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IMPROVEMENT OF TECHNICAL MEASURES FOR PROCEDURES IN ACCIDENTS ON GAS SYSTEM

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SUMMARY

Due to properties as flammability, explosiveness, suffocation (decreased oxygen content), toxicity (incomplete combustion), large lengths of gas pipelines, risk of leakage, etc., natural gas is media that requires special care during transport and use. There are many examples in the world where unprofessional and negligent use of gas led to unimaginable and tragic consequences with human casualties and huge material damages. This paper analyzes management of accidental situations at the Sarajevo Canton gas system. Problematic aspects of management will be presented through two case studies instead of presenting idealized models that integrate all structures responsible for dealing with such accidental situations. The methodological approach in this paper is presented through selection of accidents on gas network that had a significant impact and required a coordinated response from the competent services. The goal is to consider possibilities of improving technical measures by installing valves with remote control, which would raise safety to a higher level. With this step forward in technical terms, it would be possible to close the valve on gas system in the shortest period of time by controlling it from the dispatch center, which would stop the uncontrolled gas release.

The paper will suggest locations where it would be optimal to install valves with remote control, in order to close the necessary section, and at the same time, the least number of consumers would have a gas supply interruption.

Key words: gas system, accident, technical measures

INTRODUCTION - SARAJEVO CANTON GAS SYSTEM

The gas network in the Sarajevo Canton (SC) is conceived as a multi-stage distribution system. The basic city gas network is designed as a steel gas pipeline of pressures 8 (14.5) [bar] and 3 (4) [bar], which is in form of a ring due to the uniformity of gas supply to customers, so that the basis for gas distribution is steel gas network pressure 8 (14.5) [bar] with three main metering and regulating stations (GMRS): Butile, Hum and Ilijas. At the entrance to the most populated parts of the city this pressure is reduced for safety reasons in pressure reduction stations from 8 (14.5) [bar] to 3 (4) [bar]. The regional reduction stations (RRS) for the supply of a certain city area and the receiving-reduction stations (PRS) for the supply of larger industrial and other consumers are connected to this gas network. The outlet pressures from these stations are 0.1 (0.2) [bar], 0.5 [bar] or 3 [bar] depending on the further way of gas distribution and use.

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The gas network with pressure 8 (14.5) [bar] is divided into 24 sections and contains 33 valve batteries, emergency valves for RRS and PRS, branch valves and sectional valves for 53 RRS, 93 PRS-industrial consumers and 27 PRS for Heating plant boiler rooms. There are a total of 519 valves of various diameters on this network. The batteries have a function of shutting off the gas supply to certain sections of the gas network and possibly releasing the gas using the vent valves that are an integral part of the batteries. Gas pressure network 8 (14.5) [bar] is built with steel pipes and extends from GMRS I in Butile and with two branches (north and south) closes in a ring, and ends with RRSs 8/3 [bar] which supply gas to the narrower part of the city and from GMRS II on Hum. An independent unit of this gas network is part of network 8 (14.5) [bar] in the Municipality of Ilijaš, which is supplied via GMRS III. The total length of this network is 101,839 [m].

The general characteristic of the gas network 3 (4) [bar] is that it is made as an underground pipeline of steel and polyethylene pipes of different cross-sections. This network covers most city municipalities. The gas pressure network 3 (4) is 70,957.50 [m] long (Figure 1).

