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Complex evaluation of service properties of car insulation bodies

Key words

Insulation body, heat-insulation, diagnosis, heat leakage bridge.

Słowa kluczowe

Nadwozie izotermiczne, termoizolacja, diagnoza, mostek ciepła.

Summary

The paper presents the author's proposal, elaborated within the project KBN 5T07B02022, of a complex evaluation system of heat-insulating power of car insulation bodies. The system allows to carry out diagnoses for: the classification of bodies in accordance with the requirements of the international agreement ATP (concerning perishable foodstuff transportation), the determination of insulation body weak points (heat leakage bridges) in order to develop a new design or plan an overhaul, the evaluation of the repair being carried out.

1. Introduction

Insulation bodies are used for transportation of:
- perishable foodstuff
- medicines
- explosives.

The main region of using the mentioned bodies is transport of perishable foodstuff.

The basic parameter determining a climate in the environment of food products (in the transporting chamber) is the temperature – its fluctuations have

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to be kept to a minimum. The selection of optimal ranges of temperatures for the individual kinds of products is of essential importance.

The most detailed information on the transport conditions (in the international scale) of perishable foodstuff is contained in the agreement ATP. This document [1] determines as follows:

- temperatures in which selected groups of food products should be transported (there are distinguished frozen or deep frozen products and cooled products),
- classification of vehicles for food transportation and requirements which they should meet (there are distinguished insulated bodies, refrigerated, mechanical refrigerated, heated),
- methods of testing and marking the bodies for food transportation.

A criterion for the classification, from the point of view of heat-insulating power, of insulation bodies is an overall heat-transfer coefficient

$$k = \frac{Q}{A_{śr}\left(\left|t_w - t_z\right|\right)} \tag{1}$$

where:

k – an overall heat-transfer coefficient,
Q – thermal flux penetrating through the walls, roof, floor of the insulation body in the steady state,
$A_{śr}$ – mean surface of body walls,
t_w – temperature inside the body,
t_z – temperature outside the body.

The agreement ATP stands out the following insulation bodies:

- with normal insulation where $k \leq 0.7$ W/(m^{2}K), and
- with heavy insulation where $k \leq 0.4$ W/(m^{2}K).

In Poland, there are two stations dealing with tests on insulation car bodies regarding compliance with the requirements of the international agreement ATP; they are:

- Central Cooling Centre in Cracow, and
- Institute of Machines and Automotive Vehicles of Poznań University of Technology.

Representatives of these institutions take part in the works of the working group UN WP11 dealing with the development of testing methods for technical means used for transportation of perishable foodstuff.

Institute of Machines and Automotive Vehicles of Technical University in Poznan had carried out numerous works including the research project KBN 5T07B02022 [2] and in the effect of the actions the measuring procedures presented in the agreement ATP were complemented of auxiliary methods (among

others the infrared diagnosis). Finally, there was elaborated and applied in practice the complex evaluation system of heat-insulating power of insulation car bodies assisting (verifying) design and technology (mounting) solutions in a group of new products and making easier the choice of repair technologies for serviced bodies.

2. Assumptions of the complex evaluation system for new and serviced bodies

The elaborated complex diagnostic system can be applied for:

- classification of the body in accordance with the requirements of the Agreement ATP [1],
- evaluation of the serviced body to determine its condition,
- determining weak point in order to:
  - develop a new construction,
  - plan an overhaul,
  - evaluate a repair.

There will be presented below the optimum sequences of partial tests enabling the possible complete realization of the diagnosis purpose.

The classification tests for the compliance with the requirements of the Agreement ATP can be performed only with the use of a precise method of determining the overall heat-transfer coefficient. If the test result is positive, i.e. if the relation (2) is fulfilled, the body is accepted as meeting the requirements of the Agreement ATP:

$$k \leq k_{gr} \tag{2}$$

where:

k – overall heat-transfer coefficient of the tested body,

k_{gr} – boundary value of the heat-transfer coefficient for the required class of the body.

The body which will not meet the requirements of the Agreement ATP should be subjected to further diagnosing in order to develop the construction (new body) or plan an overhaul (serviced body). The above discussed actions have been recorded in a form of the block diagram presented in the figure 1.

If there is a supposition that the heat insulating properties of the body serviced between obligatory classification tests have deteriorated it should be evaluated by the transport company with the use of the similar method e.g. basing on the cooling rate [2]. If the test result is positive, the body can be designed for further service. Otherwise the body should be made a diagnosis according to the procedure applied when planning an overhaul. The above presented actions are given in the figure 2 in a graphic form.

