Definition Marginal States of Irrigated Firefighting Barriers

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Abstract. Major fire emergencies generating high thermal loads go along with intensive convective and thermal flows. One of the ways to address the problem is to provide firewalls for industrial enterprises. This paper examines how water-irrigated firewalls can be used as protection from heat radiation and related factors of danger. A firewall is an assembled vertical enclosure made of thermal-insulation sandwich panels. A thermal-insulation sandwich panel consists of two meshed surfaces, with water injected between them by special spray nozzles. The irrigation system for thermal-insulation sandwich panels includes spray impact-jet slot-type nozzles with a blade reflector, the nozzles are serially connected through the trunk pipeline. To address the objectives, the following marginal states were controlled: Loss of heat insulating capacity (I) and loss of integrity (E). The test also examined the marginal state for loss of heat-insulating capacity (W). Because the panel is irrigated with spray nozzles, we used an infrared imager to control regularity of such irrigation and that of temperature distribution over the sample surface. Our research found that such firewall can be used as protection against thermal radiation and related fire hazards. After the test, the water-irrigation firewall design was awarded fire resistance level of EIW 150 for standard fire emergency. The results of infrared imaging confirmed the results of TEC registered on the unheated surface of the firewall; they also demonstrated existence of certain areas, where irrigation is incomplete, causing heating to 341.5°C at one point. This means that the system has to be further improved.

1. Introduction

Major fires with heavy thermal impacts, e.g., at oil and gas production facilities, in the oil and gas processing sector, storage and processing of liquefied natural gas (LNG) and liquefied hydrocarbon gas (LHG), transfer bridges for highly flammable liquids (HFL), flammable liquids (FL), giving rise to intensive convective and thermal flows [1-3]. To extinguish such fires, firefighters need to address a critical task: ensuring safety of the crew, and maintaining highly efficient fire protection of the facilities. One of the ways to address the problem is for manufacturing businesses to install firewalls, acting based on multiple reduction of thermal radiation of the flames. Firewalls, including fire screens, have engineering fire protections used as fire barriers on the way of fire, thermal flows and combustion products in emergency.

The objective of this research is the need to decide the possibility of using firewalls as protection from thermal radiation and fire hazards. A test sample is a fixed firewall designed to localize and prevent propagation of fire over industrial and civil objects, oil product storage tanks, LNG and LHG tanks, to fence off the tanks holding the extinguishing agent, used to partition the indoors space into firefighting bays.

The objectives of the research included: describing the following marginal states: loss of heat-insulating capacity (I) and loss of integrity (E), using the methods of GOST 30247.1-94 “Building
Structures. Fire Resistance Test Methods. Supports and Enclosures”; researching the marginal state in loss of heat-insulating capacity (W) as per GOST R 53308-2009 “Building Structures. Translucent Enclosures and Embrasure Filling. Fire Resistance Test Method”. Because the panel is irrigated with spray nozzles, we need to decide the regularity of irrigation and use the infrared imager to map the most heavily heated structural areas.

Figure 1. General view of firewall prior to testing

2. Materials and methods
The firewall is a vertical enclosing structure made of thermal insulation sandwich panels (figure 1). A thermal-insulation sandwich panel consists of two meshed surfaces, between which water is injected with special spray nozzles [4-6]. The irrigation system for thermal-insulation sandwich panels is built with spray impact-jet slot-type nozzles with a blade reflector, the nozzles are serially connected through the trunk pipeline. Working pressure is 0.4-0.6 MPa. Water consumption rate at working pressure of 0.4 MPa is at least 0.1 liter/sec per m². Pressure of 0.4 MPa was used for testing.

According to par. 8.2 of GOST 30247.1-94, to control the fire resistance limits for supporting inner walls and partitions, the system monitors marginal states such as loss of integrity (E) and of heat-insulating capacity (I).

According to par. 8.1.2 of GOST 30247.1-94, loss of heat-insulating capacity (I) is caused by temperature rising on the structure’s unheated surface by an average of over 140°C or at any point on the surface by more than 180°C compared to the structure’s temperature before the test, or more than 220°C regardless the structure’s temperature before the test.

According to par. 8.1.3 of GOST 30247.1-94, loss of integrity (E) is caused by solid cracks or openings emerging in the structure, through which the unheated surface is exposed to the effect of combustion products or the flame. In the course of the test, loss of integrity is measured using a wad under GOST 30247.0, which is placed in a metal frame with a holder, and held close to where flame or combustion products exist, for 10 sec some 20-25 mm from the sample surface. The time from the test start until ignition or smoldering causing the wad to glow is the limit of the structure’s fire resistance based on loss of integrity. Carbonization of the wad, without ignition or glow smoldering, is not considered.

