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Experimental Verification of Contactless Heating Method in Railway Turnouts Heating System

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Summary

In winter conditions, railroad turnouts are an element of railway infrastructure that is particularly vulnerable to weather conditions such as snowfall, blowing of freezing rainfall, low temperatures. To maintain them in full operability during unfavorable weather conditions turnouts heating systems are used. The basic system used for decades on European railways is the electric heating of turnouts (ETH). This system uses resistance heaters, is characterized by high energy consumption and low efficiency. Railway authorities, in many European countries, look for new solutions in the field of electric turnouts heating. In this paper experimental verification of a new ETH concept is presented. The new methodology uses contactless heaters instead of the classic ones and is based on an innovative way of heat distribution. As a reference object for the contactless heater, the classic ETH was used. Experimental research in real conditions were carried out at turnouts exploited in the Polish State Railways (PKP) network. The research was carried out in various weather conditions. As a part of the test, thermo-vision measurements were done, as well as measurements by thermo-couples and a melting rate was observed. In each case, comparative tests were carried out. The results were gathered, analyzed, concluded and presented in the paper.

Keywords: electric turnouts heating ETH, optimization of ETH system, contactless electric turnout heating

1. Introduction

The objective of using the railroad switch heating is to ensure a failure-free operation of the railroad switches in winter conditions, during snowfalls, snow being blown in by wind and trains, freezing rainfalls and severe frosts. Those factors might lead to railway transport safety issues as a result of railroad switches blockade causing their movement impossible.

In order to ensure the operability of railroad switches in winter, the critical elements of the railroad switch are heated:

- obligatorily – stock-rails (rails), movable obtuse crossings;
- optionally – slide chairs, switchblades, point locks, under-lock channels.

The paper presents experimental verification of the application of radiator insulation from a stock rail in terms of increasing heating efficiency.

2. Heating of the stock-rails by means of electric heaters – the classic solution commonly used in Europe

The most important part in the process of heating the railroad switches is melting snow out of the working area: the space between the stock-rail and the switch blade as well as from slide chairs. Rod flat-oval heaters are most often used as heating elements. They are fixed by means of clips to the rail foot so as to allow them to come in contact with the slide chair. This is expected to provide good heat permeation from the heater to the stock-rail. The working area of the railroad switch stock-rail heating consists of two kinds of snow melting zones (Fig. 1): zones between the slide chairs – hereinafter referred to as Zones A, zones by the slide chairs – hereinafter referred to as Zones B.

As mentioned above melting out the snow and icings in zones A is to get the stock-rail heated up by

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a source of heat which is the electric heater fixed to the stock-rail. The heat is transferred from the heater to the stock-rail mainly by direct conduction of heat. Therefore, it is so important to provide the best possible contact of the heater with the stock-rail of the railroad switch. Additionally, the heat is transferred from the heater to the stock-rail also by radiation and convections, however, to a much smaller degree than by diffusion. The heated stock-rail works as a radiator, emitting heat, part of which is emitted towards the working area, i.e. into the space between the stock-rail and the switch blade which causes the snow which has been accumulating there to melt out. Partially, the snow between the stock-rail and the switch blade is also melted out by the heat emitted directly from the surface of the heater towards the zone A of the working area. The transfer of heat in the zones A (between the chairs) from the heater to the stock-rail is shown in Fig. 2.

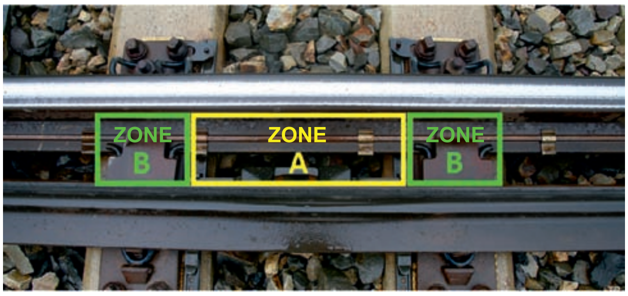

Fig. 1. Snow melting out zones in the working area of heating stock-rails [photo by D. Brodowski]

