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Method for determining the quality of cable inlets sealant using infrared thermography

The results of applying the quality control method to cable inlets sealant (hermetic lead, sealed lead-in, cable boxes) have been considered. Cable inlets are designed to prevent the spread of fire in adjacent areas through cable sealing boxes, e. g. on sea vessels. The known methods for determining the quality of cable inlets sealant are laborious and in some cases even impossible to implement when used on sea vessels. This applies to cases when the room through which the cables pass is being poured with water and some pressure stipulated by the ship specifications is being created there, or when the air pressure increases in such rooms. The novelty of the present method lies in the fact that it is based on the principles of pulsed thermal non-destructive testing of a material. The FLUKE thermovision camera Ti400 has been used as a technical means recording the temperature field of the sealant surface after exposure to a thermal pulse. The method approbation has indicated that thermal non-destructive testing can be used to detect relatively small penetration defects in the sealant volume.

Key words: sealant quality control method, cable inlets, defect, thermal pulse method, infrared thermography.

Results

The sealant quality is characterized by the absence of cracks and violations in its volume. The presence of cracks in the sealant leads to the possible water and air permeability, which is unacceptable due to fire safety.

The method under development [1] enables a quick assessment of the sealing box quality (sealed lead-in) designed to protect against the penetration of fire, water, and gases through impermeable bulkheads.

There are several ways known to determine the quality of cable inlets sealant[1] [2; 3]. For example, the cable room is filled with water which creates the pressure indicated in the technical characteristics of the vessel. The pressure is maintained within the time set by the test programme. Water leaks through the pressure seal construction are controlled visually on the other side of the bulkheads. However, this method can only be used in special-purpose premises, which can be flooded with water during normal operation of the vessel.

In order to check the sealing devices located on the upper decks of the ships, another method is used, according to which the sealing structures for cable passage are watered under the pressure of 2 kg/cm^2 from 5 m distance and from any direction during 5 min time. The quality of cable passage points sealing is considered to be satisfactory if no water is detected from the opposite side of the bulkhead. The disadvantage of this method is the complexity of its use in internal premises with electrical equipment.

Finally, to check the sealing devices located in the vessel service premises and domestic compartments, pressure cable boxes are blown with compressed air from a hose with a diameter of at least 1/2 inches from a 100 mm distance. Air leaks (defects) through the sealant structures are controlled by lubricating their other side with soap solution. The sealing quality of cable passage points is considered to be satisfactory if no air leaks are detected on the opposite side of the bulkhead or deck, or inside the room or electrical box.

The methods described above are characterized by significant complexity and in some cases cannot be implemented, e. g. during the vessel operation or its repair.

The method under development [1] determines thermophysical properties of materials and structures by measuring their surface temperature with a thermovision camera [4–6]. It is known as the "flash method" [4] – stimulating the test object with a thermal pulse from heat radiation sources (IR lamps, incandescent lamps). During the testing process, analysis of the conditions for the passage of a heat wave in the volume of the material under study has been carried out. In contrast to the methods described in [4; 5], the proposed method [1] uses thermal activation by a stream of warm air, which produces abnormal local heating on the surface opposite to the heated surface while penetrating through sealant defects (openings, cavities, pores). Application features of the heat pulses method are presented in the literature [6–11].

The present invention results [1] in improving the accuracy of the sealant continuity quality control, as well as in the localization of the air leakage point in the construction that should be water- and airtight.

The method implementation scheme is presented in Fig. 1. The method is implemented as follows. The front surface (Fig. 1) of the cable inlet is blown with heated air from a blow dryer. A pyrometer can be used to record the temperature of the sealant front surface.

A penetration defect has been created in the volume of the epoxy compound with the help of a metal string or a flat tie during the sealant polymerization (Fig. 2). Emissivity value of the epoxy compound like most polymeric materials is handled as ε = 0.92–0.95 [12]. The front surface of the sealant is blown with a blow drier

[1] OST 5R.1180-93. Industry-specific standard. Vessels. Test methods and standards for permeability and tightness. Central Research Institute "Lot", 1993 ; GOST 3285-77. Metal ship hulls. Test methods for impermeability and tightness. M., 1978.

with heated air installed at a distance of no more than 100 mm. When heated, the temperature of the sealant front surface does not exceed 50–60 °C. The wind flow speed produced with the blow dryer (heater) reaches tens of meters per second.

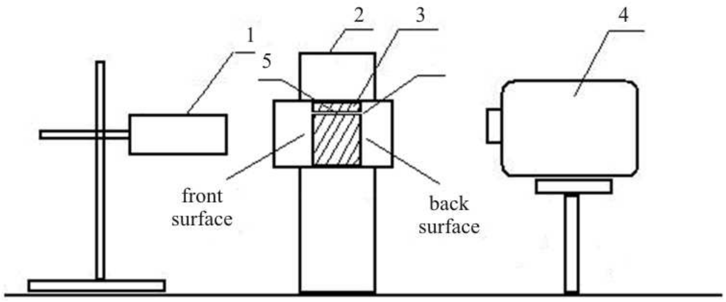


Fig. 1. Testing scheme for quality control of a cable pressure seal: 1 – blow drier; 2 – bulkhead (wall); 3 – sealant in the bushing; 4 – thermovision camera; 5 – air permeable penetration defect of the sealant; 6 – localization of the high temperature site on the back surface of the sealant
Рис. 1. Схема проведения испытаний для контроля качества кабельного гермоввода: 1 – фен (нагнетатель воздуха); 2 – переборка (стенка); 3 – герметик в проходной втулке; 4 – тепловизор; 5 – воздухопроницаемый сквозной дефект герметика; 6 – локализация участка с повышенной температурой на задней поверхности герметика

