Safety of using natural and liquefied gas under Arctic conditions

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Abstract. This article discusses and analyzes the emergency situations resulting the use of the natural and the liquefied gas in the northern areas. The normative and the technical documentation concerning the items of the control and the supervision in the gas facilities is analyzed here. It is concluded that in present there is no unified service which effectuates the control of the technical state of the gas equipment in the residential houses. That is why it is observed the use of the gas equipment of the high degree of the deterioration and not perfect technically. The equipment is missing of the systems of the control of the gas leaks and of the gas contamination in the room, there is no of the automatic shutdown of the gas supply in the emergency situations. There are a lot of violations during the use of the liquefied gas in the cylinders during the filling of the cylinders by gas. During the exploitation of the liquefied gas in the cylinders especially in non-stationary conditions in result of the not observation of the technological conditions of the safety, the decompression of the cylinders takes place and with the subsequent explosion. According to the results of the analysis of the state of the item the offers are developed concerning the increasing of the security level of the exploitation of the gas networks and of the use of the liquefied gas in the cylinders, and also of the housekeeping equipment working on gas. In the legal form, it is recommended that the functions of monitoring the state of gas equipment and networks be transferred to one organization with the rights of state supervision. Ensuring operational reliability - condition monitoring, preventive and routine repairs, replacement of equipment, it is also advisable to transfer one specialized organization. Contractual relations with these organizations must be transferred to management companies. In the technical field of safety, it is necessary to replace outdated thermal equipment with modern models with gas monitoring of gas leakage and gas burner operation. These recommendations also apply to metal cylinders for liquefied gases that need to be replaced with more reliable cylinders with a composite shell. It is necessary to diversify and improve preventive work to educate the population about safe handling of gas equipment and rules of conduct in case of emergency events with gas equipment.

1. Introduction

The safety of using natural and liquefied gases depends to a large extent on the climatic and natural conditions of the environment. The Arctic climate is characterized by a number of factors that complicate the use of gas, including:

- long period (9-10 months) of low temperatures (up to minus 500C);
- periodic ground freezing followed by thawing.

During low temperatures, gas is actively used to generate heat in residential areas with the use of thermal devices that are not intended for these purposes (kitchen gas stoves and others). The use of
 liquefied gas cylinders at low temperatures requires additional safety measures related to the special properties of liquefied gases (a sharp expansion of the volume when temperatures change). These conditions occur when moving cylinders from the environment to the room.

Freezing and thawing of soils leads to soil heaving and mechanical effects on gas pipelines, especially at the places of entry into buildings. In such cases, depressurization of gas pipelines may occur, followed by gas leakage.

Gasification largely determines the economic and social levels of development of the country, as it creates favorable conditions for improving the welfare of the population [1]. Gas supply is one of the most important life support systems for the population. At present, the level of natural gasification in Russian Federation as of January 1, 2019 amounted to 68.7 % (in urban areas — 72%, in rural areas — 59.2 %) [2].

Alongside with the positive qualities of using natural and liquefied hydrocarbon gases in the equipment, there are also negative qualities. Natural and liquefied hydrocarbon gases have dangerous physical properties such as toxicity and explosion hazard [3], [4], [5], [6]. Operation of the gas industry requires special conditions for compliance with safety measures, which are currently not fully implemented. [7], [8].

Relevance of chosen topic is due to the fact that the number of accidents that occur when using equipment running on gas increases every year, despite all the safety measures.

Today, the problem of operation of gas-fired equipment is quite acute. According to the latest data for the last three years there were more than 70 accidents involving natural and liquefied hydrocarbon gases [9]. Such accidents have serious consequences, namely human death, destruction of buildings and structures. Restoration of destroyed industrial and residential buildings and payment of insurance premiums entails large financial costs.

To ensure the safe and rational use of gas in everyday life, the system of state bodies has created special bodies that monitor the use of gas by consumers. As mentioned above, such special bodies are necessary, since the gas has dangerous physical properties, so it is necessary to strictly comply with the requirements of gas consumers operating rules of gas equipment [10].