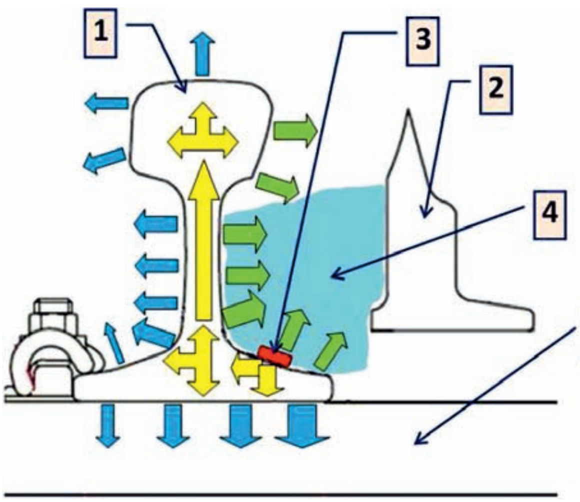

Fig. 2. The heat transfer from the heater to the stock-rail and directions of the heat emission from the stock-rail: 1) stock-rail, 2) switch blade, 3) electric heater, 4) snow in the working space to be melted out, 5) switch sleeper; yellow arrows: directions of the flow of heat in the stock-rail, green arrows: the useful heat emitted from the stock-rail and the heater, blue arrows: the useless (lost) heat emitted from the stock-rail [own study by D. Brodowski]

3. Drawbacks of the currently employed method of melting out the snow

During the last several winters, during intense snowfalls, many European railways experienced problems with the operation of railroad switches although heating systems were used. In extreme conditions of heavy snow and low temperatures, the electrical heating of railroad switches was not able to efficiently melt out the snow. This phenomenon occurred most of all in the switch blade edge zone where the distance between the switch blade and the stock-rail is the biggest (Fig. 3). The current method of snow melting between the stock-rail and the switch blade where the stock-rail is treated as a radiator emitting heat, used in the prior art, has the following drawbacks (Fig. 2):

- significant losses of heat, emitted by the stock-rail in all directions, only the heat emitted towards to the switch blade of the railroad switch is the useful heat, suitable for melting out the snow,
- the heat radiated in the remaining three directions is the lost heat; high inertia, i.e,
- a long time of heating up the stock-rail and, as a result of that, a long time needed to melt the snow out from the working zone.

Fig. 3. Inefficient melting out the snow in the switch blade edge zone during intense snowfalls. The visible irregularity of melting out the snow along the stock-rail [PKP PLK January 201]

4. Concept of melting out the snow from the working space by means of the contactless heaters

In this solution the most heat from the heater is directed towards an area between the stock-rail and the switch blade, avoiding the switch stock-rail. It requires isolating the heater from the stock-rail. The following assumptions have been made for the new

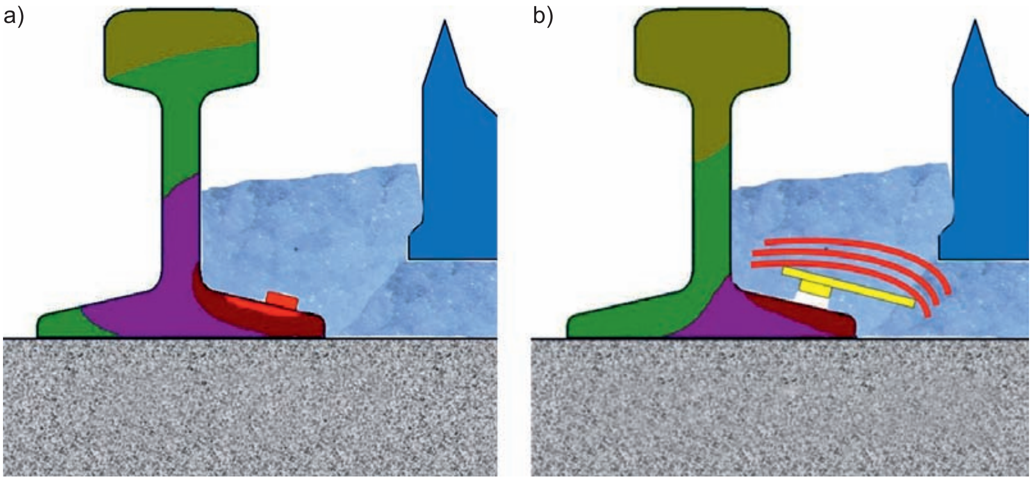

Fig. 4. Standard heater (a) and contactless heater with a radiator (b) [photo by D. Brodowski]

concept of melting out the snow between the stock-rail, and the switch blade, employing the use of new contactless heaters (Fig. 4):

