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Review paper

Temperature Measurement and Applications on Board Ships with Example from Marine Engineers Education*

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Abstract: There are various methods and sensors for measuring temperature, which are common on board ships. Hence, it is very important to choose the right sensor for a particular purpose. In this paper, two sensors and their working are described. The paper presents experimental work in measurement with these sensors. The samples measured and their parameters are also described. Additional value of this paper is connection of this paper diploma thesis. The experiments are executed under the same environmental conditions. Also, it is discussed what the best purpose is for each of the two sensors.

Keywords: Thermal imaging camera, Pt-100, Marine engineering, Education.

1. Introduction

Temperature sensors play an important role on board ships in control systems [1 - 4]. Therefore, it is important to include them in the education of marine engineers. The Faculty of Maritime Studies in Split has received a new automation laboratory. Hence, it was expected to use such equipment for educational and/or scientific purposes.

Importance of temperature measurement in marine engineering is well known. The temperature can be used for fault diagnosis and preventive maintenance [5 - 7]. Such methods are widely used, as the following examples show: thermography diagnosis of electronic elements [8], condition diagnosis of HV cable accessories [9], fault diagnosis of reciprocating compressors [10], fatigue life evaluation of filled rubber [11], detection and identification of defects in 3D printed dielectric structures [12], determination of the operating condition of a conveyor belt drive system [13], detection of trucks in rest areas under winter conditions [14], tracking of people [15], evaluation of warm roofs in cold regions [16], detection of oil spills [17], use of thermography in the diagnosis of ship piston internal combustion engines

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[18], use of fiber bragg grating temperature measurement for long-period monitoring for LNG marine auxiliary [19], etc.

In this paper, we describe the comparison of temperature measurement using PT sensor and a thermal imaging camera. Thermal imaging cameras are usually used for periodic inspection and prevention on board ships. The experimental work was carried out by a student, which is a start for incorporating new devices into education. A similar interesting research was done in [20] where the measurement of strain was studied.

The paper is divided into 4 sections. The second section describes material and equipment. The third section presents the results. Finally, conclusions are drawn.

2. Materials and Methods

Types of temperature sensors used on board ships are thermistors, resistance temperature detectors (RTD), thermocouple, and periodically thermal imaging camera, which was brought aboard with a maintenance team. Here is only the basic of this two sensing devices.

The commonly used component as resistance wire (sensing element) of the RTD are Platinum (Pt), Nickel (Ni), and Copper (Cu). Popularly used Platinum RTD are Pt-100, Pt-1000. The name Pt-100 is because at 0°C resistance is 100 Ω. Measurement of this sensor is based on one of the basic electric laws – thermal dependency of the electrical resistance:

$$R = R_0\left(1+\alpha\Delta\vartheta\right) \tag{1}$$

where R is the electrical resistance at desired temperature, R_0 the resistance at the referent temperature, α thermal coefficient and $\Delta\vartheta$ the temperature difference between the desired temperature and the referent temperature.

Thermal imaging camera, on the other hand, grasps the radiation reflected or emitted from the measured object (body). The real emission of thermal radiation from any object can be computed by multiplying the blackbody radiation and the emissivity, ε. The emissivity of an object is the ratio of the amount of radiation actually emitted from the surface to that emitted by a blackbody at the same temperature. Emissivity of the body can be derived from Kirchoff's law, which states that the amount of radiation absorbed is equal to amount of radiation that is emitted by this object, which is expressed by $\varepsilon = \alpha$, where ε and the so-called absorptivity α denote the fraction of radiation that is either emitted or absorbed. Considering the fraction of the incident radiation this law can be written as:

$$1 = R + T + \alpha \tag{2}$$

where R and T denote the fraction of radiation that is either reflected or transmitted. Hence, thermal imaging camera can detect only surface temperature or something/some process that changes the temperature of the surface.

2.1. Test material

Antifreeze is used to lower the freezing point of refrigerant for equipment operating at relatively low temperatures. The antifreeze is placed in a stainless steel (also called Inox) container with a volume of 0.001 m^3. The antifreeze used is INA ANTIFRIZ SUPER (trade mark). The basic properties of the sample are:

– The density at 20 °C is equal to 1.114 g/cm^3.

– The flow rate is -36 °C and the boiling point is 164 °C.

