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Affordable hybrid thermography for merchant vessel engine room fire safety

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Abstract

Hot surfaces in ship engine rooms are the risk objects that most frequently contribute to fire ignition. Thermography, especially when using thermal cameras, offers many advantages over more common infrared thermometers, but dedicated systems are often prohibitively expensive. An affordable hybrid approach was thus tested in this study, where a low-cost thermal camera smartphone was paired with a common infrared thermometer. Measurements were taken *in situ* during a sea voyage in an engine room under normal operating conditions, and the surfaces of the main engine, the generating set auxiliary engine, and the exhaust gas boiler were tested. Several areas were discovered to be well above the generally-accepted temperature limit of 220°C, primarily due to absent or poor insulation. Clear recommendations for remediation are made, and the proposed testing method offers fast, easy, effective, and affordable inspection.

Introduction

According to the International Convention for the Safety of Life at Sea (SOLAS), the maximum surface temperature of machinery, parts, and elements in engine rooms should not exceed 220°C. To avoid ignition and fire, all surfaces whose temperatures exceed 220°C should be insulated or otherwise protected (IMO, 2014).

To detect such dangers, thermography, specifically the use of thermal cameras, is recommended by classification societies for use in engine rooms (e.g., for non-insulated surfaces inspections). It offers rich, effective, simple, and quick detection of potential ignition sources, as well as early identification of irregularities in equipment operation. Despite its merits, applications of thermography are uncommon at any stage – shipbuilding, engine crews, and surveys – compared to infrared thermometers (Sarfels, 2018). Infrared thermal cameras, often called thermocams, are used on a small number of motor boats as part of a system that constantly monitors the engine room (FLIR Systems, 2015; FLIR, 2018). When used in this way, a contactless control-measurement device stores and displays the exact measured temperature values as well as visual evidence, which is not possible with infrared thermometers. Additionally, the systems save time and allow for prompt performance control, which are important to modern navigation. Whether permanent or periodic, infrared thermography offers greater clarity than infrared thermometers since it provides rich two-dimensional visuals rather than point samples. This enables instantaneous temperature and insulation measurement of complex surfaces, electrical circuits, electronic equipment, etc.

Merchant ships are excellent candidates for such systems due to the clear limitations of visual and infrared thermometer systems in their large engine rooms containing areas of limited accessibility, vast electrical systems, and complex electronic systems. This challenging space is where fire safety – including the early detection of potential ignition sources – is extremely important (Sarfels, 2018).

The application of thermography for the improvement of fire safety is currently a subject of research, analyses, and testing (Posagic, Muzevic & Dubravko, 2008; Bistrovic, Ristov & Komorcec, 2017). In this study, a hybrid thermography approach was tested where a relatively inexpensive thermal camera with a limited range was paired with a common infrared thermometer. This approach provides an effective thermography solution at a much lower price than dedicated thermal camera systems.

Fire safety of the engine room is one of most important aspects of vessel safety, and a thermography application should be supported by other means of fire safety, such as construction, detection, and extinguishing methods (Ubowska & Szczepanek, 2016; Bistrović & Ristov, 2017). Emphasis should also be placed on proper training (Chybowski et al., 2015).

Methods

The research was conducted in a selected engine room using a CAT S60 smartphone equipped with second-generation FLIR Lepton thermal camera and factory-installed FLIR application. The temperature range for the device is −60 to 150°C, allowing for the quick detection of the hottest spots of the selected object or surface. Compared to dedicated commercial units, the device is cheaper and more available, so it should be considered for crew use (GSMArena, 2018).

The cost of one thermal imaging camera (FLIR AX8) is 1000 $. For engine room protection, to monitor critical equipment, approximately 8 AX8 cameras integrated with Raymarine MFDs are needed. The cost of a mobile phone with a thermal imaging camera to be used by a crew member is much lower (about 400–500$).

Measurements were opened with FLIR Tools software and exported to spreadsheets for further processing. An infrared thermometer was used as a supplemental tool to exactly measure the temperature of surfaces hotter than 150°C with a measurement range of −35 to 800°C, with accuracy of ±2°C.

Statistical analyses of fire-starting locations (DNV, 2000; 2018) informed which areas were chosen for temperature measurement: main engine frame, generating set auxiliary engine, auxiliary steam boiler, and exhaust gas steam boiler. Measurements were taken in selected spots in several runs during equipment operation, for the loads required by the operating conditions at sea in December 2017 on board a Polish shipowner's merchant ship.

Results

The first object that was examined was the main engine (ME): MAN B&W, type 5S46MC, nominal speed 110 rev/min, power – take-off 4719 kW / 110 rev/min, cylinder bore 460 mm, piston stroke 1932 mm. The ambient temperature was 38°C.