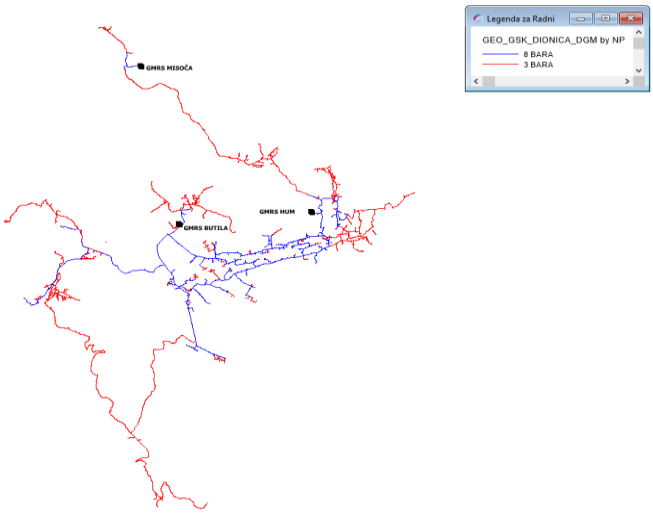


Figure 1. Gas network SC 8 [bar] and 3 [bar] [4] [8]

The gas network with a pressure of 0.1 (0.2) [bar] and 0.5 [bar], is built with polyethylene pipes and covers the entire territory of Sarajevo Canton. According to numerical indicators of the laid pipelines' length, this is the largest network with a total length of 1,074,453.50 [m].

In the recent past, Sarajevogas[5] had a number of serious damages to gas pipelines with a nominal pressure of 3 [bar] and 8 [bar], which did not result in material consequences or human casualties. However, such situations indicated that there are elements which are not within the domain of the company's responsibility and they could have impacted the further course of the accident itself. Bearing in mind that an adequate and appropriate reaction is not always possible by acting on the ground, it is necessary to enable faster and more effective handling of accidents by improving technical measures on the gas system, which results in higher safety level in the aforementioned situations. These measures would not be related to the human factor action in the field, but to the coordination and activities of the dispatch center.

This paper analyzes possibilities for technical measures improvement by installation of valves with remote control from the dispatch center.

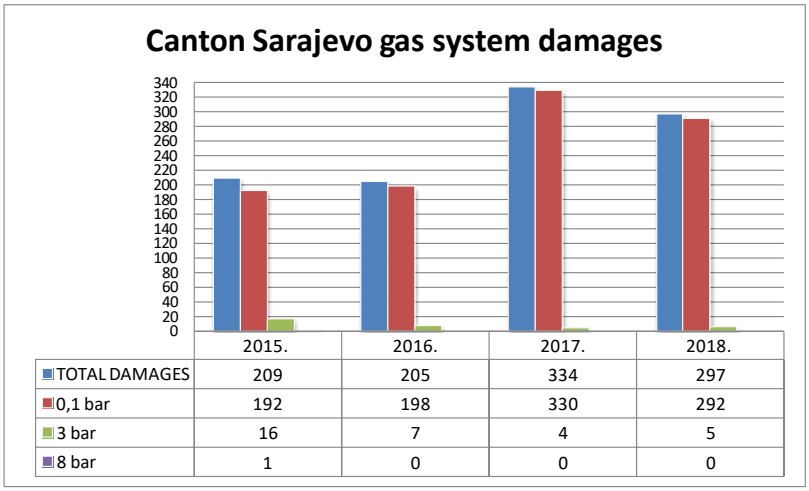
[4] 100 [mbar] network is not shown due to its size, i.e. density, as well as gas plants, i.e. stations

[5] "Sarajevogas" d.o.o. Sarajevo is a company for the supply of natural gas to the Canton of Sarajevo

1. CASE STUDIES

The risk of city gas pipelines leak is high and occurs for multiple reasons. The main reasons are pipe damage, corrosion, problems in the construction of the pipeline itself, damage from a third party, damage caused by natural (environmental) factors such as landslides.

In the observation period 2015-2018, damages to the CS gas system were recorded, with the 0.1 [bar] system damages dominating (Diagram 1).

