains the operational and maintenance problems encountered with the tube style track switch heaters (also referred to as Tubular Element style), the technical reasons they fail on the Authority's system, the steps taken by the Authority over time to solve the problem, the advantage of replacing them with the new style heater and why the new heaters function without failure. It further explains the types of heaters and heater installations that the Authority has gone through in development, the improvements to operation with resulting cost savings, and the methods of installation of this particular type of track switch heating system which have made it superior to the existing track switch heating system in operation, maintenance, cost and safety.

INTRODUCTION

The MBTA is a large traditional transportation system utilizing electrically powered 3rd rail trains, light rail vehicles, streetcars, trolley buses, diesel powered commuter rail trains, internal combustion powered buses and compressed natural gas buses. Boston lies in a region of New England that can experience harsh winters with below freezing temperatures and high snowfalls which impact rail operations. On the Authority's Green Line, routes run on ballasted rights of way and paved streets which are treated with road salts. Where track switches are located, harsh winter conditions can adversely affect their operation through the freezing of components and the buildup of snow at the switch points making them inoperable during snow storms. The Power Division of the MBTA has responsibility for maintaining 150 electric track switch heaters.

Reliable transit service requires that track switches be able to operate in all weather conditions regardless of temperature or snow and, as such, the Authority installs electric heating elements at track switch points to melt any snow or ice to prevent accumulation that would jam the switch point's ability to move. This method, when operating properly, works extremely well and instills reliability to the transit operation. When it does not work, switches become frozen and do not function properly leading to service disruptions and derailments. The Authority in its quest for "A State of Good Repair" has embarked on an ambitious program of replacing Tubular Element style track switch heaters with a new type of heater referred to as the High Efficiency Flat Profile heater (HEFP) style.

Heater Configuration and Operation

Heaters are of the electric resistance type where a heating element is enclosed in an insulated sheath with terminals on each end. A length of insulated flexible copper wire is attached at each terminal and this is spliced to wires that run to the running rail on one end and the overhead trolley wire on the other end or a negative and positive wire lead respectively.

The existing track switch heater, referred to as the Tubular Element style has a nickel chromium wire inserted into a metal tube with a magnesium oxide power surrounding it and compacted to form an insulating barrier. The heating element wire is soldered to the wire leads at each end and a wire terminal covers the connection and is bonded to the sheath. This creates a cold end of 6 inches from each end of the heater to where the element actually starts to become hot. The element is a straight wire where expansion from cold to hot can be excessive. This can create upwards to 6 inches of expansion as the wire increases in length and the heater bends and distorts. The original heaters had separable brass terminals but newer terminals are inseparable. The positive terminal is of a greater diameter than the negative terminal as the negative terminal is crimped over the sheath and wire lead making the sheath part of the negative connection. These heaters conform to an old standard of the American Railroad Association [1] from the middle of the last century.

Heat output for MBTA Power Division heaters is 250 watts per foot and two lengths are used, 10 feet and 15 feet overall with the heated length being 8 feet and 13 feet respectively.

The positive wire lead from the heater runs in conduit to an overhead wire support pole in close proximity where a controller is mounted. The controller takes 600 volt DC power from the overhead contact system (OCS). Controller types vary but for street switches, it is simply a small wooden or fiberglass enclosure with a fuse and a snap switch to open the circuit and shut off the heater (Figure 1). Conduit is typically one inch PVC. The negative wire lead is long enough to extend to the switch casting joint where it is attached to a rail bond with a split bolt connector or wrapped around a track bolt. Figure 2 shows a typical open switch heater with positive and negative connections.

Figure 1. Heater Control Configuration

Figure 2. Heater Installation for Open Switch

Heaters are laid next to the side of the point casting in a loose fashion as no clips are used. For open faced switches, parts of the heater contact the casting and the high wattage is sufficient to transfer enough heat to the casting and point to keep it clear of snow or ice. When the heater is installed in pavement, the heat produced is also successfully transferred to the switch.