2.2. Experimental equipment

The thermal imaging camera used, Testo 885, can be used in a wide temperature range from -15 to +50 °C. Humidity can range from 20% to 80%, and vibrations can be up to 2 G.

Electrical temperature sensors are implemented in the experimental unit WL 202, which covers many temperature measurement methods. A digital multimer with high-precision resistors was used for calibration.

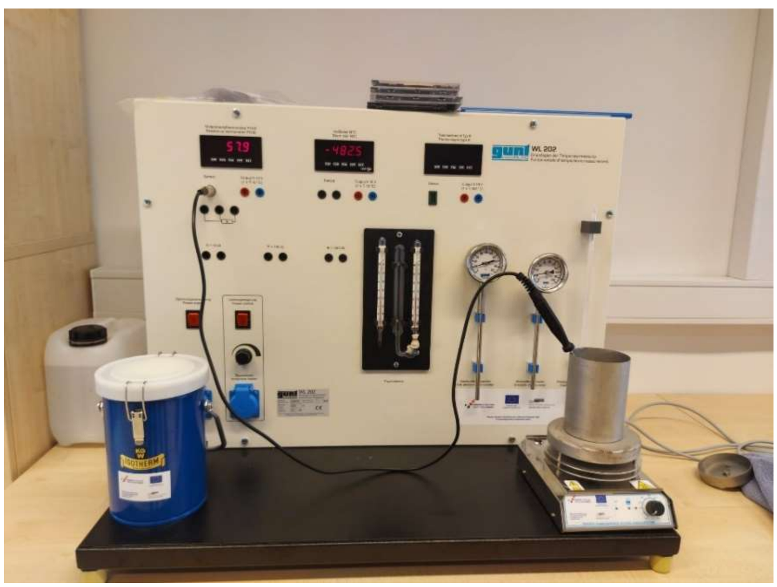

Fig. 1 – *Experimental device WL 202.*

The antifreeze was heated in a stainless steel container with a volume of one liter. The laboratory heating is set to 50 °C. The measurement started after 20 minutes of heating. The average ambient temperature was 25.4 °C.

The measurement temperatures were: 50°C, 60°C, 70°C, 80°C, 90°C, 100°C, 110°C. The emission factor of the device was ε_d = 0.95 m and the emission factor of the antifreeze was ε_a = 0.98.

3. Results

In this section, we present the experimental results. Table 1 shows the measurement results for the two sensors used: Pt-100 and thermal imaging camera. The first obstacle in the comparison lies in the nature of the devices. The thermal imager displays the spatial distribution of the temperature. Therefore, it is possible that there are points with the same temperature detected by the Pt -100 sensor. However, we need to determine the measurement point visually.

Table 1 – *Measured temperatures with sensor and thermal imaging camera.*

	Measured temperature (°C)		
	Thermal imaging camera		Pt-100 sensor
Measured set point (°C)	Measurement point (M_I)	Average temperature (AV_I)	Measurement temperature
50	49.9	51.1	50
60	57.8	57.3	60
70	73.2	73.3	70
80	80.6	80.5	80
90	91.6	90.6	90
100	99.6	98.4	100
110	112	112.9	110

Figure 2 shows comparison of measured results. It can be seen that thermal imaging cannot grasp the exact temperature due to various external factors, such se refraction, abortion from the air, etc. Consequently, the Pt-100 sensor is better when exact measurement is necessary. However, in cases when Pt sensor cannot be applied, there is a use of thermal imaging cameras, such is in detection of cracks and stress.