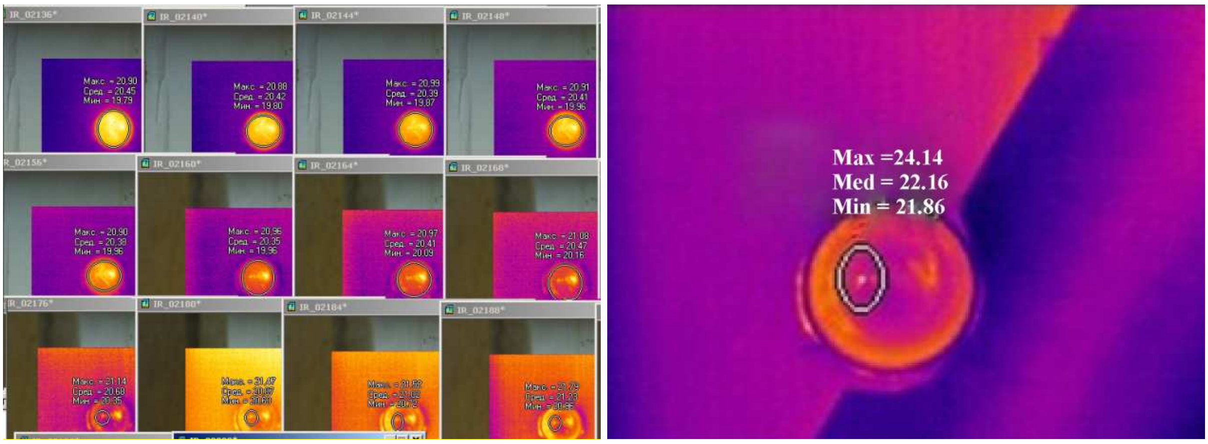
Fig. 2. External view of the cable inlet back surface with a flat penetration defect (0.1 mm thick, 4 mm high, 57 mm long)
Рис. 2. Внешний вид задней поверхности модели кабельного гермоввода с плоским сквозным дефектом толщиной 0.1 мм, высотой 4 мм, длиной 57 мм

After blowing the sealant front surface with warm air for several minutes (up to two or three minutes), the back surface temperature is continuously monitored with a thermovision camera in order to record the thermal wave passage from the front to the rear surface. The FLUKE Ti400 thermovision camera is used to record the temperature of the back (non-irradiated) surface and localize the defects on the back surface. During the testing process, thermograms are analyzed after 15–30 s within the next 15–20 min depending on the thickness of the sealant and the size of the penetration defects.

The results of thermal imaging of the object under study have been processed using the software attached to the thermovision camera. The temperature of the cable inlet back surface T_b was monitored. Values of the maximum (max), average (av), and minimum (min) temperatures of the object rear surface are estimated over time, as well as localization of the observed sealant defects (Fig. 3, 4). Fig. 4 shows an example of a histogram after image processing using the specialized software of the "FLUKE Ti400" thermovision camera. The value of the ambient temperature is within T_0 = 21–22 °C.

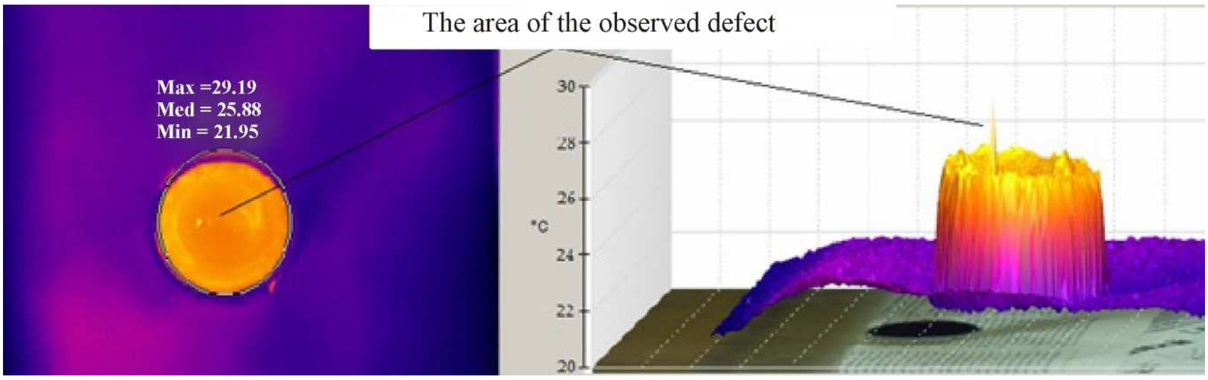
Analysis of a series of sequential thermograms (Fig. 3, *a*) shows that the highest surface temperature is found in the defect area, e. g. in Fig. 3, *b*: $T_{b\max}$ = 22.14 °C, T_{bav} = 22.16 °C.