Heaters in paved locations are turned on and off manually by personnel going to the controller box and turning on each heater before a snow storm and shutting them off when snow at the switch points is no longer a problem. This is done because there are no existing separate control cables in the light rail yards or along the lines for remote control operation.

History of Track Switch Heating on the Authority's System

Three major types of track switch heating are generally used on railroads and transit systems and they are hot and cold air blowers, gas heaters and electric heaters. Air blowers either cold or hot and gas heaters are impractical for clearing snow and ice on public streets and other paved track areas so that the electric heater must be used. Of the types of electric heaters available, the Tubular Element style heater which was developed during the last century is still effective for certain operations such as open or ballasted track. Where paved track is encountered, Tubular Element style heaters have proven problematic for the Authority.

The Tubular Element style heater in use at the Authority was directly embedded in the pavement next to the switch casting containing the moveable switch point and covered over with excavated earth and then paved over. The positive wire connection of the heater was connected to a another wire that ran to the switch controller where a connection was made to a positive 600 volt attachment at the trolley wire (also referred to as catenary or overhead contact system with OCS as its acronym). The negative lead of the heater was connected to a rail bond or track bolt on the track switch casting at the rail joint as shown on Figure 1.

This method of installing heaters works for a short period as the heaters fail prematurely and replacement requires excavation of the area around the heater, removing the failed unit and replacing it with a new unit. The hole must be backfilled and then repaved for the entire excavated area. Difficulty is encountered during snow storms when a heater fails as excavating in a street at the height of a storm is dangerous and in many instances impossible.

In an attempt to rectify these problems, the Authority has attempted numerous solutions which had various degrees of success prior to the new HEFP heater being adopted. The typical track switch heater that was used had a rating of 250 watts per foot and the high heat being emanated contributed to the heater failing. Another prime factor in heater failure was the sheath being connected to the negative wire lead which was done to reduce the diameter of the negative end to allow the heater to be pulled through a switch dirt box.

ATTEMPTED SOLUTIONS

Teflon® Covered Heater

One of the trials conducted utilized a reduced wattage heater with a Teflon® covered sleeve over the element housing to prevent road salts and other contaminants from corroding the metal sheath and was tested at a paved street switch. Teflon® was chosen as it has unique characteristics in that it never corrodes and will withstand extreme temperature changes of heat and cold without changes in mechanical characteristics. One particular grade, PTFE (Polytetrafluoroethelyne) has a continuous operating temperature of 500°C and dielectric strength of >1400 @10 mils (932°F) Heater wattage was reduced to 150 watts per foot and a small quantity of the heaters purchased. With Teflon® covering and its unique characteristics, it was felt that corrosion and chemical attack could be eliminated and that the heat produced could be withstood by the Teflon® covering. One of these heaters was installed at a street switch and at a ballasted switch with open switch points for a comparison. The track switch components were typical street type with a cast point mate style with girder rail closure rails to the frog.

With this particular heater, the steel sheath was insulated as the terminals on the heater were identical and insulated for 600 volts. This required the switch point operating rod dirt box, a cast box that housed the outer end of the operating rod on the opposite side of the mechanism to keep dirt and debris away from the rod so that it could move freely, to be removed from the point casting and then reinstalled over the heater. Each dirt box has a notch at the rail base interface to allow heaters to be pulled through it but the Teflon® heater could not fit due to both ends having a larger positive type terminal.

The street installation was installed in the usual manner with the heater placed next to the point casting and buried. The ballast installation had the heater placed in the same manner except that it was open to the air. The street switch was installed and after less than one month, failure occurred. Inspection revealed that the Teflon® had completely melted and the steel tube was burnt out from corrosion. The Teflon® jacket offered no resistance to corrosion as it could not handle the heat produced by the heater and it was considered a failure.

The heater with Teflon® installed at the open switch did not fail but the Teflon® sleeve melted away exposing the steel tube. The heater continued operating for over six months until a snow storm rendered it ineffective. The unit did not fail but the 150 watt per foot heat output was insufficient to melt snow as the heater was not tight against the casting. Expansion deflection caused the heater to bulge out and away from the switch. In order to compensate, the heater was then covered with eight to twelve inches of ballast as a means to insulate the unit and this allowed enough heat to be contained that the snow melted and the switch point could be thrown.

