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Short Communication

Thermo-Vision Analysis of Iron Foundry Production Process Concerning Secondary Usage of Heat

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Abstract

Increasing demand for energy and the shrinking of natural resources necessary for its production have led to the introduction of a wide range of activities and research about saving energy and using alternative sources. The industry in which such research is sensible is the founding industry, an industry of high energy demand. Energy use includes melting, heating, and keeping constant temperature of liquid metal, cooling the cast, and ventilation. At present it seems justified to regain the energy lost during the foundry process. However, before such research starts it is vital to establish the areas of greatest heat emission during the production process in the foundry. One way of getting such data is to use a thermo-vision camera.

Keywords: iron foundry, thermo-vision, heat energy

Introduction

The foundry industry is one of the fastest developing industries in the world in regards to production, modernity, and technological invention. Cast production in China has risen 3.5 times since 2010 and in India almost 3 times. In Poland the growth was 14% (Fig. 1), but concerning non-ferrous cast production the growth was 25%.

Production of castings in Poland has reached 1 million tons in 2011, which makes Poland a leading producer in Europe, (Fig. 2).

Increase in the production of casting and its use in recent years has proven its significance for the development of modern industry and the world economy. Looking at the above data, one has to realize how great the amount of energy used for production, (Fig. 3). The foundry industry in the U.S. uses more than 485 billion kJ of energy a year, from which around 346 billion kJ (71%) is used for metal casting. Most industrial energy (73%) comes from fossil fuels (83% gas, 16% coke, 1% other sources) [1].

Considering the great amount of used energy in production of casting it is necessary to introduce a wide range of activities and conduct research into saving energy.

The Polish foundry industry depends on energy cost which, due to production costs and the condition of Polish energy plants, is becoming an increasingly expensive resource. Similar to energy, there is a problem of emissions of greenhouse gases. European Union countries, including Poland, have fixed limits for CO_2 emission established by the European Committee. They are then shared by governments among different industries, including the foundry industry. The aim of such a policy is to make EU members introduce smaller emissions due to modernization of existing installations, change to clean technologies, and saving energy. Poland produces electrical energy mainly from coal, which means greater CO_2 emissions.

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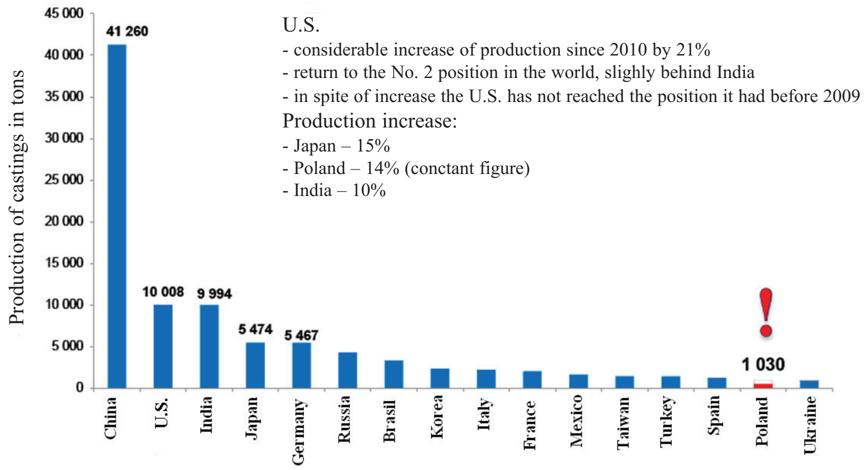


Fig. 1. Production of castings in leading countries in 2011.
Source: Modern Casting Dec/2012; CAEF – The European Foundry Industry 2011, Statistical data of Foundry Institute.

If production costs rise, one must consider the necessity of buying more shares of CO_2 emissions, which concerns industries using a lot of energy, including the foundry industry [2].

