TECHNICAL SCIENCES

ACCIDENT RISK CONTROL IN INDUSTRIAL LIQUID AND GAS FUEL BOILERS

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https://doi.org/10.5281/zenodo.12746264

Abstract
The publication describes the possible risks of an accident that may occur during the operation of industrial boilers, examines the possibilities of controlling and managing these risks, as a form of guaranteeing the safe operation of this type of equipment with increased danger, presents a study of a group industrial boilers regarding their normal and safe operation.

Keywords: Industrial boilers; Risk assessment of industrial boilers; Steam boilers; Accidents and risks with steam and water boilers

1. Introduction

Industrial boilers, as equipment working under pressure, are usually installed in industrial enterprises, where it is necessary to provide hot water for heating or for the needs of various technological processes, including those related to the hygiene of special premises, such as, for example, in processing enterprises of meat, milk, food products and others. Industrial boilers are installed in places where production processes require the provision of low-medium or high-pressure steam, for example, autoclaves, production of pre-made products, milk processing, etc. Defining and assessing the risks that may arise during the operation of industrial boilers is of utmost importance and requires special attention. Making mistakes in their design, production, operation or maintenance can lead to serious accidents, such as explosion, implosion or damage to various elements of the facility or adjacent installation, as well as to elements of the room where the industrial boiler is located. The manifestation of the accidents that occurred can be in the form of flying elements and pieces of the destroyed facility, pressure from the shock wave that arose as a result of the explosion, ignition of an explosive mixture obtained during the occurrence of the accident, leakage of fuel (liquid or gaseous, depending on the used such). These effects as a result of accidents very often cause serious injuries to personnel directly involved in the daily maintenance and operation of industrial boilers. As an indirect result of the impact of the results of the accident, people who are in the vicinity but are not part of the service personnel can also suffer. They can suffer trauma from being hit by heavy objects or flying pieces, cuts, injuries and burns. In addition, in the event of ignition of working fuel, harmful emissions may be released as a result of the accident, creating a risk of suffocation, poisoning or inflammation of the skin and respiratory tract. This publication presents the dangers and risks that may arise in the process of operating industrial boilers and the possibilities for their management and prevention. Along with this, the results of the author's study of monitored industrial boilers and the deviations from normal operation, damage and accidents that occurred in them are also presented.

2. Risks with industrial boilers

2.1 Risks associated with working under pressure

Industrial boilers are equipment operating under pressure. Since the environment in which they work is subject to thermal expansion and contraction, as a result of the heating of the working fluid from the combustion device, there are real risks of structural breaks and failure occurring. In this failure, the pressure that is normally in the [hermetically sealed space seeks to be released through the opening of the resulting microcrack in the material or weld and is thus in a condition to cause an explosion][2]. As a result, shock may occur. An explosion can cause various structural elements or parts or pieces of them of the installation around the boiler to fly at high speed and possessing enough energy to destroy and injure.

In steam boilers, two types of explosions occur most often: gas and steam-water.

The gas explosion can occur as a result of ignition of the fuel mixture, consisting of gas or liquid fuel vapor, collected in certain parts of the combustion chamber. Such a mixture can appear with incomplete combustion of the working fuel, which is usually the result of poor burner adjustment. A gas explosion occurs if, after reaching a certain concentration of the fuel-air mixture inside the combustion chamber of the boiler, an attempt is made to ignite the combustion device (burner) without venting (purging) the chamber. The strength of this explosion depends on the amount and concentration of fuel in the resulting fuel mixture.

[The steam-water explosion occurs when the working fluid is in direct contact with superheated surfaces][2], when there are breaks in the heating surfaces inside the boiler and ingress of water on the walls of the combustion chamber or the flame tube, while there is an extreme decrease in pressure in the water space, which leads to the rapid formation of steam. As a result of the water and steam flowing through the cracks and

the sharp increase in pressure, they expand, and the resulting reactive force sharply increases its value and acquires destructive power. Safety devices can also create a pressure risk. [When the pressure is exceeded, these devices should release the excess part of it by discharging the excess pressure][3]. This discharge is associated with the release of a working fluid (most often steam), which, in addition to pressure, also has a high temperature. This discharge may injure service personnel or anyone in the area of overpressure discharge. If these safety devices are damaged, the increased pressure cannot be released and there is a risk of an accident, which most often takes the form of an explosion of the boiler.