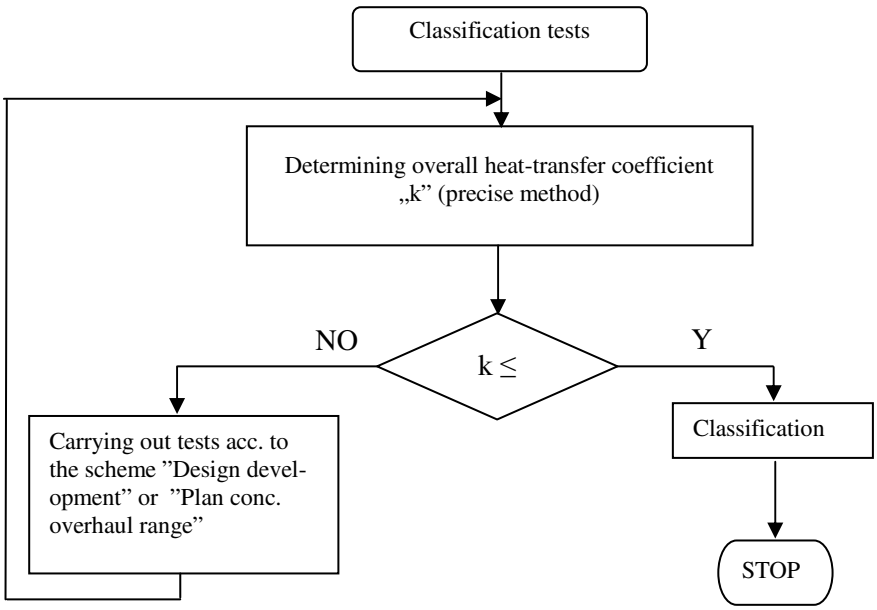

Fig. 1. Body classification tests
Rys. 1. Badania klasyfikacyjne nadwozia

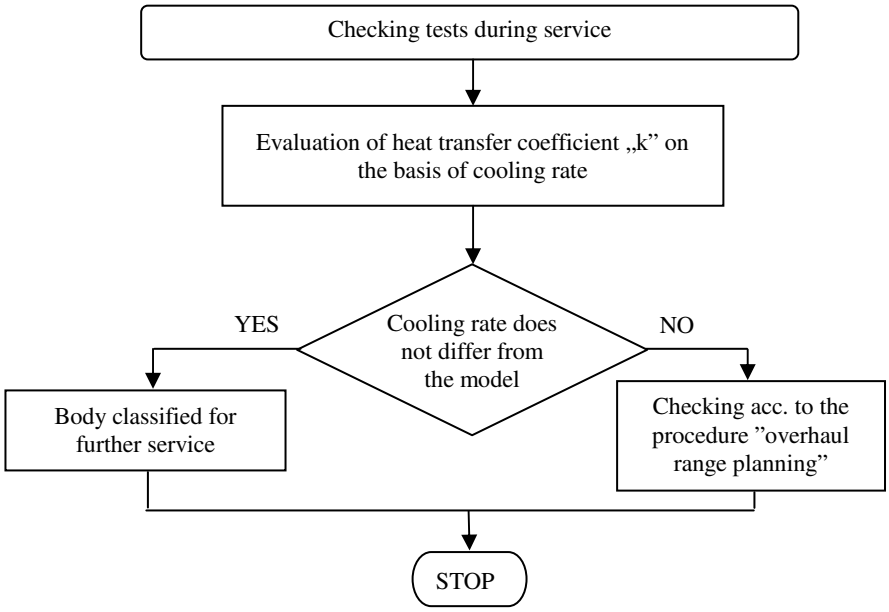

Fig. 2. Checking test during service
Rys. 2. Badanie sprawdzające w trakcie eksploatacji

New design of bodies should be developed after making a prototype. The task of the development process is, among others, to eliminate weak points of so called "heat leakage bridges". In order to localize them a infrared camera should be used after making a difference of temperatures between the body interior and its environment. Analyzing infrared photo one can determine the number of bridges, the surface of each of them and their location. If the surface A_i of the n^{th} bridge can be contained in the circle of the surface A_{kr}, it can be assumed that the bridge is of punctual character. The quantity assessment (local heat transfer coefficient) for such a bridge can made with the use of the auxiliary wall. The value of the surface A_{kr} depends on the gauge diameter of the "auxiliary wall" type [3]. If the mentioned relation does not occur ($A_i \subset A_{kr}$), the heating box [4] should be used to evaluate the bridge.