More effective use of energy in foundry industry should be associated with efficiency improvement, lack reduction,

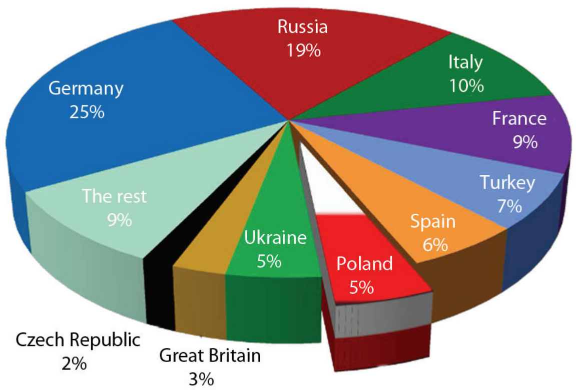


Fig. 2. The leading producers of casting in Europe in 2011.
Source: Modern Casting Dec/2012; CAEF – The European Foundry Industry 2011, Statistical data of Foundry Institute.

introduction of new melting technology, reduction of pollution emissions, reduction of production waste, and inventing a method for regaining the energy lost in the casting process. The necessity of saving energy concerns Poland as well, which as a leading producer in the UE should make management of the foundry together with their representatives take action into more competitive founding industry regarding the use of energy. The analysis of available literature shows no data concerning the use of energy in different stages of the casting process, which shows the necessity of conducting such research as a base for saving energy action. Taking that into consideration, our work presents the possibility of using thermo-vision to study the distribution and amount of heat emitted during casting production in one Polish foundry.

What is Thermo-Vision?

Today thermo-vision is regarded as one of the most attractive methods for diagnosis and observation in the world. It is widely used in the power industry, construction, metallurgy, environmental research, medicine, and many other fields [3-5]. The use of thermographic images is more

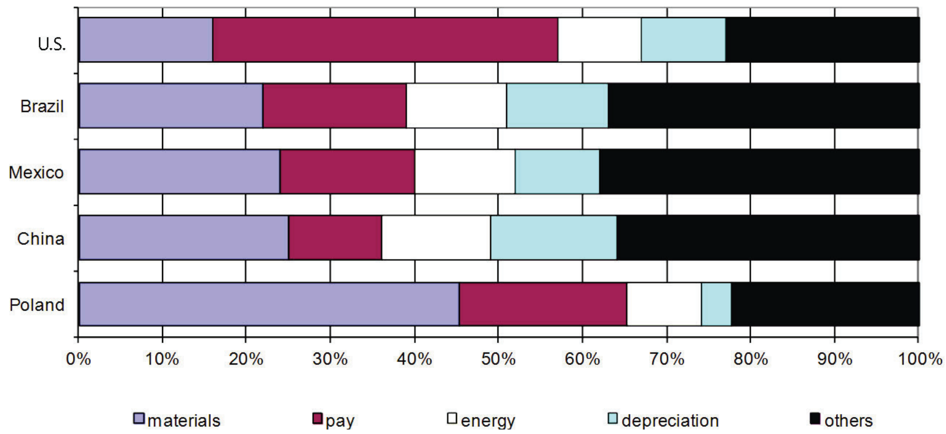


Fig. 3. Structure of production costs in chosen countries.
Source: Modern Casting Dec/2012; CAEF – The European Foundry Industry 2011, Statistical data of Foundry Institute.

and more popular. In some areas thermographic research has become common and even necessary [6-8]. However, in Poland, it is still not popular, which means it is underestimated. Thermo-vision can be used in different branches of the economy thanks to the fact that the measuring systems based on thermo-visional analysis of examined objects have many benefits. One of them is contactless measurement of examined objects which, in many cases, is a basic criterion that decides the best use of thermo-vision techniques [9-12].