Steam regulators can also pose a risk during their operation because [if damaged, they may release a certain amount of working fluid][3] and, similar to the risk of safety devices, cause injury to personnel or provoke a boiler accident.

2.2 Risks associated with the equipment

The main risks associated with the equipment are the release of steam or hot water in the event of a leak and breach of the boiler casing and/or the pipes around it.

If flexible pipes are used to compensate for vibrations and if they break, there may be a risk of injury to personnel due to whiplash or dousing with a working fluid that is under pressure and at high temperature. Another risk associated with the equipment is possible leakage of working fluid under pressure in case of failure of a shut-off valve or a breakthrough through an insulating gasket of a flange connection. Released working fluid can cause burns if service personnel in this area are doused with it. With the fuel systems used, there are risks depending on the working fuel. When using gas fuel, there is a risk of gassing the working room in which the steam boiler is located and a possible risk of ignition and explosion. And when using liquid fuel (usually it is naphtha), there is a risk of spillage of naphtha and subsequent ignition and fire, which, in addition to injuries and burns, can also cause suffocation from the harmful smoke gases formed. In the event of damage to some of the control and measuring devices or the safety and protection devices, it is possible that there is a risk of an accident and even of an explosion of the industrial boiler.

2.3 Risks associated with incorrect actions of the personnel servicing the industrial boilers

The main risks associated with personnel actions are:

- Insufficient knowledge of safety rules - this risk can cause accidents in boilers, due to wrong actions or decisions of personnel in critical situations
- Leaving the boilers unattended - in this risk, the staff does not guarantee a sufficient degree of visual control of the boiler during its normal operation and thus does not have the opportunity to detect the occurrence of some preliminary indications informing about an impending accident, for example, vibrations, atypical noise , whistling, etc.
- Incorrect actions with the safety, regulating and measuring fittings - this risk almost always leads to serious accidents, because it deprives the boiler of its protection, guaranteeing correct and safe operation during operation
- Improper actions when detecting deviations in the normal operation of the boilers

3. Process research and analysis

This observation and research was carried out on 132 industrial vehicles working in different spheres of industry in the Bulgaria.The boilers have capacities from 450 kW to 1200 kW.

Type of research: Open monitoring of facilities and analysis of documented records.

Duration of the study: From January 2023 to January 2024

Sample size: 132 industrial boilers

Sample size calculation: The sample size was obtained and estimated based on an analysis of the total number of registered industrial boilers in the country. The author believes that when examining 10% of the total number of registered industrial boilers, results with a confidence level of at least 95% will be obtained. The actual sample size for this study was 132 boilers, which were grouped into groups by region. The total number of groups by region is 7, and the distribution of boilers by these groups is:

- Group I - 25 pieces (out of a total of 245 pieces),
- Group II - 42 pieces (out of a total of 416 pieces),
- Group III - 10 pieces (out of a total of 103 pieces),
- Group IV - 13 pieces (out of a total of 133 pieces),
- Group V - 14 pieces (out of a total of 135 pieces),
- Group VI - pieces (out of a total of 189 pieces),
- Group VII - 9 pieces (out of a total of 92 pieces)

Subjects and selection method: As a result of a study, it was estimated that the study should include boilers that work in heavier operating modes, compared to the rest of the same group, and the criteria for evaluating the operating mode include: working time within 24 hours, boiler load by power, working environment (normal or extreme). As a result of the research conducted and the following results obtained for the operation of the boilers within 24 hours (fig. 1), it was found that they work between 16 and 18 hours, and their average working time is about 17 hours in one day..