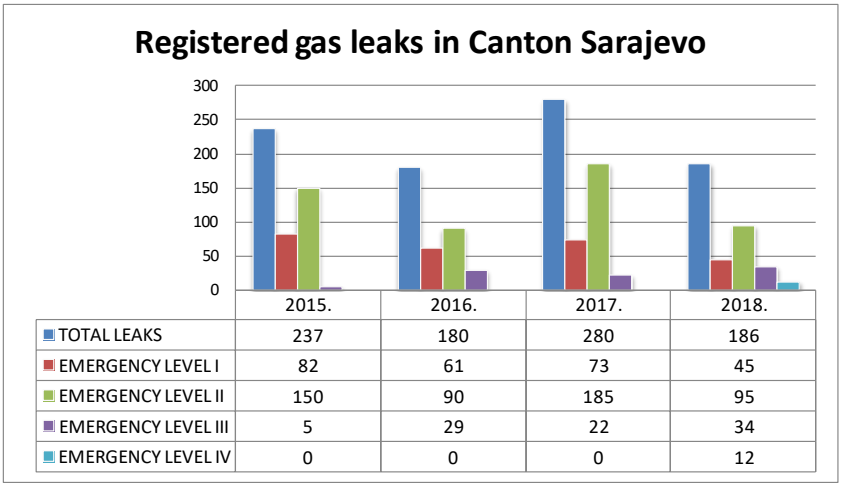


	2015.	2016.	2017.	2018.
TOTAL DAMAGES	209	205	334	297
0,1 bar	192	198	330	292
3 bar	16	7	4	5
8 bar	1	0	0	0

Diagram 1 - Statistics of damage by network (pressure) during period 2015-2018 (source: Sarajevogas)

In order to help in deciding on urgent measures, as well as to help decide on the type and order in underground gas pipelines repairs, 4 levels of urgency are defined, where the degree of urgency 1 is the highest level of threat (explosions, fires, large-scale gas leaks, damage to the distribution gas network, etc.) and 4 is the lowest (regular maintenance of the gas system).

Diagram 2 shows an overview of detected gas leaks on the CS gas system during period 2015-2018, with regard to the urgency degree. The largest share of the total registered leaks in each year belongs to the urgency level II: the location of it or the boundary line is located at a distance of less than 1 meter from the building, where the presence of gas is not registered in the building and buildings or hollow spaces near the leak location. Safety measures for the level of urgency II, which are being implemented without delay, include, for example, the excavation (release) of piping with the aim to enable the unhindered gas discharge into the atmosphere, control of neighboring buildings and cavities, after which repairs are being carried out.



	2015.	2016.	2017.	2018.
TOTAL LEAKS	237	180	280	186
EMERGENCY LEVEL I	82	61	73	45
EMERGENCY LEVEL II	150	90	185	95
EMERGENCY LEVEL III	5	29	22	34
EMERGENCY LEVEL IV	0	0	0	12

Diagram 2 - Statistics of detected gas leaks during the period 2015-2018 (source: Sarajevogas)

Detection is one of the most important segments of gas system maintenance, with task to carry out planned measures to check the distribution gas system for permeability, as well as visual control of the correctness of the distribution gas system parts. After gas leakage is detected, appropriate measures are taken. It is necessary, if there are buildings nearby, to carry out detection in them as well.

There are several possible approaches and methods of dealing with natural gas accidents. It is necessary to have procedures or written documents that will define roles and tasks of persons conducting repairs as well as those who manage, whether management is on the spot or indirectly from a remote center through the communication system.

Through case studies, this paper investigates the management of crisis situations during uncontrolled gas leak in Sarajevo Canton. The first case study refers to the uncontrolled gas release under the surface that occurred in 2010 in the central part of the city in the area of a very busy street, in the immediate vicinity of business premises and residential buildings.

The second case study presents a gas leak from 2018 in the settlement of Bjelave, when gas concentrations were also registered in a large number of residential buildings.