The ME measurements using a thermal camera were aimed at providing prompt identification of areas with elevated temperatures, which correspond to objects at risk of catching fire.

Figure 1 shows an overall view of main engine that was processed with the FLIR Tools software to identify temperature values in spots with the highest temperature as indicated by the camera. The uppermost value was recorded on the fuel injection pumps – Sp2 (92.7°C) and Sp7 (97.1°C).

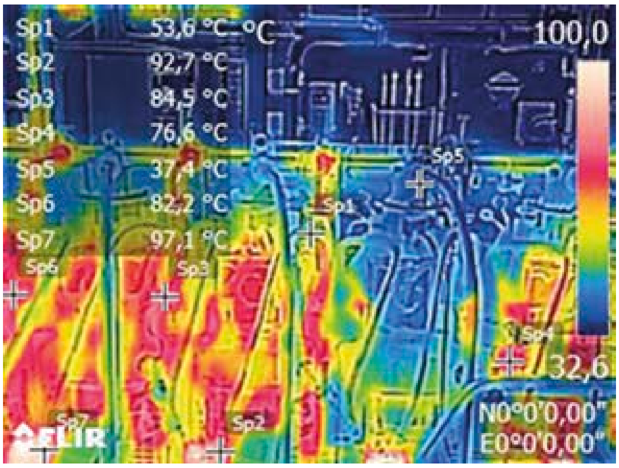

Figure 1. Main Engine (ME), Thermal Map

Figure 2a similarly shows the main engine exhaust system, where the FLIR showed values exceeding 150°C on the uninsulated bolted flange at the exhaust gas outlet from the turbocharger. The hybrid approach was thus applied (Figure 2b) to determine the exact temperature since values over 300°C are particularly hazardous. The temperature of uninsulated bolted flange at the exhaust gas outlet from the turbocharger was 307°C.

Figure 3 shows the screen of the exhaust manifold between the exhaust valve and the collective exhaust manifold, with significantly lower temperature of approximately 60°C (e.g., Sp1, Sp4). Other spots were much hotter, approaching or at the thermal camera limit of 150°C (e.g., Sp2, Sp3, and Sp5–Sp10). The infrared thermometer showed that the hottest spots were the manifold joints – bolted flanges – which were 320°C. These are major fire risks.

Figure 4 shows the remote readout of the pyrometer sensor of the cylinder exhaust gas temperature a)

b)

Figure 2. Uninsulated bolted flange at the exhaust gas outlet from the turbocharger: a) thermal map and b) infrared thermometer

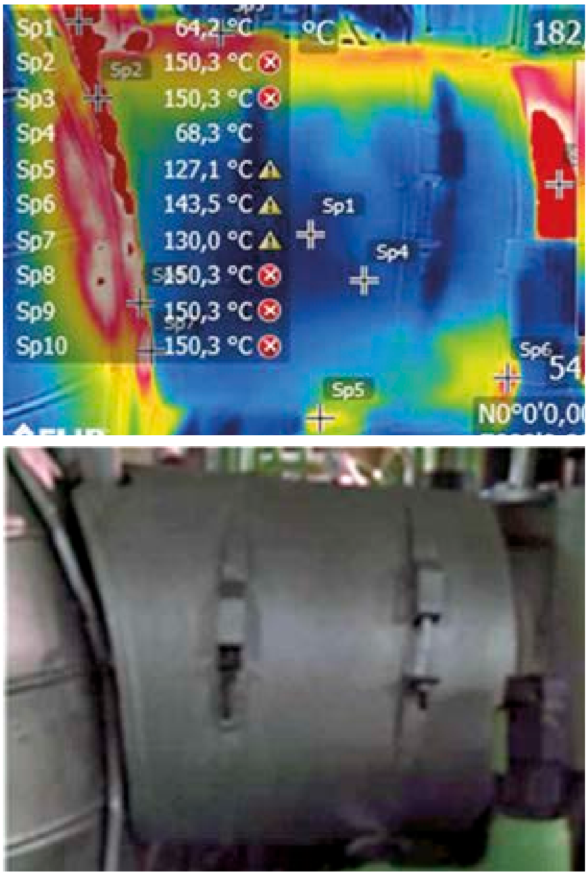

Figure 3. Exhaust manifold, FLIR Tools

Sp1	150.3°C	⊗
Sp2	150.3°C	⊗
Sp3	150.3°C	⊗
Sp4	150.3°C	⊗
Sp5	150.3°C	⊗
Sp6	141.6°C	⚠
Sp7	150.3°C	⊗
Sp8	146.7°C	⚠
Sp9	125.9°C	⚠
Sp10	146.4°C	⚠