Thermo-vision research makes use of electromagnetic radiation emissions by every object whose temperature is higher than absolute zero. The temperature -273.15ºC, which in practice is everything surrounding us. The electromagnetic spectrum is divided into many regions of wavelengths that are recognized by methods used to detect radiation. There is no basic difference between the radiation in different bands of the electromagnetic spectrum. They all are subject to the same rules and the only difference is the wavelength. Thermographic research makes use of a part of the electromagnetic spectrum concerning infrared radiation, which is often divided into four smaller sub-ranges, called close infrared radiation (0.75-3 μm), medium infrared radiation (3-6 μm), distant infrared radiation (6-15 μm), and very distant infrared radiation (15-100 μm) [13].

The camera registers radiation emitted by the examined object and then processes that into a colored map of temperatures, which creates the picture. That's why a thermo-vision system is a kind of thermometer that allows measuring temperature from a distance in many places at the same time.

The value of radiated energy rises with the growth of the temperature of an object, which enables one to measure its temperature through the measurement of the emitted energy, especially in the infrared radiation spectrum. Intensification of electromagnetic radiation depends on a received thermo-vision picture, either colored or black-and-white, reflecting the temperature distribution on the surface of the examined object [14].

Thermo-vision cameras used for measuring energy of an examined object are similar to ordinary video cameras, with one difference, namely that every point in the picture reflects the temperature of the object and not its color. A thermo-vision camera consists of the optical system, a detector of infrared radiation together with a proper cooling system, and the electronic path of strengthening, processing, and visualizing. Depending on the spectrum range in which they operate, thermo-vision cameras are divided into shortwave (range of operation 3 to 5 μm) and long-wave (8 to 15 μm).

A Flir T335 thermo-graphic camera was used in our research. It is a modern measuring device used for contactless, remote measurement of temperature and then to analyze its distribution on the examined object using thermo-vision pictures. The range of temperature when the camera is used is as follows: -20...+650ºC, and measurement accuracy is ±2% of reading. The camera used here is equipped with a micro-bolometric matrix with resolution 320×240 pixels and thermal sensitivity (N.E.T.D.) < 0.05ºC, while the lens is 25º×18.75º.

Study of Heat Flow during the Casting Process

The research was conducted in the KRAKODLEW S.A. foundry plant in Poland whose main production is metallurgical equipment, namely ingot moulds, collars, bottom plates, traps, and slag ladles. The plant is equipped with two induction furnaces of medium frequency and capacity of 5 and 25 tons together with a setter for a liquid pig iron blast furnace.

The mass of produced casting from grey cast iron, ductile cast iron, and vermicular cast iron is almost 80 tons. Besides metallurgical fittings the foundry also produces weights for travelling cranes, so-called "ballasts."

The study included the thermo-vision measurement of heat distribution and the amount of heat emitted during the production process. The observation included processes such as: pouring the cast iron into moulds, cooling moulds, shaking-out of castings, and cleaning them. The study also included the temperature distribution of the shaken-out mass and the systems of cooling and ventilation.

The study was conducted in the foundry in February 2013. The temperature of the surroundings was 0ºC and was constant during the whole measurement cycle.

Before taking the measurement one should set up the following values in a thermo-vision camera: the surrounding and replacement temperatures, emissivity of the examined object, air humidity, and distance from the object [15]. Measurement of the replacement temperature of the surroundings resulting from the radiation of objects near the examined object is not easy. It demands a careful radiation analysis of heat exchange. The value of that temperature depends on mutual orientation of the examined object, referring to other objects that emit radiation near the camera. Specification of the emission of a given object depends on the emission character and the reflection of its surface. Most objects send radiation in all directions and the reflection is of a diffusive character [16]. As for opaque objects in infrared, one must consider the reflectance of a given object when measuring the emission.

There are several technical methods of measuring the emission which are used, namely the calorimeter method, reflective method, or the method with a reference body [13]. However, the emission measurement becomes more complicated when the examined object is not homogenous in infrared, which takes place in thermo-vision measurements in the above-mentioned foundry. Bearing in mind the influence of many factors on measurement accuracy, for the sake of following study one has taken into consideration maximum registered temperature of the examined object, which occurs in the spots having the greatest emission.