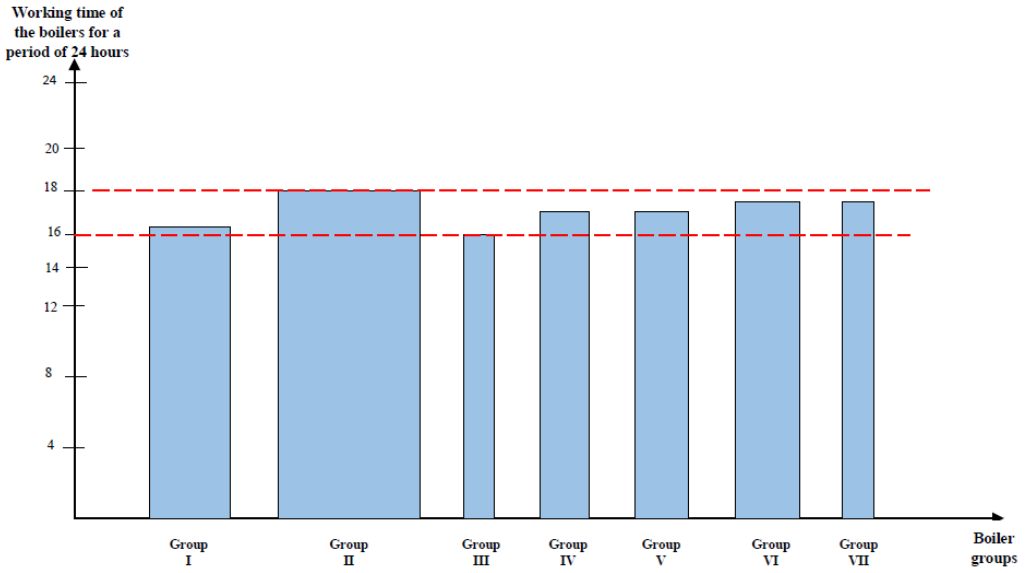

Figure 1

Regarding the load of the boilers by power, it was found that the boilers work with a variable load, which is consistent with the technological processes they serve and in which they participate. It is essential to note that, in percentage terms, boilers operate between 85% and 95% of their maximum power. Fig. 2 shows the loads of the boilers by power. Results are shown as averages for each study group.

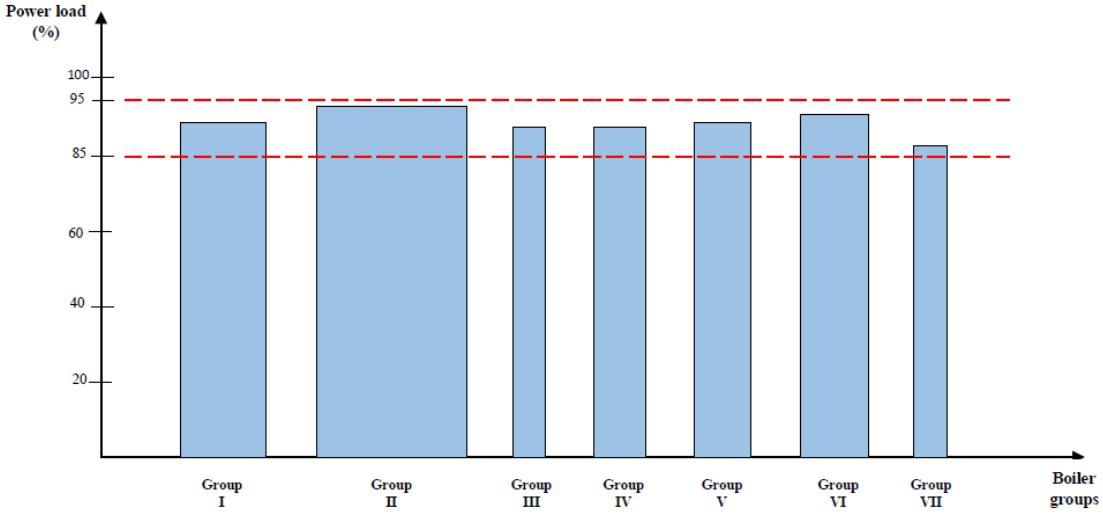

Figure 2

After analyzing the research data and establishing the impact of various risks on the normal operation of the boilers, it was found that the greatest probability of negative impact on a potential risk is the risk of incorrect actions of the personnel (R_s). The graph shown in Fig. 3 visualizes the impact of individual risks within the studied boilers.