1) the rail heat element need to be move back from the rail, preferably 2 mm; thanks to that, the heater will reach higher temperature, because the heat is not flowing through the rail (Fig. 4b);
2) the way to achieve the contactless heater is contactless radiator, which is mounted on the currently used flat elements (Fig. 4b). In that way, the heating surface is increased.

In 2010/2011 TERMORAD (BACKER Group, 2016) made various concepts of contactless heating elements, based on the presented solution (Fig. 5). The design of the heating element itself does not differ from the wire heaters which have been used so far to heat up stock-rails. It is a resistance wire heater, with a heating coil, in a metal jacket. Therefore, it requires isolating the heater from the stock-rail. So that it is a total reversal of the stock-rail heating principle against the currently employed one. The new method of heating concerns only the zone between the chairs (zones A). The heating principles in the zones by the chairs (zones B) remain the same.

Fig. 5. Contactless heaters produced by TERMORAD, a) contactless heater, b) radiator [photo by D. Brodowski]

5. Contactless radiator for rod flat-over heater

The simplest method to achieve the contactless heater is based on a contactless radiator, which is mounted on the currently used flat elements. This solution increasing efficiency of melting snow and defrozing ice on the rail switch points. Radiator is mounted on the currently used flat elements, existing on the rail switch point (Fig. 6).

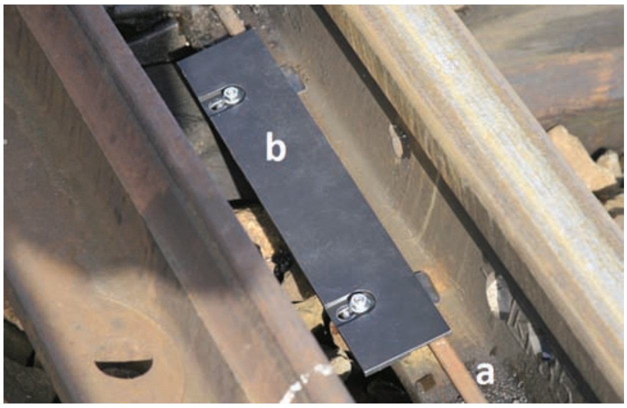

Fig. 6. Contactless radiator for rod flat-over heater. a) flat-over heater, b) radiator [photo by D. Brodowski]

Mounting contactless radiator to the flat heating element is very quick and simple. There is no need to disassemble rail heat element in the rail switch point. Standard clips mounted on the flat element are replaced by contactless grips. The radiator is screw to those contactless grips. Contactless grips making a space between rail foot and the heater, focusing the heat energy into radiator, which is also not in contact with rail. Radiator sending the heat energy directly to the zone between slide chairs.

6. Tests of the contactless heaters on the PKP railroads in the winter seasons 2010/2011 and 2011/2012

The tests of the new contactless heaters were carried out by the Railway Institute in Warsaw by order of the producer, Termorad. The primary proving ground was the station Prostki station, in the north-eastern Poland, not far from the Lithuanian, and Belarussian border. This region of Poland is known for long, and heavy winter seasons, with heavy.

Comparison of melting snow by standard heaters and contactless heaters with a 35 mm aluminum heat sink, at an ambient temperature of −24°C, heating time 4 hours, without precipitation and wind

In the beginning of the tests both heaters (Fig. 7a, 7b) were fully covered by the snow. The measured air temperature was −24°C. In the ambient temperature of −24°C barely any snow was melted by the standard heater (Fig. 7c), whereas the new contactless heater, with a full aluminum radiator, 27 mm wide, melted out about 2/3 of the snow from the space between the stock-rail and the switch blade (Fig. 7d). Significant differences in the degree to which the stock-rail was heated up were visible. In case of heating with a standard heater, 330 W/m, after 4 hours of constant heating, the temperature of the stock-rail head was +18°C, the temperature of the foot achieved +20.7°C. So, the increase of the temperature was ΔT = 44.8°C. Meantime, in case of heating with a contactless heater, 308 W/m, after 4 hours of heating the temperature of the head was only 0°C.