Such an approach guarantees the smallest influence of external conditions on the study results. Select study results showing particular phases of the production process in the foundry are presented in the thermo-grams below, together with chosen photos of examined objects.

Use the FLIR QuickReport computer program attached to Flir T335 camera to analyze temperature distribution. It has great possibilities for treating the thermo-vision photos, including analysis of only selected parts of a photo, or the ability to read the temperature in every point of the thermo-gram. Also, it allows checking the settings for the surrounding temperature, replacement temperature, emissivity of the examined object, air humidity, and distance from the examined object used in the camera during the measurement. Having done the treatment of the photos with the use of FLIR QuickReport software, one can prepare a detailed report, including a careful description of the analysis of study results.

To analyze the photos received during the study we used a tool called "measurement area" that enables measuring temperature inside the indicated area, and "a measurement line" – measurement along an indicated line. The measurement using "a measurement line" was used to check the temperature of a pipeline and high-pressure wires, whereas a tool called "measurement area" was used to describe the temperature of the open mould, stamped molding sand, and the furnace.

Following analysis of the received results we can state that the temperature of the mould in the examined area in Fig. 4. is 583ºC. The analysis of the thermo-grams of a furnace lid (Fig. 5) enabled us to observe in the examined area a maximum temperature 52ºC. The measurement of high-

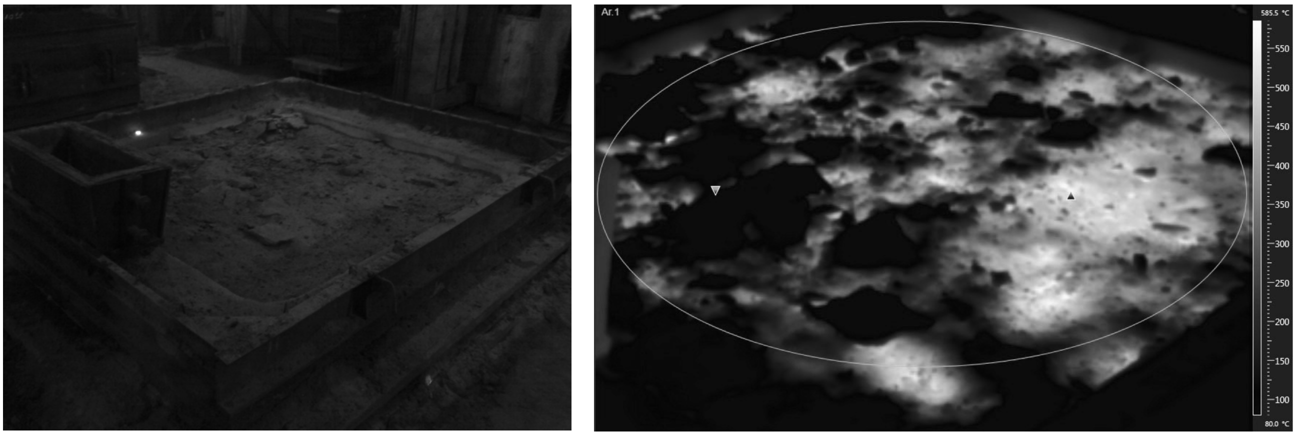


Fig. 4. Thermo-gram of an open mould.