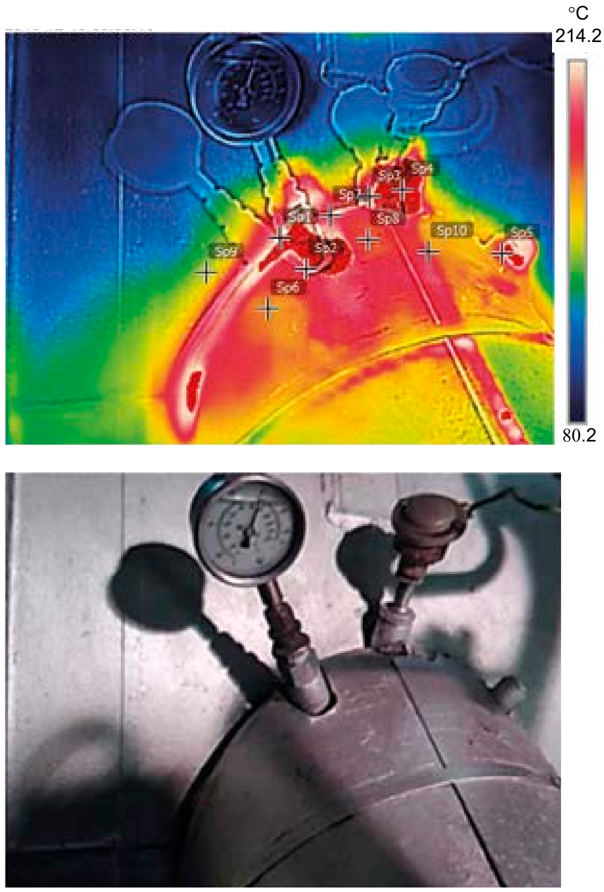

Figure 4. Pyrometer sensor of the cylinder exhaust gas temperature and the FLIR Tools

and the area of the local temperature measurement at the cylinder outlet. According to the infrared thermometer, many areas exceeded 150°C, and the remote pyrometer sensor was 298°C, while the cylinder outlet temperature was 261°C where the local measurement meter is attached.

Figure 5 shows the ME cylinder indicator cock, which was 172°C, according to the infrared thermometer. High temperature values exceeding 200°C were also recorded on the ME collective exhaust manifold foundation bolts.

In addition to the ME, the VX auxiliary steam boiler was inspected. The MISSION OS 1600 boiler

Sp1	150.3°C	✖
Sp2	138.9°C	⚠
Sp3	150.3°C	✖
Sp4	150.3°C	✖
Sp5	150.3°C	✖
Sp6	145.9°C	⚠
Sp7	128.5°C	⚠
Sp8	150.3°C	✖
Sp9	105.5°C	
Sp10	143.9°C	⚠

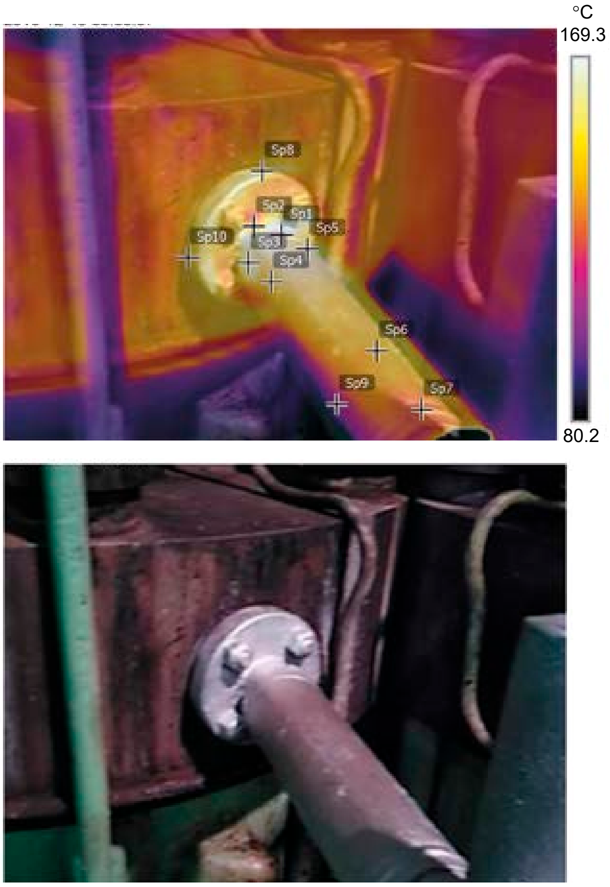

Figure 5. Thermal map of the ME cylinder indicator cock

was manufactured by Messrs Aalborg Sunrod, and had a capacity of 1600 kg/h and a steam working pressure of 0.7 MPa. Figure 6 shows both the visual and thermal views.