The Authority, at that point, reverted back to the 250 watt per foot heater with a positive lead terminal and a smaller negative lead terminal as these posed no problem to proper heating for open switches, could be used at paved switches do to easy placement through the dirt box but continued to search for solutions to buried heater failure problem.

Insertion Pipe and Joint Boxes

The next design that was considered utilized a one inch pipe with access boxes at each end so that a failed heater could be withdrawn and a new heater installed without excavating the pavement. Heater types could be such that they had insulated ends with a neutral sheath (in that it was not connected to the negative wire lead) as the pipe had consistent diameter allowing large terminals to be drawn through. The access boxes were fabricated with standard girder rail joint bars and welded with sides in such a manner that a cover could be placed onto it that would lie flush with the top of rail and the pavement. The bottom was omitted for drainage. One box was installed at the switch casting joint and a mirror image box at the opposite joint with a hole in the side wall for the pipe to be inserted.

The joint boxes were actually the joint bars for the casting and attachment rails and allowed the track bolt to be inserted from the other side of the rail and nutted inside the joint box. The pipe was tack welded to the casting and the dirt box altered to allow the pipe to fit through. With or without a heater, the switch operated properly and safely with the joint boxes and pipe attached. The steel used for the joint box was standard A36 plate steel non-galvanized and extra heavy black pipe. Due to the requirement of welding on the switch casting, galvanizing was not used. Figure 3 shows the joint box attached to the rail joint with open cover.

When installed, the pipe/joint box installation worked very well and heaters could be installed in paved areas quickly and removed quickly if failure occurred. At the Boston College terminal and yard, all of the paved switches at the yard entrance (total of 8) were equipped with the pipe/ joint box heaters and remained in service without incident for four heating seasons. The Reservoir yard and Cleveland Circle areas were also equipped with the pipe/joint box heaters (total of 31) and operated well for two heating seasons with minimal heater failure.

The pipe system initially worked without incident but as time progressed, the corrosion from water combined with road salts attacked the pipes and joint boxes and saturated water with salts drained into the pipes causing sheath corrosion and failure. As heaters failed during storms and cold weather, the water froze in the pipes making simple removal impossible. Road dirt also drained into the joint boxes and pipes and coupled with water became almost like concrete when frozen. Failed heaters had to remain in the pipe and the pavement excavated so that a new heater could be laid in near the surface of the street. Continued corrosion of the pipes rendered the installations unusable so that the pipe system was abandoned and the former direct bury system was continued.

Figure 3. Pipe/Joint Box Configuration

In order to melt the frozen switches, crews used special "Hock" heaters to melt the ice or piled road salt onto them further adding to corrosion of the joint boxes, pipes and track components.

Channel Containment

By 2004, the heater problem had continued to plague the Operations Directorate and the Power Division with heater failures and switch problems during winter months. A method was devised by the Authority where heaters could be quickly replaced without excavation and burying the heaters. A double channel consisting of two stainless steel U shaped parts was designed and fabricated at the

Authority's Everett shops for a trial at one of the street switches.

The system consisted of an angle shaped bottom piece that was to be welded to the switch at the running rail head. A cover piece of a slightly smaller U shaped channel piece fit into the bottom channel area creating a smooth surface that was flush with the rail head and the pavement. When the two pieces were together, there was space for a track switch heater between the two.

The bottom angle and channel area had a series of drain holes so that any accumulated moisture could drain out. The top piece had security bolts holding it to the bottom channel so that it could not become loose but could be easily unscrewed from the top for heater installation. The heater was to be laid into the channel area on ceramic spacers so that the heater element would not contact the sides of the containment channels.

After fabrication the unit was readied for installation and a location chosen but it was never installed.

New Style Heater

During the year 2009, a new style track switch heater was introduced to the Authority and evaluated as to whether it would be acceptable for trials. The design of the heater and the method of installation along with its history on other transit systems was considered and a determination made to allow testing of one unit at a paved street switch. The material cost for the heater was of concern but the initial trial was at no cost to the Authority so installation proceeded.