Comparison of melting snow by standard heaters and contactless heaters with a 35 mm aluminum heat sink, at an ambient temperature of −6°C, heating time 3 hours, without precipitation and wind

As in the previous test, the cooled turnouts were covered with a layer of snow up to the height of the rail head. After 3 hours of heating at an ambient temperature of −6°C, without precipitation and wind, the standard heater melted about 20% of the snow volume, while the contactless heater with a heat sink melted all the snow between the resistor and the needle. The

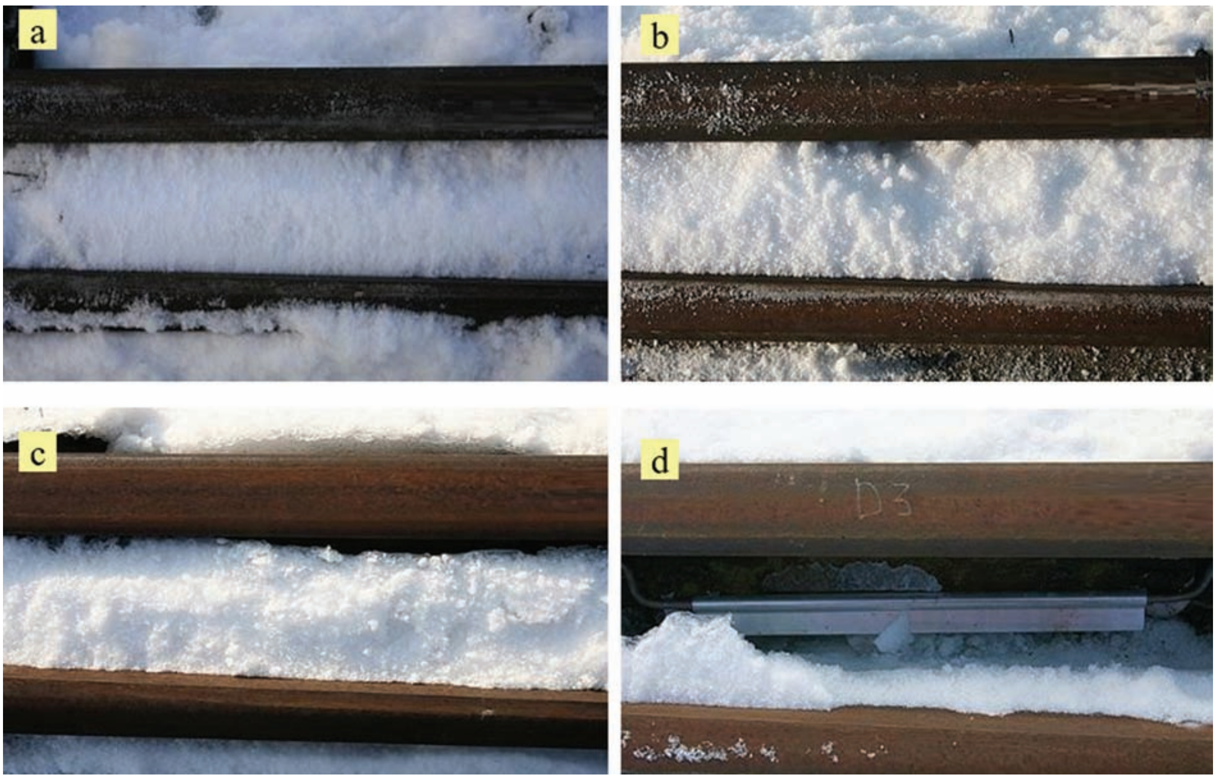

Fig. 7. Comparison of the effectiveness of snow melting by standard heaters and contactless heaters with an aluminum heat sink. Measurement in conditions without precipitation and wind, ambient temperature −24°C; a) standard heater before heating starts, b) contactless heater with a heat sink before starting heating, c) standard heater after 4 hours of heating, d) contactless heater with a heat sink after 4 hours of heating [photo by D. Brodowski]

remnants of snow visible in Fig. 8b are located below the movable spire and do not collide with it. Figure 8 a and b show the visible differences in the degree of snow melting.