Similarly, in Fig. 4 the thermogram shows the values of $T_{b\max}$ = 29.19 °C, T_{bav} = 25.88 °C, $T_{b\min}$ = 21.95 °C at the air temperature T_0 = 21 °C. The temperature rise in the area of the analyzed penetration defect (Fig. 4, *b*) reaches D$T_{b\max}$ = 7–8 °C.



a *b*

Fig. 3. A series (*a*) and one of sequential thermograms (*b*) obtained during non-equilibrium thermography
Рис. 3. Серия последовательных теплограмм, полученных при проведении неравновесной тепловой термографии



a *b*

Fig. 4. Thermogram of the back surface with a through hole (*a*) and volume histogram with localization of the defective area (*b*). Sealant thickness (epoxy resin) is equal to 10 cm
Рис. 4. Теплограмма задней поверхности со сквозным отверстием (*a*) и объемная гистограмма с локализацией дефектной области (*b*). Толщина герметика (эпоксидная смола) 10 см

Fig. 5 shows a typical dependence of the temperature change on the sealant surface in the area of the penetration defect. In this case, a flat penetration defect with the thickness of 0.1 mm, 4 mm height and 57 mm length in the volume of the epoxy compound is analyzed. The front surface has been heated during 1 min, as a result of heating the temperature of the front surface reaches 42 °C.

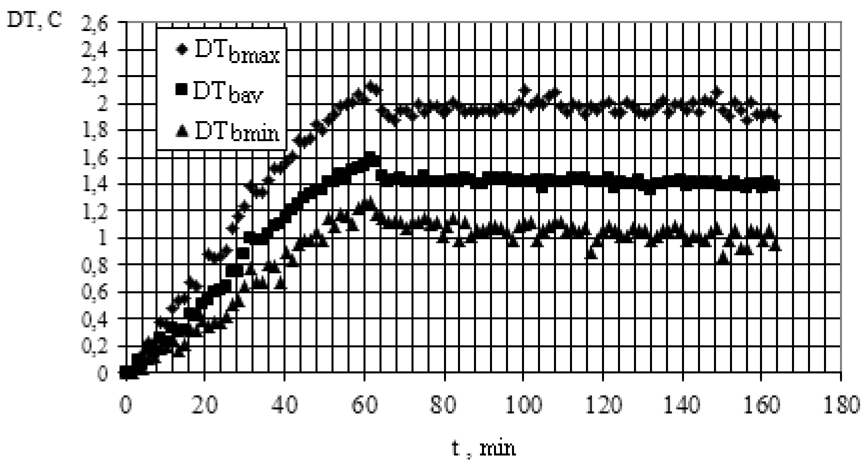


Fig. 5. Dependence of the temperature change on the sealant surface in the penetration defect area
Рис. 5. Зависимость изменения температуры поверхности герметика в области сквозного дефекта

The defect in the observed area is characterized by the increased temperature $T_{b\max}$. The defect can be localized in the spot of the surface area with the maximum excess temperature $DT_{b\max}$; the value $DT_{b\max}$ is found from the relation

$$DT_{b\max}(t) = T_{bmax}(t) - T_0,$$

where $DT_{b\max}(t)$ – the change in the maximum temperature of the material layer back surface at the moment t; T_0 – the initial (equilibrium) temperature of the back surface of the material layer.

It can be seen in Fig. 4 that in the defect localization area the temperature evenly increases as the air comes through the penetration defect, after which the temperature value stabilizes. The time for setting the maximum temperature in the defect area depends on the parameters of the defect, the temperature, and the heating time of the front surface.

The developed method enables to carry out tests in accordance with the non-equilibrium thermography in order to assess the thermophysical characteristics of the sealant and to detect defective areas in its volume.

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Метод определения качества герметика кабельных гермовводов с помощью тепловизора

Рассмотрены результаты применения метода контроля качества герметика кабельных герметичных вводов (герметичный ввод, гермоввод, кабельные коробки). Гермовводы предназначены для предотвращения распространения пожара в смежные помещения через кабельные уплотнительные коробки, например на морских судах. Известные способы определения качества герметика кабельных гермовводов отличаются трудоемкостью и порой невозможностью реализации при применении на морских судах. Это относится к случаям, когда помещение, через которое проходят кабели, заливают водой и создают в нем давление, оговоренное спецификацией судна, или при увеличении давления воздуха в подобных помещениях. Новизна метода заключается в том, что способ определения качества кабельных гермовводов основан на принципах импульсного теплового неразрушающего контроля материала. В качестве технического средства, регистрирующего температурное поле поверхности герметика после воздействия теплового импульса, использовался тепловизор. При апробации метода показано, что тепловой неразрушающий метод контроля может применяться для выявления относительно малых сквозных дефектов герметика.

Ключевые слова: метод контроля качества герметика, кабельный ввод, дефект, тепловой импульсный метод, инфракрасная термография.