All measurements were below the 150°C thermal camera threshold and were deemed only moderate risk.

The next object inspected (not pictured) was the exhaust gas steam boiler, an Aalborg type AV9. For this boiler where ME was not running, the thermal camera showed the door to be 52–68°C, and the boiler air duct to be 80–118°C. When the ME was running, the temperature increased significantly at the exhaust gas space inspection door

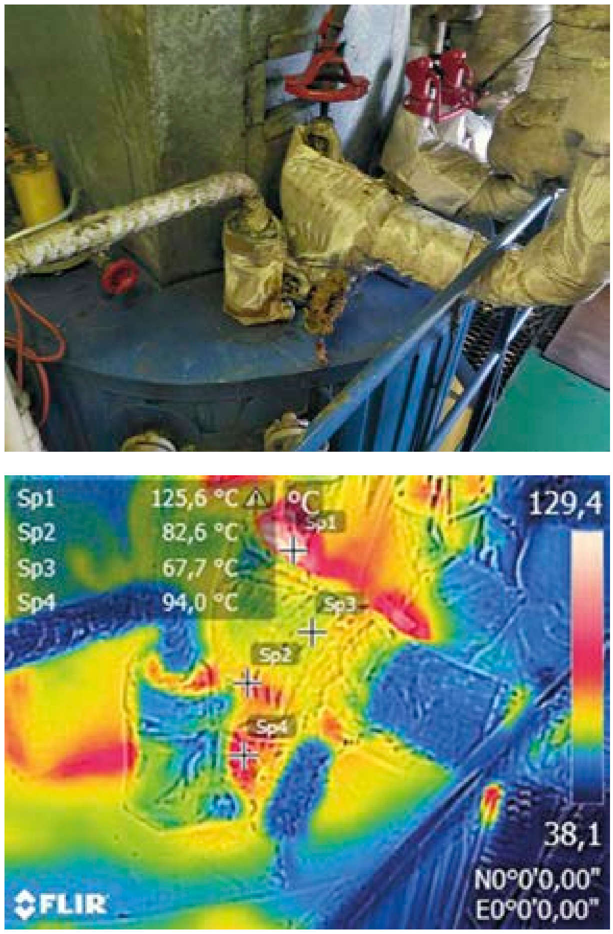

Figure 6. VX boiler main steam valve: a) visual and b) thermal map

to a value of 296°C, according to the infrared thermometer.

The generating set auxiliary engine (a Cegielski Poznań MAN B&W 7L16/24 1999, with a load on network of 250 kW and speed of 1000 rev/min) was also inspected. The measured temperature was 38–84°C at the auxiliary engine cover. At the bolted flange connecting the exhaust part of the turbocharger, the temperature was 301°C as measured by the infrared thermometer. According to the infrared camera, the temperature of the turbocharger casing at the exhaust gas side ranged from 85°C to the limit of the thermal camera measuring range, i.e. above 150°C.

Figure 7 shows the turbocharger casing air inlet, with a temperature range of 84–118°C. The turbocharger gas outlet side (not pictured) ranged from 114°C to over 150°C. The infrared thermometer revealed a max temperature of 321°C. The bolted flange connecting the turbocharger exhaust gas port was 301°C. The turbocharger casing was 321°C, the exhaust gas manifold behind the turbocharger was 341.6°C, the flushing stub for turbocharger exhaust