7. Thermal measurements

Tests were conducted in Szklarska Poręba. Railway Institute, research unit ordered by Termorad, conducted a full research on mounted at the station switch points flat railway heaters manufactured by TERMORAD, and also S.A.N. Purpose of the research was to conduct comparative analysis of snow melting efficiency with usage of classic heaters and the proposed method with heaters equipped in contactless radiators.

Temperature tests were carried out using a FLIR-E50 thermal imaging camera and a thermocouple temperature meter. Weather conditions: ambient temperature −7, −8°C, no precipitation, with a slight wind. Temperatures measured 30−40 minutes after switching on the heating. Temperature images from a thermal imaging camera are shown in the following Figure 9.

From the temperature distribution measured at the sliding plates (saddles), it is clearly visible that the temperature increases achieved at the saddle surfaces are clearly greater when heated with contactless heaters with radiators. The average temperature on the surface of the saddles in the cold state, before the heating was switched on, was −0,5°C. Then temperatures shown that in the temperature increase in the saddle with non-contact heating it was 16,5°C, and in the travel with standard radiators, it was 10,5°C. The temperature on the surface of the radiator with standard heaters was 150°C, on the surface of the contactless heatsink from 125°C to 132°C.

Average temperatures from a series of measurements. Temperatures achieved by the head and neck of the rail heated with standard radiators are about 2 times higher than the temperatures when heating with contactless radiators. However, with contactless radiators, higher temperatures are achieved on sliding saddles. This confirms the idea of contactless heating, where less heat is directed to the rail (resistors) and more to the working space between the spire and the resistor, and to the sliding saddles, so where it is needed most. It is necessary to emphasize the fast heat-up time of radiators. The fixed temperature is reached after about 15−20 minutes.

8. Conclusion

The classic ETH system is characterized by high energy consumption. Often, it's efficiency is not sufficient to fully melt lying in the turnout snow. Melting of snow lying inside the working area requires a significant amount of energy. It's because the heater heats up the rail, then is dissipated all around and only a little of heat melts the snow. By providing thermal insulation between stock rail and the heater (optionally, with a radiator) the heat is distributed directly into the working area. The use of the new solution would reduce installed heaters' power while increasing heating efficiency. It's supposed that contactless ETH implementation will drastically reduce operating costs of ETH system exploitation.

The research showed that the new solution has significantly higher efficiency in comparison to classic ETH. With the same heaters' power in both cases, contactless ETH is characterized by: a higher level of melted snow, the time of heating is reduced even twice. Experimental tests validated that an increase in heating efficiency may be achieved by means of changing

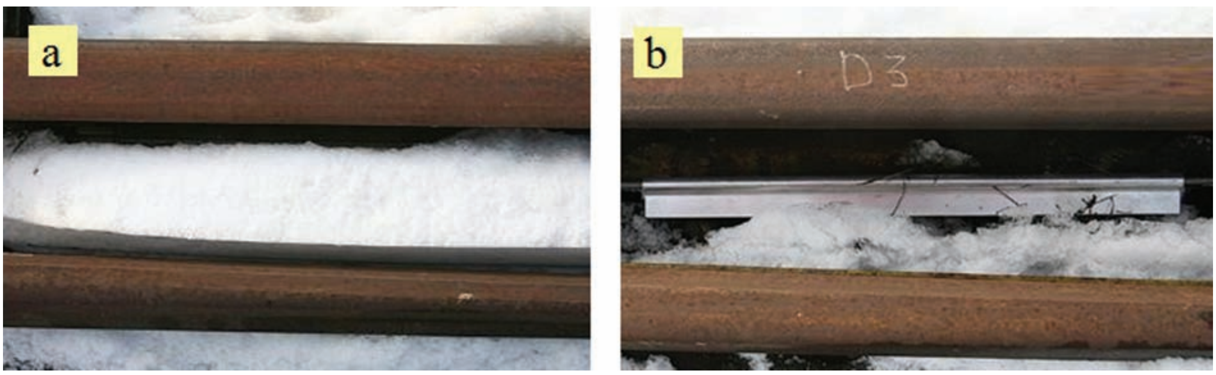

Fig. 8. Comparison of the smelting efficiency of a standard heater (a) and a contactless heater with a 35 mm aluminum heat sink (b). The state of melting snow after 3 hours of heating at an ambient temperature of −6°C, without precipitation and wind [photo by D. Brodowski]