A number of factors led to the decision to allow trials and the primary one was the claim that the heater was designed for direct embedment without failure. Another factor was that the heater used less power but claimed to still provide adequate heat for snow and ice removal. Still another feature was the sheath being neutral and not connected to the negative wire lead. These factors and the overwhelming need to find a suitable replacement to the Tubular Element style heater were convincing enough for a trial to commence.

The heater has a flat configuration in that it lies against the side of the point casting providing more surface contact. The increase in contact areas compensates for the reduced wattage and power consumption without sacrificing heating efficiency. A clip on spring clip keeps the heater positioned tight against the rail for new installations insuring heat transfer is accomplished as efficiently as possible. For replacement of existing heaters, the area next to the switch casting is excavated and the new heater layed in next to the casting near the top and then back filled and paved over (Figure 4). The heater is able to pass behind the dirt box in the same recess as the old style heater (Figure 5).

The heating element itself is resistive and of constant wattage with only one terminal where the positive negative lead wires are connected to their respective wire leads (Figure 6). This initially was of concern to the Authority as all existing heaters are designed with two terminals, a positive on one end and the negative on the other end. Re-wiring the heaters at each track switch would be required but if the trials proved successful, this was a minor inconvenience.

The sheath of the new style heater is made from MONEL 400 steel, a compound that is impervious to corrosion from salts and natural contaminants. The sheath also, as previously mentioned, is electrically neutral so that it does not have an electrical potential that would allow electrolytic currents to flow off and destroy it as with the Tubular Element style heaters.

Figure 4. New Style Heater Installed

A unique feature of the heater design is the heater element wire. It is a nickel chromium resistance wire that is spirally wound around a fiberglass core which yields substantially reduced thermal stress and expansion/contraction so that bulging of the unit does not occur. The element is connected to the positive lead wire at the terminal, passes down the length of the heater to the end and then passes back along the length of the heater to the terminal where it is connected to the negative wire lead. This gives twice the heat at half the wattage per foot. These heaters, used at the MBTA, have an expansion of only 1/2-3/4 of an inch longitudinally keeping the heater against the rail for heat transfer.

Figure 5. New Style Heater Passing by Dirt Box

After a lengthy trial of one full year with the heater continually energized putting out heat and buried in pavement, the test was deemed successful and the Authority commenced replacing the existing Tubular Element heaters at paved street switches as they failed with the HEFP style heater.

Figure 6. New Style Heater Terminal

Cost Advantage with New Heaters

As shown in Table 1, heat output in terms of current is from 1.5 to 2.0 amperes resulting in an overall wattage of 900 watts for a 10 foot heater and 1200 watts for a 15 foot heater. The cost to operate a 10 foot HEFP style heater continuously for 24 hours is approximately $1.94 compared to a Tubular Element style heater for the same period which is $4.32. This shows a significant cost savings of 222%. The cost savings for a 15 foot HEFP style heater is 271%.

For 150 heaters, approximately 75% are 10 footers and 25% are 15 footers giving 112-10 foot heaters and 38-15 foot heaters. The cost to operate all the heaters with Tubular Element style heaters is therefore $750.60 for a 24 hour period and $315.70 for the same period with the HEFP style heaters. Total 24 hour savings are $434.90. It is 2.37 times more expensive to operate Tubular Element style heaters as regards electricity costs.

A typical MBTA line crew performing heater replacement on a daily basis has a loaded daily cost of $256.00 per hour. Given the fact that direct imbedded Tubular Element heaters fail on a daily to monthly basis and that a crew may be called out to replace each heater on a daily or weekly basis so that there is essentially a line crew assigned to heaters during the winter, the cost becomes excessive. Compared to the cost of an HEFP heater versus a Tubular Element heater with subsequent installation/replacement costs included, the new style heater has proven to be far more economical than the old style as the HEFP style heaters initially installed over two years ago are still functioning.