1.1 UNCONTROLLED SUBSURFACE GAS LEAK IN THE CITY CENTER

In 2010, the gas leak was registered in the evening based on a notification from citizens that presence of gas was felt in M.M. Baseskije street. Measurement and detection found the presence of gas with different concentration values depending on the location where the measurement was performed. The highest concentration of gas was found in two shafts used by the telecom operator for its installations in the immediate vicinity of the intersection of M.M. Baseskije and Jeliceva street, and in M. M. Baseskije street near number 22 in the sidewalk area, and in two sewer shafts in the M. M. Baseskije road itself near the aforementioned intersection of M. M. Baseskije and Jeliceva and near the intersection of M. M. Baseskije and E. Mulabdica streets (Figure 2). The measured concentration in these shafts reached a value of up to 95% of the gas volume, and all employees from the "Standby Organization" as well as additional employees who perform work tasks in detection jobs were called and directed to the location.

Given that this street is the central one through which traffic for vehicles and trams takes place, the police closed this street to traffic, as well as to pedestrians, for preventive - safety reasons; Members of the Sarajevo Professional Fire Brigade were also present, as were the workers of power supply company, who turned off the electricity for a wider area around the accident site.

The presence of gas was not registered in the building itself. Excavation was carried out at several locations, but the cause of the uncontrolled presence of large concentrations of gas was not discovered. In telecom operators shafts, the concentration varied, it would increase over time and then decrease, and it had to be constantly ventilated.

Figure 2. Uncontrolled gas leak location

Taken into account that the location of the uncontrolled gas leak was not found during the night, construction of sections started next day by installing section valves. Electricity was still out for the wider accident site. By installing sectional valves using the method of eliminating part of the gas network, the area of uncontrolled leak was narrowed. First, two valves were installed at the ends of the gas network pipes where the devices did not registered gas. By closing these valves, it was determined by measurement that there was a decrease in gas concentration in the section between these two sectional valves, and then installation of a two more valves began. When the sectional valve was installed, it would be closed for a certain period and during that period the gas concentration would decrease, and then by opening it, the concentration would be measured and checked again in order to determine more closely the location of the gas release. Four measuring points were placed on the section that could be, with certainty, determined to being damaged. These measuring points served to eliminate sections by measuring the pressure drop and narrowing the area where excavations should be carried out for the final finding of the damage (Figure 3).

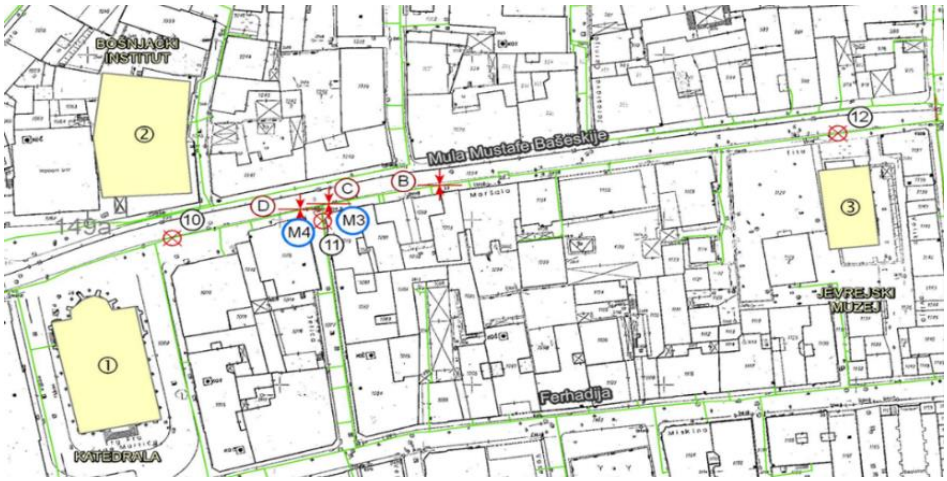


Figure 3. Locations of valves and pressure gauges placement to narrow section during the damage site locating

When it was identified a section of about six meters long gas network where there was a constant concentration of gas, excavation of this section started. After these actions, damage was found on the gas network pipe where the gas was leaking. The cause of the damage was a 0.4 [kV] electric power cable that was completely resting on the gas system pipe, and the heating of the cable caused plastic pipe melting (Figure 4) and an opening was created where the gas flowed out in large quantities.