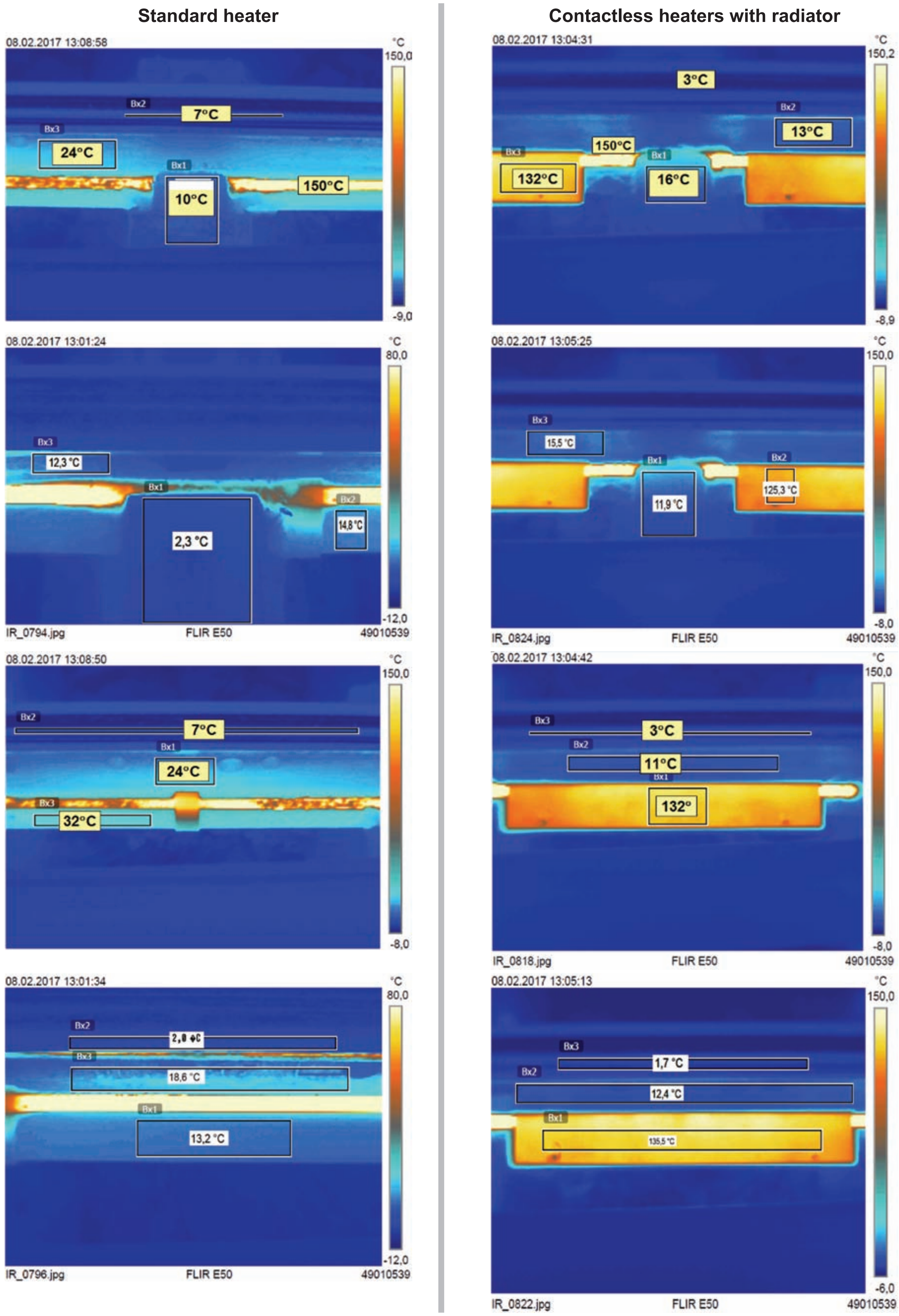

Fig. 9. Temperatures in turnouts heated with standard heaters and heaters with contactless heat sinks, images from the FLIR-E50 thermal imaging camera [own study by D. Brodowski]