Table 1

Heater Comparison		
	Tubular Element Style	**HEFP Style**
Cost to Purchase	$250	$532
Current Draw--10 Ft Heater	3.3 A	1.5 A
Current Draw--15 Ft Heater	5.41 A	2.0 A
Time to Install (new)	2 Hrs	2 Hrs
Service Length Before Failure	1 day to 3 months	2 years without failure
Authority Cost for Electricity	$0.09 kW	
Cost to Operate—10 Ft	$4.32 /24 Hrs	$1.94 /24 Hrs
Cost to Operate—15 FT	$7.02 /24 Hrs	$2.59 /24 Hrs

Although statistics and records for which heaters fail during the course of the heating season are not kept and given that some heating seasons are not as severe as others, it can be estimated that 50 Tubular Element style heaters fail in a monthly period. With a heating season of approximately four months, 200 heaters must be replaced. Considering that a line crew must get stock and has travel time, two to four heaters can be replaced in a day (conduit and controls complete and intact and not part of replacement) given the type and location of the heater. Cost for a line crew is $256/hr loaded and with a crew working daily for four months, the cost is $163,840.00. The cost for heaters is $50,000.00 and to keep the Tubular Element style heaters operating during winter months the ***total cost is 213,840.00.***

With the new style HEFP heaters, the initial investment to replace the Tubular Element style heaters when they fail will be $79,800 for all 150 locations but the Authority would have to spend $37,500 to purchase the Tubular Element style heaters as they do not last longer than three months. The cost for labor would be included in the cost for regular Tubular Element style heater replacement which is constantly occurring so that labor would not be considered in the conversion cost.

Once all 150 heaters are changed over to the new style HEFP heater, daily and weekly burnouts will be minimized to a point where the winter heater crew can be assigned to other important overhead contact system maintenance tasks and only used on a minimal basis heater inspections. It is estimated that in one heating season, a savings in labor and materials of $213,840.00 with a savings in power costs of $52,188.00 will be realized. This provides a ***total yearly savings of $266,028.00.***

The costs associated with the new style heaters can be justified when the alternatives are considered, i.e. heater outages, constant replacement, inoperable track switches, derailments, political outfall, and difficult emergency repairs. The Authority's Power Division will therefore continue with its replacement of Tubular Element style track switch heaters with the new HEFP style track switch heater in its quest to achieve a state of good repair.

CONCLUSION

The Massachusetts Bay Transportation Authority has experienced extreme failures of Tubular Element style electric track switch heaters used for switches in paved streets. In the Authority's program to return to a "State of Good Repair" and to overcome the switch heater problem, various solutions have been implemented but have proved unsuccessful. A recent solution for problem resolution was the use of a new style High Efficiency Flat Profile track switch heater which has proven to be highly successful as it is able to operate under the adverse conditions imposed upon it when buried in pavement and has done so for periods of over two years without failure.

Replacement costs for burned out Tubular Element style heaters are expensive over a yearly period and the new style heaters have minimized need for replacement to an almost zero level so that mean time between failures is no longer days but years. The new style heater is less expensive to run and has saved the Authority on power costs without sacrificing heating capability.

Savings realized over a yearly basis have amounted to $266,028.00 which includes a reduction in power consumption of over 200%. Heater operations have become extremely reliable in snow and ice storms as the new style heaters have extensively long service life and can be depended upon to operate whenever needed. The Authority's goal of "A State of Good Repair" has been advanced as the track switch heater problem for paved switches has been eliminated and Green Line transit service has become more reliable.

ACKNOWLEDGMENTS

The primary author was employed as Superintendent of Transmission and Distribution of the Massachusetts Bay Transportation Authority prior to retirement and the secondary author now holds that position with the Authority. The authors wish to acknowledge the support of the MBTA Operations Directorate, the MBTA Power Division, RTR Technologies, Inc. and HNTB Corporation during the preparation of this paper. The views presented herein are those solely of the authors and in no way reflect the opinions or beliefs of the MBTA, RTR Technologies, Inc. or HNTB Corporation.

END NOTES

1. A.A.R. Section 11 Electric Heating, Latest Revision, Chapter 2, Part 4

LIST OF FIGURES

LIST OF TABLES