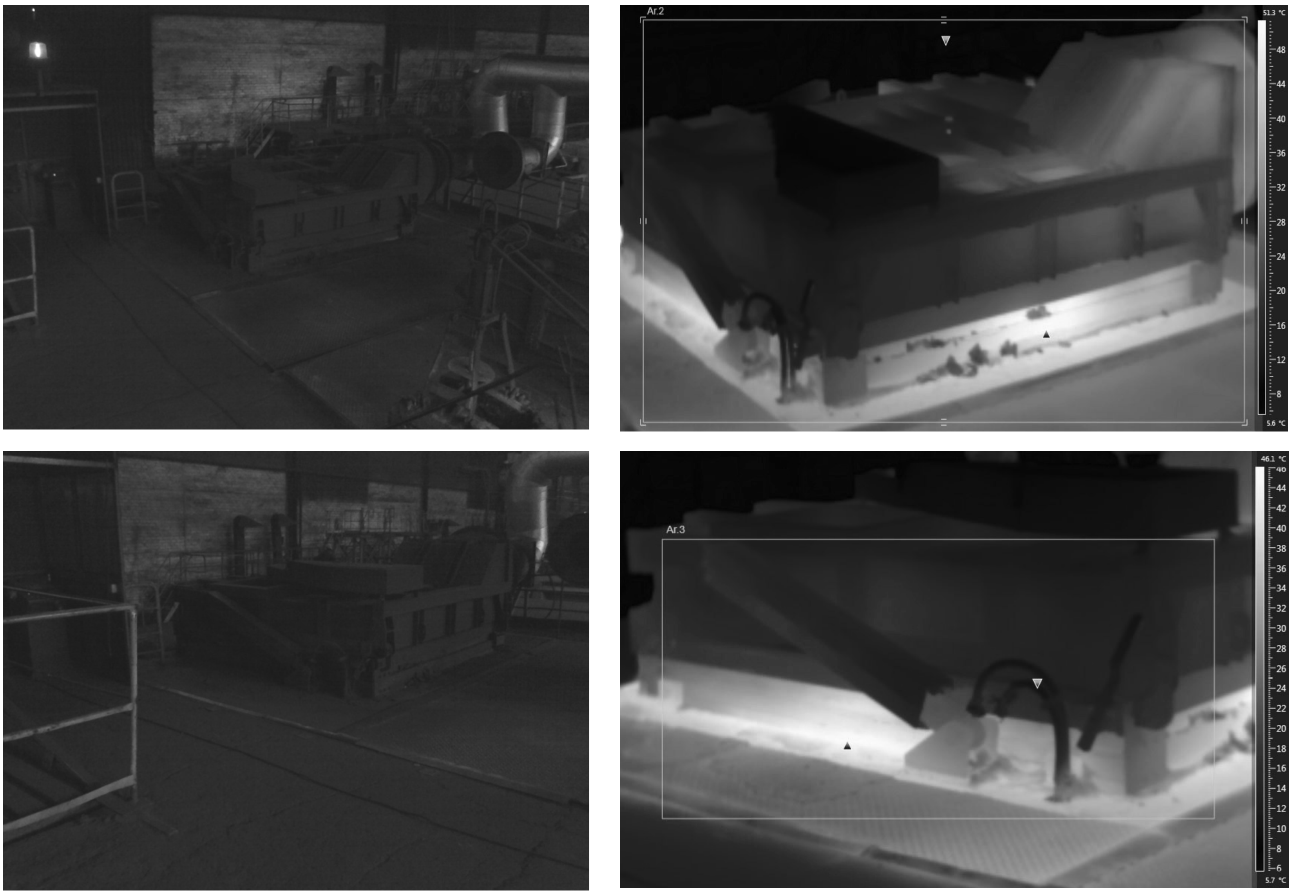


Fig. 5. Thermo-gram of a furnace lid.