2. General provisions

The main task of the gas supervision bodies until 1993 was to prevent cases of violation of safety rules and regulations that could lead to accidents at the supervised facilities. Along with this, the gas supervision authorities are responsible for monitoring compliance with the rules of design and construction of gas facilities, creation of rules for the operation of gas equipment, monitoring the rational use of gas and some other functions. Until 1993, gas supervision was carried out by state committees and gas inspections.

In 1993 when the Order of State Property Committee [11] came into force, the enterprises of gas economy were privatized. This situation led to the fact that the in-house gas equipment actually remained ownerless. Gas distribution organizations continued to monitor the technical condition of the in-house gas equipment, but the planned replacement of obsolete equipment was out of the question, since it was not on the balance sheet of any organization. In 1997, the Federal Law of 21.07.1997 No. 116-FZ "On industrial safety of hazardous production facilities" [12] was issued, where the gas equipment of residential buildings was not included, as it was not classified as hazardous production facilities. With the reorganization of the Country's Supervisory bodies, the system acting as Supervisory bodies has changed. The changes were significant enough to have a negative impact on the control of the technical condition of gas equipment related to civil engineering.

Rostekhnadzor supervises only gas distribution and gas consumption facilities, if the pressure of natural gas exceeds 1.2 MPa, and the pressure of liquefied hydrocarbon gas exceeds 1.6 MPa.

National fire authorities monitor compliance with the rules of safe operation of equipment of only certain requirements of legal acts of the Ministry of emergency situations of Russia. Thus, it can be concluded that the control over the safety of equipment operation is carried out by organizations that have neither experience nor diagnostic devices.
The in-house gas equipment remains on its own again and continues to wear out, which leads to emergency situations.

Federal rules and regulations in the field of industrial safety "Safety rules of Gas distribution and gas consumption networks" were introduced in 2015 [13], and did not apply to gas equipment of residential buildings.

Thus, since 1993, when the privatization of gas distribution systems began, there has been a void in the regulations concerning gas equipment not related to hazardous production facilities, which leads to dangerous consequences. We observe these consequences frequently when we hear in the news about the next explosion of household gas.

In 2004, when the "Housing Code of the Russian Federation" of 29.12.2004 N 188-FZ (ed. of 15.04.2009) was issued (as amended effective of 26.04.2019) in-house gas equipment was transferred to the condominium associations and management companies [14].

Has it improved the situation concerning gas equipment? Judging by the number of accidents – no.

The gas industry consists of gas supply systems and devices operating on gas fuel, among them boilers, water heaters, heating furnaces, burners, furnaces. As fuel for the listed equipment natural and liquefied hydrocarbon gases are widely used.

Natural gas from the main gas pipeline is supplied to residential buildings through gas distribution stations or gas control units. Before the gas enters the equipment, the pressure from the pipeline is reduced to the required value at the gas distribution station or installation. Then the gas pressure in the equipment is maintained constant automatically.

The gas distribution system is obliged to deliver fuel to the final consumer in a timely manner and without delay, in accordance with the rules of energy security. System must be safe in operation; all variants of abnormal events development must be considered for timely disconnection of individual elements of the gas pipeline section in order to provide an opportunity to eliminate the problems.

The natural gas supply, the technical maintenance and the supervision of the gas networks to the point of entry to the object is effectuated by the state specialized organization. The separate invoice for these services is issued to the consumer. Farther the gas equipment of the object is divided on communal (till to the shut-off cocks and the gas counters) and indoor (properly the gas equipment – the gas ovens etc).