The above analysis should be carried out for all found bridges; meeting this condition means that the relation i = I is true, where i – successive number of the analysed bridge, I – the highest number prescribed to the bridge. After making a quantitative analysis of all registered bridges one should establish the reason of their occurrence. The body project and the description of body elements production technology and their assembly are useful in this process. The performed analysis should determine the reasons of the occurrence of bridges, i.e. if they are caused by:

- necessary design solutions (for ex. due to strength),
- design errors, e.g. wrong design of strengthening under the unit,
- technology errors (e.g. occurrence of foam misrun in the foaming process due to the lack of vents in the plates lining).

After removing bridges being the effect of design and technology errors there should be made a determination of the overall heat transfer coefficient with the use of a precise method. If the „k" coefficient value does not exceed the boundary value (the inequality 2 is met) the body gets a class certification. Otherwise suggestions concerning body design changes should be formulated, for example: roof or floor thickening. The discussed actions are shown in the figure 3 in a form of a block diagram.

Planning the range of the body overhaul one should make a visual inspection of the heat-insulating plates lining as moisture can penetrate in damaged places adding to degradation of the heat-insulating plates core. Then using a infrared camera the thermal bridges should be listed and evaluated from the point of view of quantity in the analogical way as in case of the design development procedure. After analyzing all the bridges the decision should be made whether to eliminate them or not.

In case of the decision on making a renovation, after finishing it, it is necessary to determine a overall heat transfer coefficient value in order to confirm the body class. If the body does not reach parameters allowing to transport food in it, it can be used to transport other things. The system of diagnostic actions performed when planning the overhaul range is presented in the figure 4.