the direction of heat flow in a turnout. It was found, that new solution of contactless heater melted accumulated snow between stock rail and blade noticeable quicker in comparison to the classic method. It is possible to reduce melting time by half, compared to the currently used approach. The cause of the efficiency increase is modified heat distribution. The heating process effectiveness might be improved to the great extend in a heating system supported by radiator. The most amount of heat energy is conducted to the zone between stock rail and blade. Heat energy loses are reduced by air gap, or insulation material essential in contactless method.

The elements which determine the speed of melting out the snow are primarily the two following factors: the temperature of the jacket surface or the heater radiator and its surface. The temperatures of contactless heaters achieved on the surface of the radiator, in spite of slightly lower power level, are much higher than the temperatures achieved on jackets of standard heaters. The lower temperatures of the standard heaters result from significant reception of heat by the rail, for this reason, nearby the clips where the contact of the heater with the rail is the best, the temperatures on the heater jackets are the lowest.

Therefore, the relatively low temperatures obtained on the surface of the standard heater result from the high amount of heat collected by the railroad switch stock-rail with which the heater is in contact along its entire length. On the other hand, the lack of contact between the heater and the radiator results in higher temperatures on its surface. At the same time, the almost three times larger heating surface of the contactless heater with a radiator is the cause of the much higher snows melting efficiency.

References

1. Brodowski D.: *Raport z badań grzejników eor z radiatorami bezstykowymi GKA na stacji Szklarska Poręba Górna* [Report into EOR experimental research at SPG railway station], Poręba Górna, Instytut Kolejnictwa, Warszawa, 2017.
2. Übersichtsstudie Energieeffiziente Weichenheizung. Grüniger GmbH: A. Grüniger H. Luzern, Technik&Architektur Kompetenzzentrum Thermische Energiesysteme&Verfahrenstechnik, L-rn 2014.
3. Jana S., Ray S., Durst F.: *A numerical method to compute solidification and melting processes*, Elsevier, Applied Mathematical Modeling 31 (2007).
4. Kloow L.: *Eksploatacja pociągów dużych prędkości* [High-speed train operation], KTH Railway & Transrail, Sztokholm, 2011.
5. Flis M.: *Analiza efektywności energetycznej systemów ogrzewania elektrycznego* [Energy efficiency analysis of ETH systems] PhD Thesis, Politechnika Gdańska Wydział Elektrotechniki i Automatyki, 2018 [in Polish].
6. Prezentowane rozwiązanie grzejników bezstykowych do wytapiania śniegu na kolei, patent nr 2677079 [Presented solution the contactless heaters, to melt out the snow on the railroad is protected by patent number, 2677079], opublikowanym przez Europejski Urząd Patentowy w dniu 27 kwietnia 2016 roku.
7. Brodowski, D.: *Ogrzewanie rozjazdów kolejowych* [Railway turnouts heating], Instytut Kolejnictwa, 2002, z. 135.
8. Dutil Y. et.al.: *Przegląd materiałów zmiennofazowych: Modelowanie matematyczne i symulacje* [Review of phase change materials: Mathematical modeling and simulations] (2011).
9. Flis M.: *Przegląd metod wytapiania śniegu w rozjazdach kolejowych* [An overview over the methods of snow melting in railway turnouts], Zeszyty Naukowe – Poznański Uniwersytet Techniczny, Elektrotechnika nr 83, Poznań, 2015.
10. Flis M., Wołoszyn M.: *Analiza efektywności energetycznej ogrzewania rozjazdów kolejowych z wykorzystaniem uproszczonego modelu śniegu* [Energy Efficiency Analysis of Railway Turnout Heating With a Simplified Snow Model], 8. Warsztaty Doktoranckie, Materiały z konferencji, Polska.