The maintenance and the control of the communal gas equipment are effectuated by the housing maintenance and utilities by means of the management company and the payment for these services is included in the residential rent. The control of the state and the maintenance of the indoor gas equipment including the installations of the gas cylinders with the liquefied gas must be effectuated by the organizations having the licenses for such works execution. The owner of the flat equipment has to conclude the individual maintenance service contract with such organization. That way the maintenance and the control of the state of the gas networks and of the gas equipment are effectuated by three individual organizations and the owner pays separately for the each type of the service.

Accidents related to the use of gas fuel have two main causes of occurrence. First, outdated gas equipment, which is not going to be changed in the near future, or artificially prolong the service life, replacing individual parts. Secondly, the gas-fired equipment is not equipped with an automatic gas cut-off system in case of detection of a problem, for example a gas leak. There are no sensors to monitor the operation of the equipment. Third, the problem in the legislative system, the features of the problem discussed above.

The other reasons of the emergency situations have place during the use of the liquefied gas in the cylinders. The filling and the exploitation of the liquefied gas in the cylinders has the special safety requirements, resulting by the physical and chemical features of the gas in liquid phase. The transmission of the liquid phase in gas phase is possible in case of defined temperature, depending on the pressure of the saturated steam forming the liquefied mixture. The dependency of the steam pressure for the propane / butane mixtures of different percentage ratio of temperature is presented in pic.1. The different boiling temperatures of the components define the ratio of these components in different periods of the year. So for the summer period this ratio is 40% of propane and 60% of butane, and in the winter period is 60%
of propane and 40 of butane. For the northern areas with cooler climate the processes of the evaporation of the liquefied gas because of that are difficult and require the special conditions for the exploitation of the cylinders.

![Figure 1. The dependence of the pressure for propane-butane mixtures to the temperature. Here: 1- 100/0, 2- 70/30, 3-50/50, 4-30/70, 5-0/100. % propane/butane](image)

The filling of the cylinders must be executed only with the control of the mass of the liquid phase calculated as 0.425 kg for 1 l of the volume at any temperature of the mixture. The increasing of the temperature of the mixture will result to the increasing of the pressure in the cylinder. That is why the cylinder must have the free volume (approximately 20%). In conditions of low temperature of the northern areas it is especially important to follow this safety condition. So during the moving of the cylinder from the ambient environment with the low temperature in the warm room the evaporation of the liquid phase will take place and in case of the absence of the free volume it will result to the increasing of the pressure in the cylinder.

The increasing of the pressure in the cylinder takes place in any other circumstances of the temperature increasing of the walls of the cylinder (the action of the open flame, stove fittings, the sun rays etc.).

The situations with the excessive heat of the walls are especially dangerous in case of the entry of the cylinder in the fire seat. In such case when the cylinder breaks, the pieces of the shell are shattered to the distance of 2 thousands meters and the formation of the “fire ball” takes place with the subsequent wave of the exceeded pressure.

The factor of the excessive heat of the liquid phase of the gas in the cylinder is the most frequent cause of its decompression, and that results to the formation of the steam gas mixture and the explosion. The gas explosions provoke the building demolition and the damage of people. The scale of the damage and of the demolition depends on the gas volume, participating in the explosion and on the constructional characteristics of the room, of the building.

In practice the filling of the cylinders by the mass of the gas is executed only on the gas filling stations (GFS), having the conditions of the mass control of the filling of the cylinder. In other cases the filling by the mixture is executed from the gas dispensing columns, without the mass control and it is possible to fill the whole volume of the cylinder (including by demand of the owner of the cylinder).

The reasons of the emergency situations during the storage and the exploitation of the cylinders with the liquefied gas are related to the exceed heat of the cylinders from the household heat devices...
(electrical heaters, batteries of heating system, gas ovens etc.) and with the gas leaks from the casing and the heat devices. The circumstances of these reasons are equal to those in the gas networks with the natural gas which were discussed above.

Let’s compare the parameters of emergency events that are possible when using natural and liquefied gases.