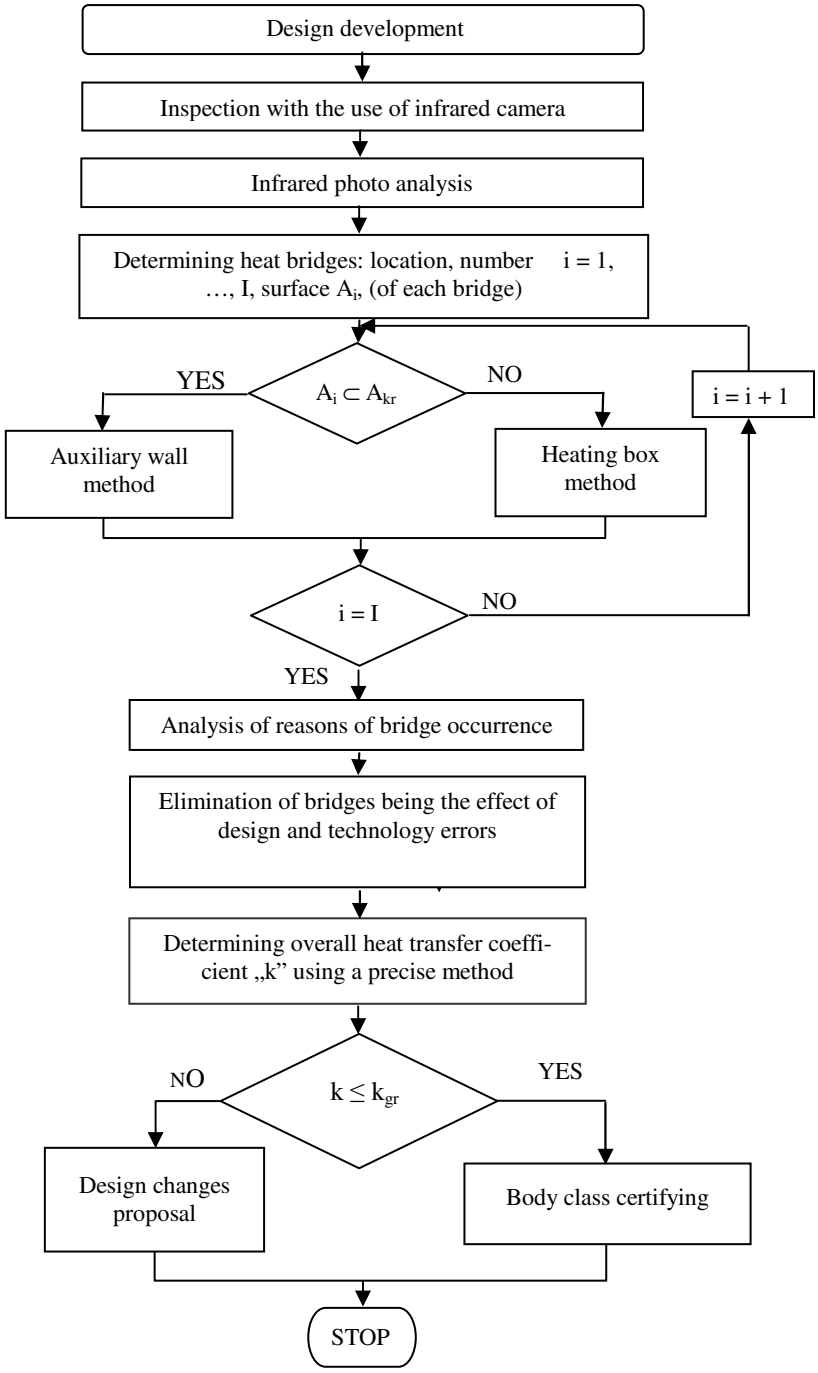

Fig. 3. Tests assisting the design development process
Rys. 3. Badania wspomagające proces doskonalenia konstrukcji