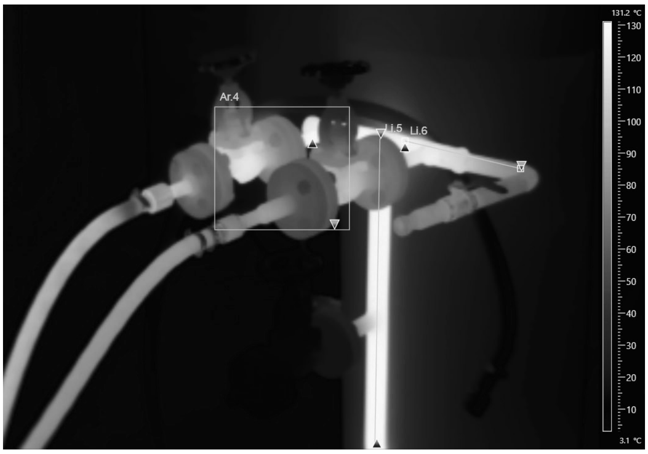
pressure wires in the examined area showed changes of temperature from 128ºC to 131ºC (Fig. 6).

To analyze the thermograms of the pipelines of cooling and ventilation systems (Fig. 7 a and b) an area measuring device was used, whereas while measuring long pipelines the best results were obtained when the line measuring devices were used. In the examined areas one could observe changes of maximum temperature from 21ºC to 46ºC. In the second line of the examined pipeline the maximum temperaure changed from 17ºC to 40ºC. The thermograms received from the last observed production phase in the foundry, concerning stamped molding sand (Fig. 8), enabled us to state its temperature, which was 286ºC at the moment of spiking the ingot, and the temperature of stored molding sand in the examined area, which was 233ºC.

Conclusions

Thermo-vision devices are more and more often used for measuring and controlling the processes in different fields of industry. The possibilities they offer are relatively great in comparison to their price. Making use of thermo-vision devices enables us to observe the moulding process

a)



b)

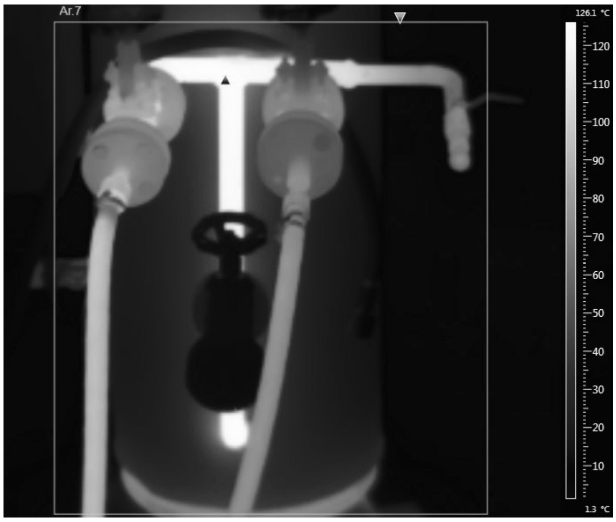


Fig. 6. Thermal image of high-pressure cables.

a)

b)

Fig. 7. Thermo-grams of pipelines for cooling and ventilation systems.