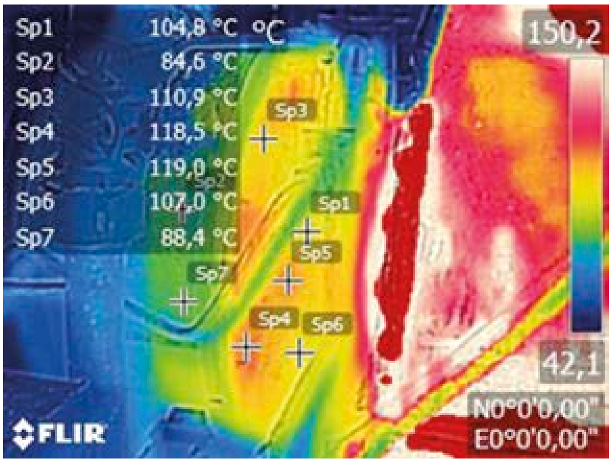

Figure 7. Turbocharger casing temperature – air inlet side – thermal map

Sp1	43.2°C
Sp2	48.3°C
Sp3	55.0°C
Sp4	44.5°C
Sp5	37.7°C

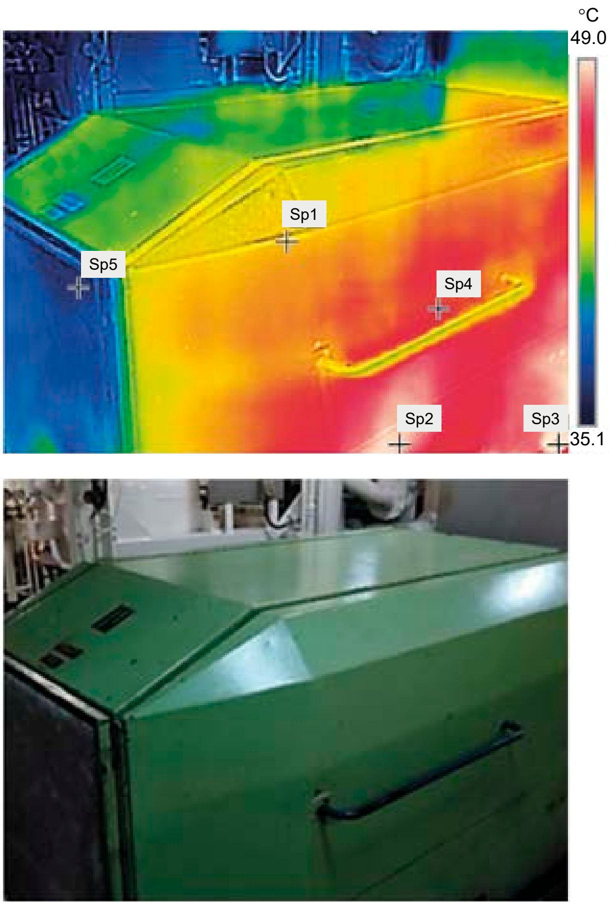

Figure 8. Generator casing and FLIR Tools

gas was 339°C, and the connector of the collective exhaust gas manifold to the turbocharger was 486.3°C. These values are all well above 220°C, and represent the highest temperatures and thus the highest risks observed.

Figure 8 shows the generator cover, with temperature of 37–55°C, making it low-risk.

Discussion

According to regulations, all surfaces in a ship's engine room that exceed 220°C should be effectively insulated. In the studied engine room, a hybrid approach that combined an affordable thermal camera and a common infrared thermometer revealed 11 surfaces (Table 1) whose temperature significantly exceeded that limit, and the highest recorded temperature was 486°C. Most of the dangerous surfaces were connections that weren't sufficiently insulated (i.e. the insulation was not designed for the location), and contact with fuel in these areas is a notable concern. The hybrid approach was effective and allowed hazardous areas to be quickly identified.

Regular inspections of insulation and potentially dangerous uninsulated areas, particularly after any major overhauls, are recommended. In the observed cases, remediation was achieved using spray–coat insulation or insulating blankets, which are readily commercially available.

Table 1. Areas in the ship's engine room classified as particularly dangerous

Item	Area	Temperature [°C]
	Main engine	
1.	Connection: bolted flange, exhaust manifold between exhaust valve and collective exhaust gas manifold	320
2.	Uninsulated bolted flange at the exhaust gas outlet from turbocharger	307
3.	Cylinder exhaust gas temperature remote readout pyrometer sensor	298
4.	Local temperature readout at cylinder outlet	295
5.	Uninsulated plugged measuring cocks at the ME collective exhaust gas manifold	261
	Exhaust gas steam boiler	
6.	Exhaust space inspection door during ME operation	296
	Generating set auxiliary engine	
7.	Connector of collective exhaust manifold to the turbocharger	486
8.	Exhaust gas manifold behind the turbocharger	342
9.	Turbocharger exhaust side flushing stub	339
10.	Turbocharger casing	321
11.	Bolt set connecting the turbocharger insert to the casing	302

Awareness of the locations of hot surfaces and the potential release points of flammable materials allows identification of fire scenarios for a selected engine room, their potential stages, and the probability that they will spread to other areas (Krystosik-Gromadzińska, 2016). Future work will thus aim to produce a complete engine room map of hot surfaces and potential leakages, which will provide a more accurate risk index.

Conclusions

This study has demonstrated that a hybrid thermal analysis approach can be both affordable and effective. It is thus recommended that crews have access to thermal cameras, even if they have limited ranges, to make the use of infrared thermometers faster and more effective. This approach could even be used for daily inspections to identify failures and risks before they cause catastrophes.

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