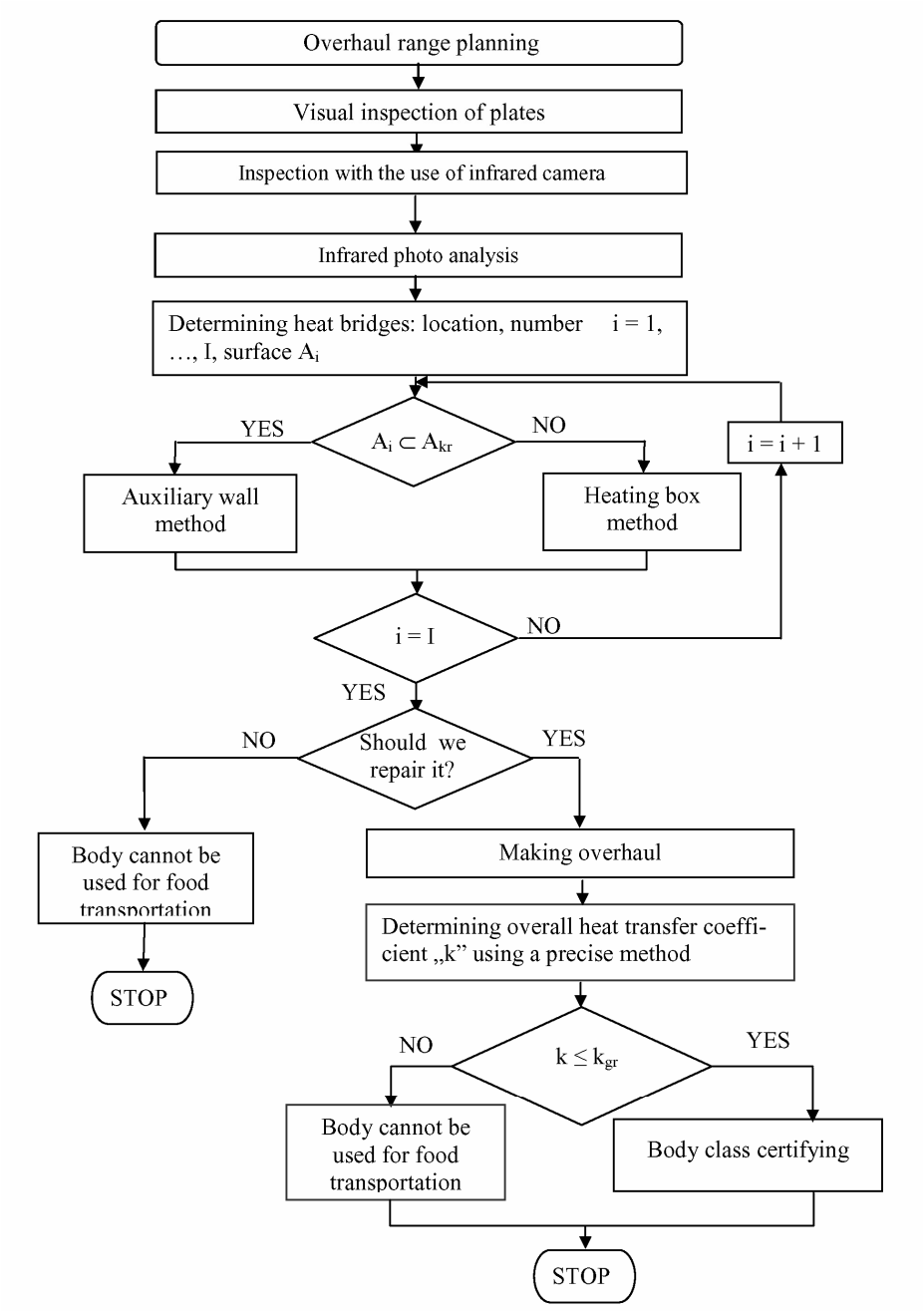

Fig. 4. Tests assisting the overhauls plans
Rys. 4. Badania wspomagające planowanie remontu

The overhaul quality checking procedure includes local (punctual) damages and damages ranging considerable areas. In case of damages of local character one can use "auxiliary wall" type gauges to evaluate quality of the repair. Otherwise one should make an inspection using a infrared camera. If, in the repaired area, there are no bridges, one can assume that the repair has been done correctly. Otherwise, bridges should be evaluated with the use of a heating box, then the reason of their occurrence should be established, and finally the bridges should be eliminated. After getting rid of the bridges, the inspection with the use of the infrared camera should be made again. The described procedure has been recorded in the form of the block diagram presented in the figure 5.

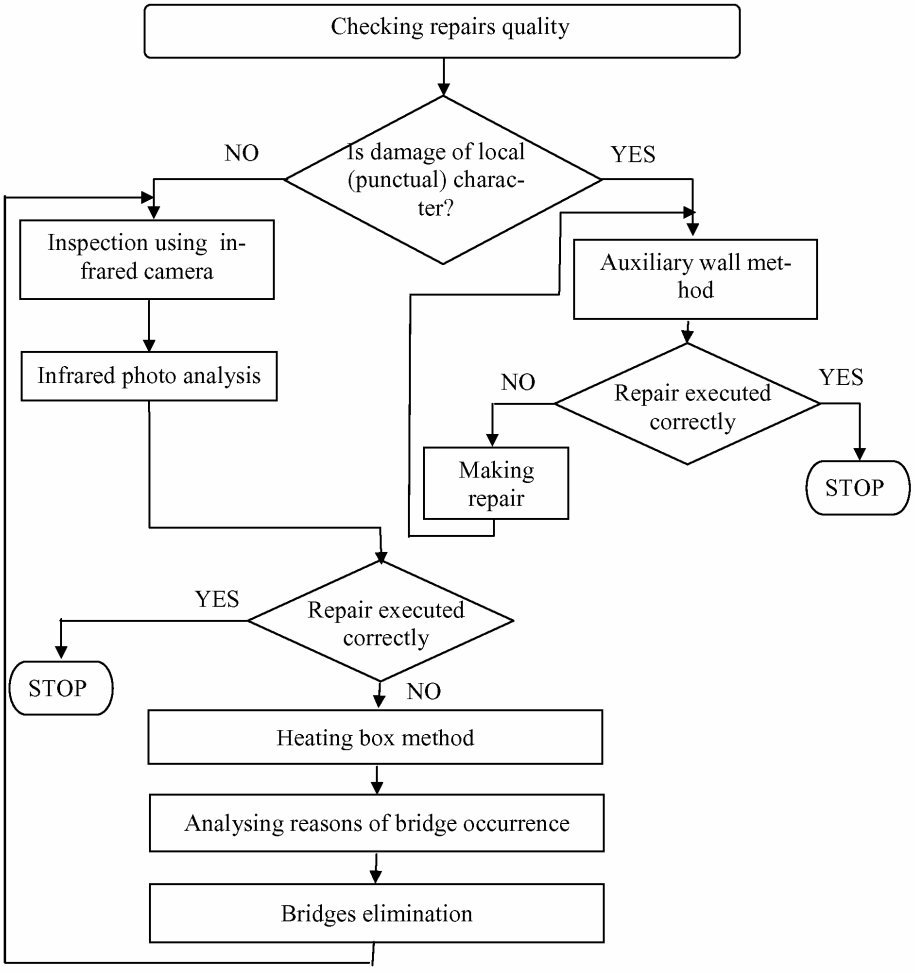

Fig. 5. Tests checking the repair quality
Rys. 5. Badanie sprawdzające jakość naprawy

3. Examples of elaborated procedures application

Effectiveness of applying the procedures discussed in the previous item is shown in the infrared photos presented in the figures 6 – 9. In each of the figures, there are given two photos illustrating the condition of the selected body fragment before and after actions improving its infrared properties. The photos were taken from the outside of the body in the ambient temperature 7.5^0C and in the temperature of the body inside or in the insulation tank temperature of 32.5^0C.