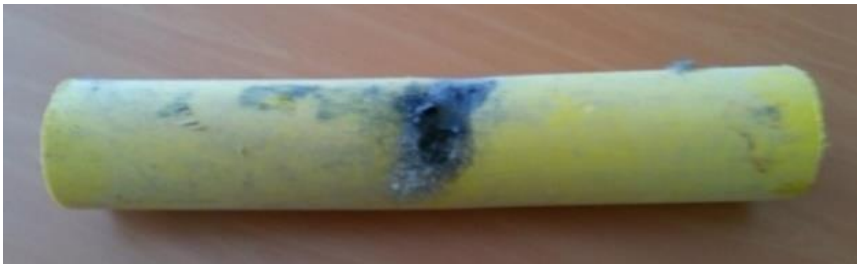


Figure 4. Damaged gas network pipe

It can be concluded that in the accident in M. M. Baseskije Street, during which a large concentration of natural gas was released, the action was systematic and organized; and the cause of this accident is exclusively human factor.

1.2 GAS DISTRIBUTION NETWORK PIPES ACCIDENTAL DAMAGE

In the afternoon of 2018 (Friday) at Bjelave address no. 43 due to works on the water supply network reconstruction, the DGM pipe (gas distribution network) PE Ø 160mm pressure 3 [bar] was damaged and team from the "Standby Organization" went to the scene.

Officials of the Ministry of Internal Affairs of Sarajevo Canton who secured the scene, members of the Professional Firefighting Unit of the Sarajevo Canton Civil Protection Administration, as well as members of the Voluntary Firefighting Society of Bjelave were present at the location. The damage occurred when the local utility company excavator damaged the DGM pipe while excavating water pipe for the purpose of repairing it (Figure 5).

Figure 5. Damaged gas pipe (Source: https://www.faktor.ba)

Taken into account that the damage occurred during the peak traffic hour in the city, the arrival of the teams at the scene took longer. The mitigating circumstance was that the damaged pipe was supplied on one side, so it was enough to locate the nearest valve and shut off the gas. Upon arriving at the scene, the B3-07 valve battery was located, about a hundred meters from the gas leak, and the gas was shut off on the damaged DGM pipe. Taking into account that the intervention teams needed a longer time to arrive at the scene due to rush traffic hour, and the time necessary to locate and close the valve battery, about forty minutes passed from the moment of damage to the moment of shutting off the gas supply. Due to the gas pressure of 3 [bar], it was not possible to perform a temporary repair, but the gas supply had to be closed at the valves.

The long period of gas leakage had a psychological effect on citizens due to the fact that the pressure in the damaged pipe was 3 [bar] (which, due to the sound it created, also had a psychological effect on the citizens), and leakage happened in an old town settlement where the roads are narrow and the buildings are close to each other (Figure 6), and also due to this certain amount of gas entered the nearest residential buildings caused fear and panic among the citizens.

A large number of calls to the dispatcher on duty were made due to citizens' fear of the possibility of a gas explosion. Response to this accident was characterized by good coordination between the duty dispatchers of Sarajevogas and the duty dispatchers of external entities such as power supply company and the Professional Fire Brigade. The power company team immediately arrived at the scene, whose employees turned off the power supply to the affected location. Also, the duty dispatcher of the Professional Fire Brigade sent one fire engine of the Professional Fire Brigade and one vehicle of the Bjelave Volunteer Fire Brigade to the scene.

Picture 6. Damaged gas network pipe in the settlement of Bjelave

After the gas was turned off, the gas detection in buildings which were located in the immediate vicinity of the damage site started. After first control, the presence of gas in concentrations of 600 [ppm], 800 [ppm], 200 [ppm] and 120 [ppm] was registered in individual residential buildings, while the presence of gas up to 50 [ppm] was registered in the buildings of Home for children without parental care (which are in the immediate vicinity). In all buildings where detection was carried out, the windows were opened and ventilation of these buildings were carried out. After half an hour, the detection of these buildings was performed again, when the gas presence was not determined in the buildings where it was registered during the first measurement.