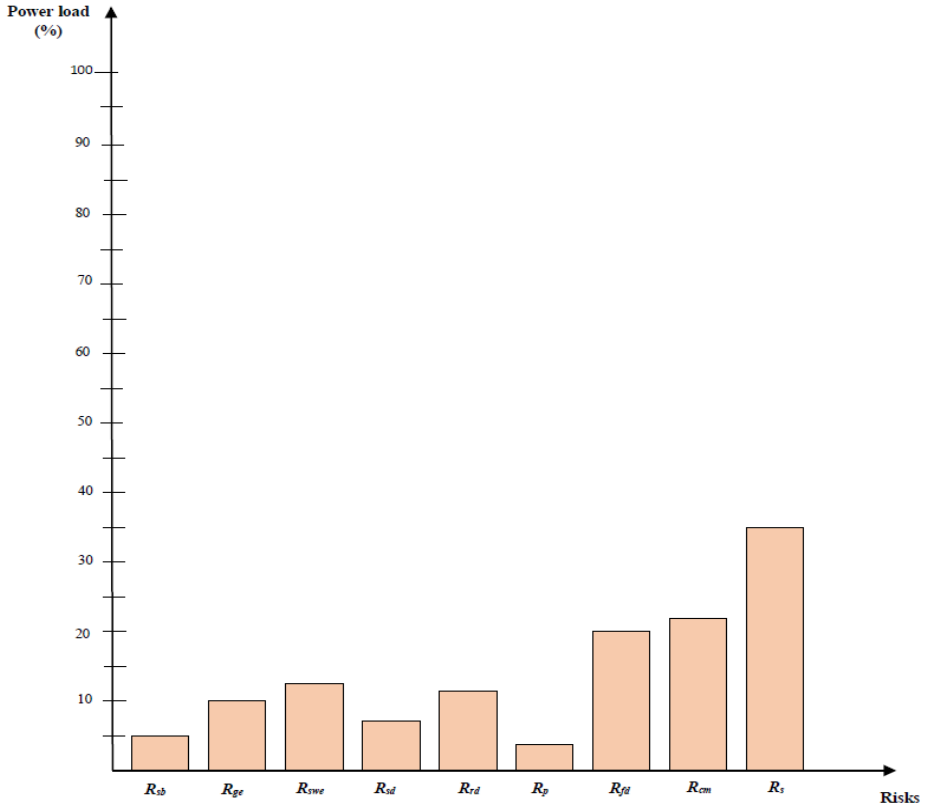

Figure 3

The individual groups of risks are indicated as follows::

- ***Rsb*** - risk of occurrence of breaches in construction
- ***Rge*** - risk of gas explosion
- ***Rswe*** **-** risk of steam-water explosion
- ***Rsd*** - risk of damage to safety devices
- ***Rrd*** - risk of damage to the regulating device
- ***Rp*** - risk of damage to pipes and connections around the boiler
- ***Rfd*** - risk of damage to the fuel system
- ***Rcmd*** - risk of damage to control and measuring devices
- ***Rs*** - risk of incorrect actions of personnel

To assess the possibilities of predicting the risk of an accident occurring in industrial boilers, it is necessary to calculate the complex risk (***Rb***). The assessment of this risk is complex and is composed of the sum of all individual risks,

$$R_b = R_{sb} + R_{ge} + R_{swe} + R_{sd} + R_{rd} + R_p + R_{fd} + R_{cmd} + R_s$$

By determining the value of the complex risk, we have the opportunity to assess how much a given industrial boiler can fall into an emergency state and thus plan and carry out a complex of preventive measures and activities to avoid the occurrence of an emergency situation.

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