One of the key functions of this firewall is to reduce the impact of the thermal flow. Analysis of the applicable regulations on the use of thermal-insulation screens has demonstrated that currently no criteria and standard test methods exist to assess efficiency of such type of screens. Therefore, we propose that the test basis should be the requirements and values of a permissible thermal flow on the
unheated side of the screen, 3.5 KW/m2 distanced 0.5 m, for an unprotected human [7-12]. Such measurements used the methodology set forth in GOST R 53308-2009.

To assess regular irrigation of the firewall design, we used infrared imaging: monitoring and measuring distribution of temperature on the surface in question [13-15].

A firewall sized 1,500x1,500 mm was installed in the sample holder. The gap between the ends and frame of the sample holder was filled in with refractory ceramic glass fiber. Thermal electric converters (TEC) were installed on the unheated surface: one thermocouple at the center, the others in the middle of the straight lines connecting the center and the corners of the furnace’s fire gate (figure 2). The time of exposure to fire was 150 min. The test was conducted under ambient temperature of 14.8°C.

![Figure 2. Layout diagram of thermocouples on sample surface](image)

3. Results and discussion

One of the test results is the image of temperature distribution on the surface of the firewall. The figure 3 represents how temperature of the unheated surface of the sample depends on the time of exposure to heat. The diagram shows that for the first 40 minutes’ temperature keeps rising to 55°C. After this, temperature changes slightly, and after 120 minutes’ temperature rises by the average of 10°C. During the 150th minute, the readings were as follows: highest mean temperature 71.5°C, highest temperature on sample surface 76.7°C. This means that the marginal stage of heat-insulating capacity loss (I) was not realized.

The next parameter monitored during the test was loss of integrity. In the course of the test, use of a wad in a metal frame with a holder failed to register any loss of integrity (E). Examination of the firewall following the test found no damage of the heated firewall surface.

Experimental research also measured the density of thermal flow, registered 0.5 m away from the geometrical center of the unheated surface of the firewall structure. Figure 4 represents how flow density of the thermal radiation relates to the time of exposure to heat. In the 150th minute heat-insulating capacity (W) did not drop due to achieved permissible level of flow density of thermal radiation was 3.5 KW/m2. As they are extinguishing a fire emergency, firefighters may have to confront dangerous heatwaves of 20 to 80 KW/m2 and even stronger (3.5 KW/m2 is recognized as the safety threshold).
Figure 3. Relation of temperature on the unheated surface to time of exposure to heat:
1 – TEC 1, 2 – TEC 2, 3 – TEC 3, 4 – TEC 4, 5 – TEC 5

Figure 4. Relation of thermal radiation flow density to time of exposure to heat

Infrared imaging was done along with measuring the parameters. Figure 5 and figure 6 represent shots of minute 30 and minute 140, respectively. If minute 30 featured only one area where temperature differs from the average on the firewall’s unheated surface, then minute 140 has as many as 4 such areas, with temperature 3-5 times above the average.
Figure 5. Infrared image of minute 30. Temperature at points:
M1 – 34.1°C, M2 – 34.6°C, M3 – 38.7°C, M4 – 18.9°C, M5 – 17.9°C, HS1 – 83.5°C

Figure 6. Infrared image of minute 140. Temperature at points:
M1 – 69.7°C, M2 – 72.2°C, M3 – 70.0°C, M4 – 69.1°C, M5 – 62.9°C,
HS1 – 341.5°C, HS2 – 262.5°C, HS3 – 261.8°C, HS4 – 237.1°C

The table 1 contains the results of infrared imaging from minute 30 and minute 140 of the fire test in the standard fire mode. Points M1 – M5 correspond to the locations of thermocouples TEC 1 – TEC 5. Point HS1 represents the highest temperature on the entire surface of the firewall. At points HS2 – HS4, highest temperature was registered at the selected areas marked with red circles.
| No. | Temperature [°C] at minute 30 | Temperature [°C] at minute 140 |
|-----|------------------------------|--------------------------------|
| M1  | 34.1                         | 69.7                           |
| M2  | 34.6                         | 72.2                           |
| M3  | 38.7                         | 70.0                           |
| M4  | 18.9                         | 69.1                           |
| M5  | 17.9                         | 62.9                           |
| HS1 | 83.5                         | 341.5                          |
| HS2 | 262.5                        |                                 |
| HS3 | 261.8                        |                                 |
| HS4 | 237.1                        |                                 |

The results of infrared imaging confirmed TEC readings taken on the unheated surface of the firewall; they also demonstrated that in some areas, irrigation was incomplete, driving temperature to as high as 341.5°C at some point. This confirms that the irrigation system requires further improvements.

4. Conclusions

This firewall can be used as protection from thermal radiation and fire hazards. After the test, the water-irrigation firewall design was awarded fire resistance level of EIW 150 for standard fire emergency.

Infrared imaging demonstrated that the irrigation system requires further improvements to ensure more regular distribution of the water screen.

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