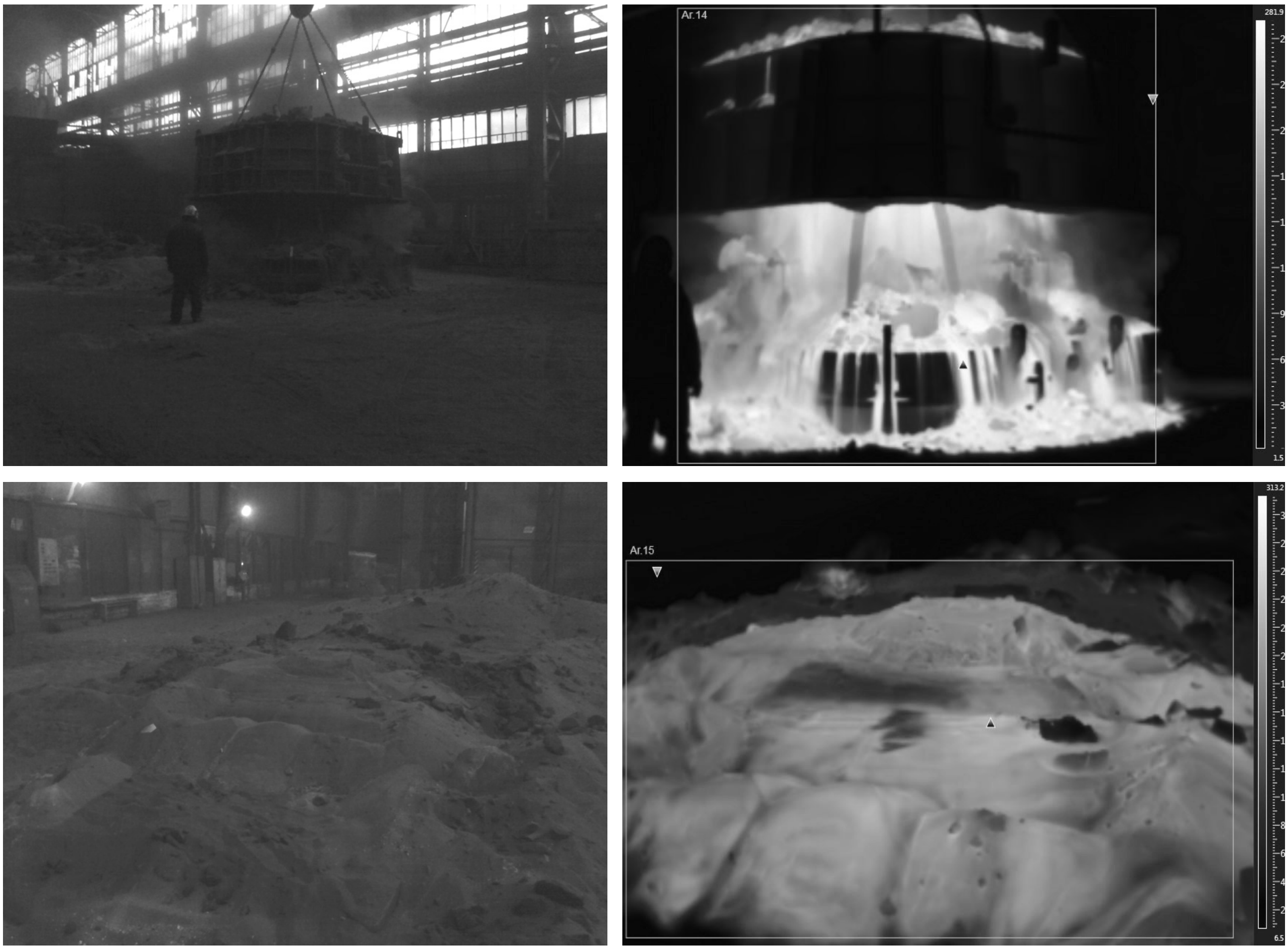


Fig. 8. Thermo-grams received during spiking of a cast.

concerning its proper course in its particular phases of moulding, and to establish the areas of greatest energy use. In addition, thermo-vision is a perfect tool to detect defects in pipelines, high-pressure wires, and their isolation. Using a thermo-vision camera we are able not only to create a picture of the whole installation very quickly, but also to detect clogged or leaking pipes. There is no need to check each pipeline separately.

Following the received results, one can state that during particular phases of the casting process a lot of heat energy is lost. One of these phases is a process concerning stamp moulding. This process includes spiking the ingot from the stamped molding, which goes to further treatment, whereas the stamping moulding is stored in big halls where it is cooled until it reaches the surrounding temperature. All the heat from the moment of spiking the ingot to reusing the moulding is irrevocably lost as shown in the foundry. The analysis of the temperature distribution of the moulding justifies the necessity of taking up action concerning the ways of regaining the lost energy in order to reuse it. One way to do this is to apply heat exchangers where the energy regained could be used for an example of heating the building, or water in the foundry. Other solutions include heat recovery from the foundry ventilation and from the cooling water.

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