The most often applied procedure was the prototype solution development.

The body of unsatisfactory heat-insulation being due to too small thickness of the thermal core insulation, is presented in the figure 6. The same figure shows the body being made again and having the right thickness of thermoinsulating material.

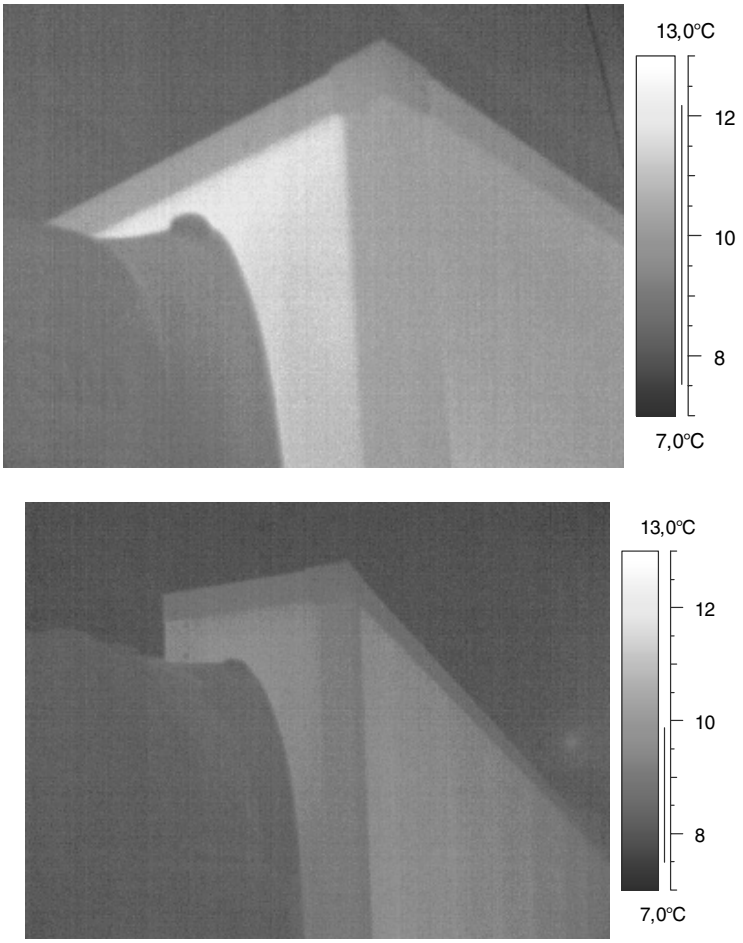

Fig. 6. The influence of the thermoinsulating core thickness to the body thermal insulating power
Rys. 6. Wpływ grubości rdzenia termoizolacyjnego na izolacyjność cieplną nadwozia

The way of coupling sheets of external panelling and internal back door is of great importance for their insulating power. In the incorrectly executed door the coupling was made through the sheet bending whereas in the correct execution the sheet bending was substituted by the plastic clamp of little thermal conductivity. The discussed solution is presented in the figure 7.