When using natural gases, the most likely emergency situation is a gas leak when the network or gas appliances are depressurized. In case of a leak from the network, the parameters of an emergency event will depend on the volume of gas that has leaked out and the location of the leak. If the concentration of the leaked gas is within the lower and upper concentration limits, the following consequences may occur:
- toxic contamination of the volume of the room or territory;
- gas explosion if there is a source of ignition and no gas dispersion.

If gas leaks from thermal equipment, the emergency event parameters will depend on the thermal capacity of the equipment and the duration of the leak. So for a conventional gas stove, the heat output of the burners on the working surface is 1-3 kW, which corresponds to a gas leak, in the case of burning out, 0.1-0.3 liters per hour. The burning time of a normative emergency is 1 hour and the following consequences are possible:
- dispersion of gas leaks in the presence of natural ventilation.

A gas explosion is not possible for the considered leak option, since the gas concentration in the room will be less than the lower concentration limit of the flame propagation for natural gas (4.5%).

When using liquefied gas in cylinders, emergency situations should include:
- leaks of the gas mixture from hoses, pipelines and thermal equipment;
- depressurization of the balloon.

If a gas mixture leaks, the parameters of the emergency event will depend on the volume of the cylinder and the extent of the leak (power and duration).

When the cylinder is depressurized, the following damaging factors and consequences will occur:
- scattering of fragments of the metal shell of the balloon and the probability of human damage;
- explosion of the gas mixture with the subsequent formation of excess pressure. Thus, if a propane-butane mixture with a capacity of 5 liters is depressurized, the damage will be significant if an explosion occurs in a room with a volume of 50 m3. In this case, the destruction of the building will depend on the location of the room and the characteristics of the building itself.
- If people are in the room, they will get fatal injuries.

3. Conclusion
Having considered the causes of accidents in the use of natural and liquefied gas and the state control and supervision of heating equipment, the authors recommend to increase security and reduce emergency situations to make the following proposals to the rules of operation of gas equipment.

Offer 1. Organizational. The strengthening of the supervision manual for household appliances running on gas.

After the accident in Magnitogorsk in the end of 2018, many cities Rostekhnadzor, which is not related to household gas appliances checked in the apartments on their own initiative. It was revealed more than half of the equipment requiring replacement. This suggests that the current gas stations cannot cope with their responsibilities. Not doing for the reasons that the control of observance of safety rules use of appliances operating on natural gas, are organizations that do not have all the necessary equipment to carry out inspections and related verification poor that spend their unskilled professionals [16]. Since the responsibility at the moment for the inspection of gas equipment is on the homeowners associations, management companies and communal services [17].

Proposal 2. The use of automatic devices to interrupt the gas supply in the event of irregularities in the operation of equipment running on gas.

To equip a household gas units with gas detectors and shut-off valve which stops the gas supply if a gas leak the result of depressurization that occurs most often. This proposal will carry high economic costs, approximately more than three hundred billion rubles, given the number of appliances operating
on gas throughout Russia. But it is worth considering the financial losses upon payment of premiums after the accident occurred. It is also worth to note that accidents involving domestic gas often ends with casualties and deaths. What is worth more – human life or automatic and control devices [18].

Offer 3. Advocating responsible operation of gas equipment

At the moment, regulations for the safe use of equipment running on gas, not widely voiced [19]. All the propaganda is reduced to silent cartoons from the Ministry of Emergency Situations to which few people pay attention.

The authors suggest to return the propaganda that was widespread in the Soviet Union, when children at school were taught how to use gas stoves on the lessons of life safety. The same reminders about safety rules were repeated in universities and at work. The authors propose to improve literacy in relation to the operation of gas equipment by means of lectures, posters in public institutions and public transport.

When using gas appliances, the users must strictly comply with the basic safety rules:
- do not leave running thermal gas appliances unattended;
- in case of violation of their operation (extinguishment of the burners, odors in the room, etc.), it is necessary to disconnect the devices from the gas network, ventilate the room and call the emergency gas service;
- do not repair or connect new gas appliances to the network by yourself.

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