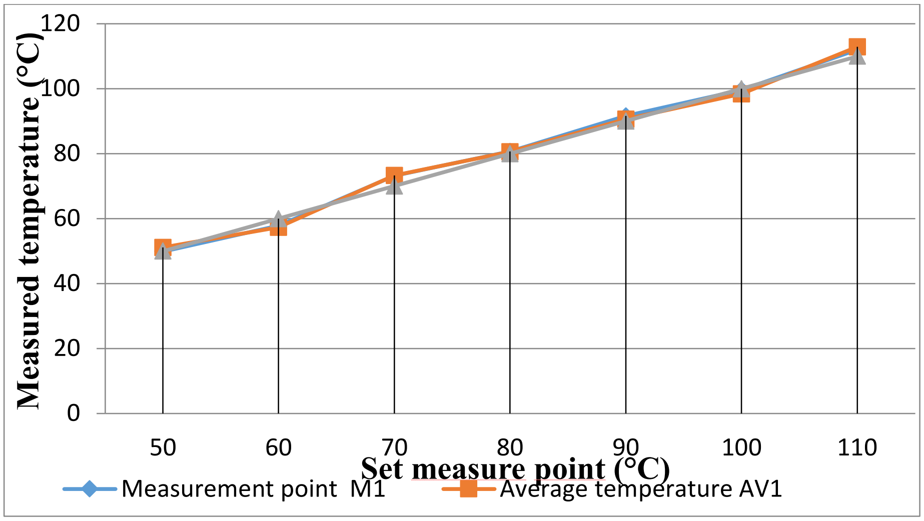

Fig. 2 – *Comparison of measured temperatures for Pt-100 and camera's average temperature.*

Figures 3 and 4 shows examples of measurement by thermal imaging camera. The images and tables are taken exactly from the camera app.

It can be seen that the thermal imaging camera provides more data, but it is difficult to know which temperature is the correct one for a possible control system.

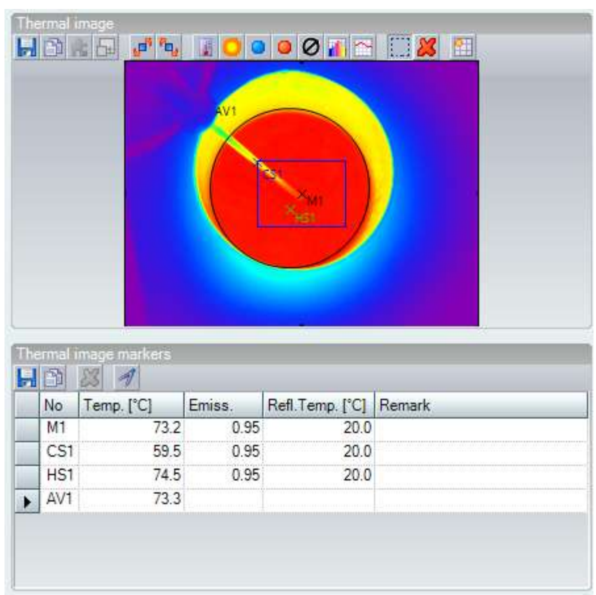

Fig. 3 – *Example of measurement obtained by thermal imaging camera: the set temperature is 70 °C.*

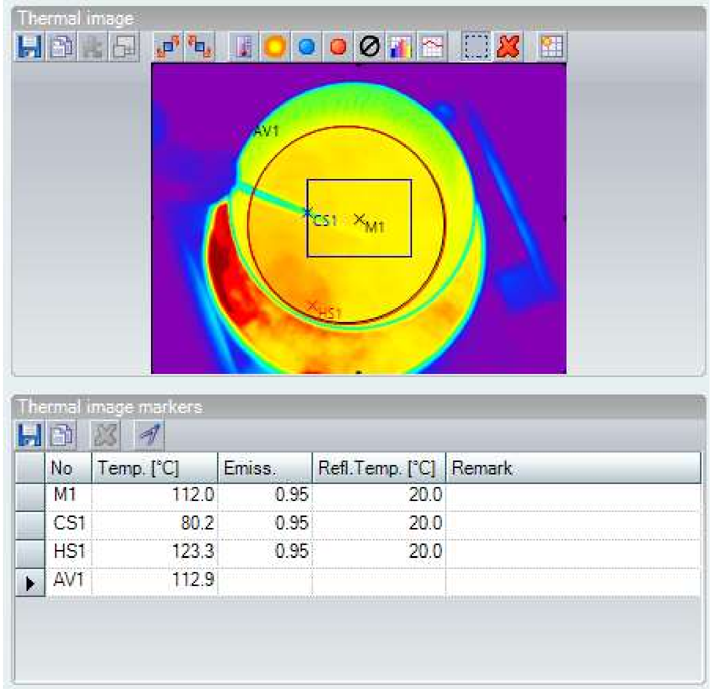

Fig. 4 – *Example of measurement obtained by thermal imaging camera: the set temperature is 110 °C.*

4. Conclusion

Students could make conclusion that PT -100 sensors measure temperature more accurately even though the camera is more expensive and a more sophisticated device. There is also confusion about what temperature should be used for the control system in the case of the camera. On the other hand, PT -100 gives a temperature that is not confusing. Students should be taught that both sensors have their range of application. In such an application, the respective sensor has an advantage.

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