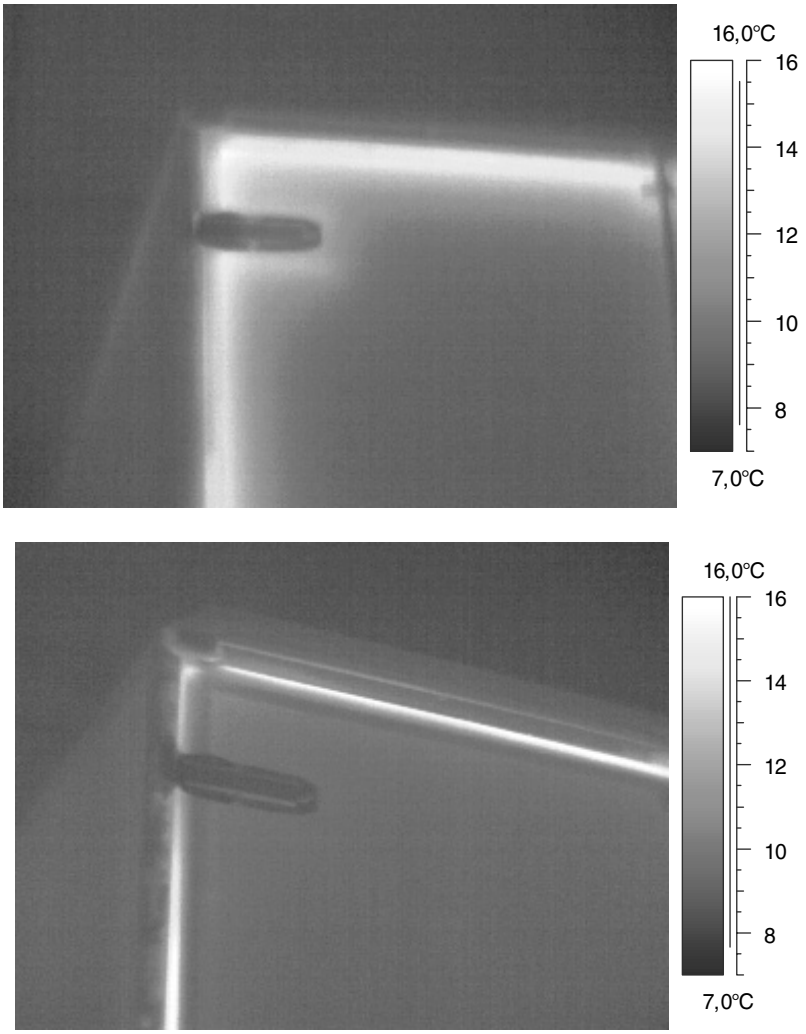

Fig. 7. The influence of the door design solution on its insulating power
Rys. 7. Wpływ rozwiązania konstrukcyjnego drzwi na ich izolacyjność

It is difficult to insulate certain elements being the equipment of insulation tanks such as for ex.: drain valves, manholes and frames fastening tanks to the base.

The infrared images of the incorrect and correct insulation of the drain valve are shown in the figure 8.

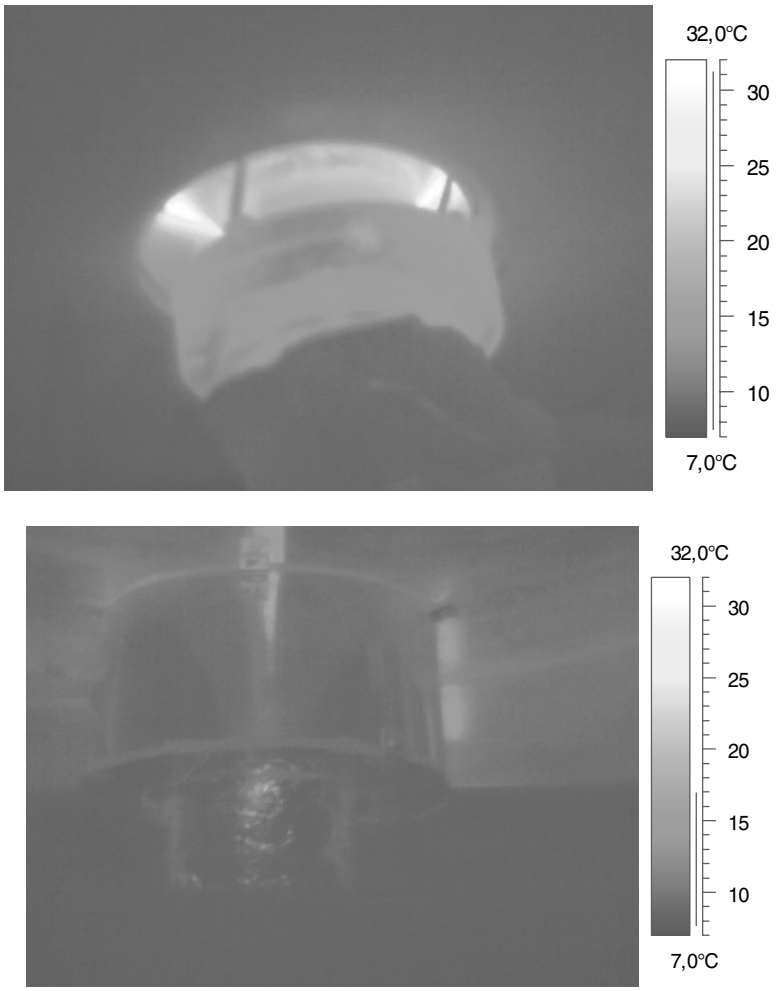

Fig. 8. Heat-insulation of the drain valve
Rys. 8. Izolacja cieplna zaworu spustowego

Purposefulness of applying the planned overhaul procedure is shown on an example of a body used for fresh fish transportation. In the mentioned body its floor was not made as a tight tub of riffled plate. Water leaking from containers (because of ice melting) was penetrating the construction of walls and floor, and especially the thermoinsulating core causing the crucial increase of the overall heat transfer coefficient. The view of the body, before and after the overhaul works executed by drying the walls and floor, is presented in the figure 9. In the mentioned vehicle, the floor was made during the overhaul as a tight tub.

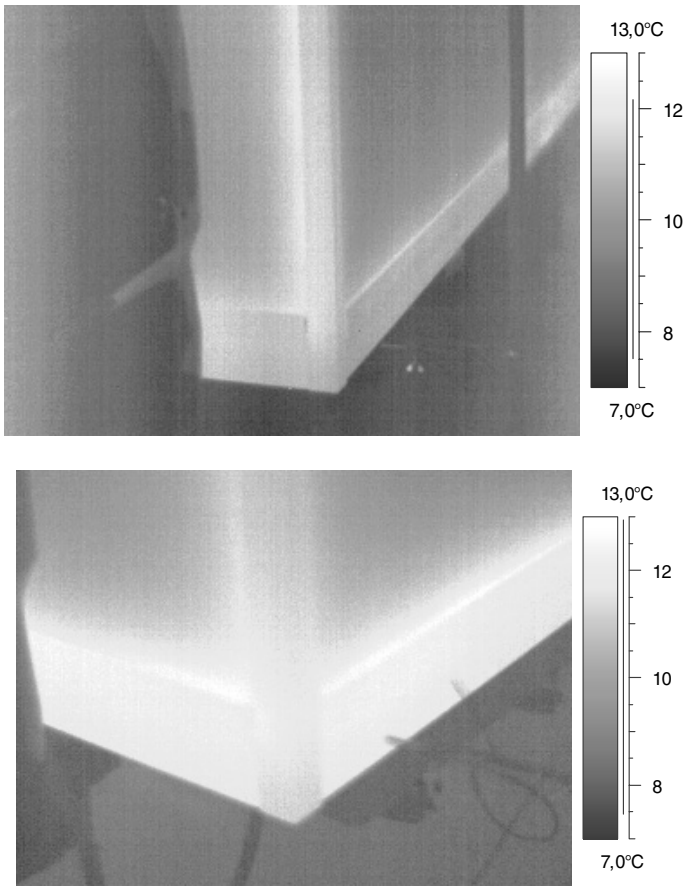

Fig. 9. Body before and after overhaul works
Rys. 9. Nadwozie przed i po wykonaniu prac remontowych

4. Summing up

The elaborated diagnostic procedures proved to be useful in the insulation bodies development process. Applying the mentioned procedures, the firms building new bodies and overhauling them can win with the competing firms. One of the most important effects of the research project KBN 5T07B02022 was also the elaboration, with the use of the infrared technique, of "a catalogue" being unique on the national and European scale, containing several thousands of photos of heat bridges occurring in cooling bodies due to design, technology (mounting) and service. Comprehensive examples of this collection have been presented in publications [2, 5, 6]. The elaborated "catalogue" as well as the complex evaluation system have been introduced in many enterprises producing and overhauling insulation bodies.

Praca wpłynęła do Redakcji 02.04.2007 r.

Literature

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Kompleksowa ocena własności eksploatacyjnych samochodowych nadwozi izotermicznych

S t r e s z c z e n i e

W artykule przedstawiono, opracowaną w ramach projektu KBN 5T07B02022, autorską propozycję kompleksowego systemu oceny termoizolacyjności samochodowych nadwozi izotermicznych. System ten umożliwia przeprowadzenie diagnoz służących: klasyfikacji nadwozi zgodnie z wymaganiami międzynarodowej umowy ATP (o transporcie żywności łatwo psującej się), określeniu słabych miejsc (mostków cieplnych) w nadwoziu izotermicznym w celu doskonalenia nowej konstrukcji lub planowania remontu, ocenie wykonanej naprawy.