After the investigation by the authorized officers of the Ministry of Internal Affairs was completed, the repair of the damaged pipe began. After repairs were completed, gas was released into the DGM.

2. BLOCK VALVE STATIONS INSTALLATION PRIORITIES ANALYSIS

When responding to accidents without fire or explosion, it is necessary to stop uncontrolled gas release as soon as possible, in order to prevent the aforementioned phenomena. Stopping uncontrolled gas release at the dispatcher's order is mainly done by emergency teams on duty, or other teams if they happen to be nearby.

A big problem is the accessibility of the valves and possibility to act, i.e. their timely closing. It often happens that valves cannot be accessed due to parked vehicles or other obstacles. There are a series of events that happened in practice, which showed that closing the valve and stopping the gas flow could have been done in a shorter time.

Possible solutions that would enable faster action in extreme situations would be the installation of devices on some valves (valves batteries) that would enable remote control from the dispatch center. This way, in case of accidental situations, the valves would be closed in a short period of time, and the only amount of gas that would be released is the amount that remained trapped in the distribution gas network. Sometimes, in practice, this could require closing several valves, but most often two valves or two valve batteries (given that the network is made in a ring, closing one valve would not be effective).

Remotely controlled valves systems are also called blocking devices (block valve stations). There are three ways to activate the system and control blocking devices: manual, automatic and remote control. The older generation of these devices was pneumatically driven, while the new generation is electronically controlled. With devices managed in this way, greater reliability, insensitivity to weather conditions, etc.

would be obtained. The role of gas block valve stations is to perform sectioning of the transport gas pipeline or distribution gas network in the event of accident or damage. In more densely populated places, they should be installed at smaller intervals, if possible.

Damage to a pressure pipe of 0.1 [bar] does not represent a significant accident, and its temporary repair can be done in several simple ways and operations. However, damage to the pipe with the pressure of 3 [bar] or 8 [bar], will cause a general danger that may ultimately result in human casualties. It is not possible to stop gas leakage in case of damage to the pipes where the mentioned pressures prevail in the same way as in the case of damage to the pipe with the pressure of 0.1 [bar]. In case of damage to a pipe with a smaller diameter and a pressure of 0.1 [bar], it can be stopped by bending the pipe or possibly inserting a wedge, which prevents further gas release, thus eliminating the risk of fire or explosion.

When there is damage to pipes with the pressure 3 [bar] or 8 [bar], the only way to stop the gas leak is to close the valve and cut off the gas flow. Logical solution is to close the gas at the nearest valves in relation to the place of damage. However, the problem is that it is sometimes not possible to do this in practice since valves are often not accessible due to parked vehicles, unmarked valves or some other reasons. In such situations, the solution would be the installation of block valve stations with devices for automatic or remote control.

Respecting safety reasons, when designing the CS gas system, care was taken of its dimensioning, and a gas system with a pressure of 3 [bar] was designed in the very center of the city. This system starts with gas stations at the end of the system 8 [bar], which lower the pressure to 3 [bar].

2.1 INSTALLATION OF BLOCK VALVE STATIONS ON THE 3 [BAR] NETWORK

The gas system 3 [bar] is made in "ring" formation that is with both sides supply. There are 11 valve batteries on this part of the system, and the system is divided into 16 sections. Considering that almost the entire 3 [bar] system is in the center of Sarajevo, it would be a priority to install a blocking station on each of the valve batteries, because damage to pipe 3 [bar] in dense and frequent settlements always represents a great danger and the possibility of unwanted consequences.

In addition to the valves on the batteries, Fig. 7 also shows installed sectional intervention valves as well as a proposal for the installation of additional sectional valves which would require the installation of actuators in order to achieve remote closing.

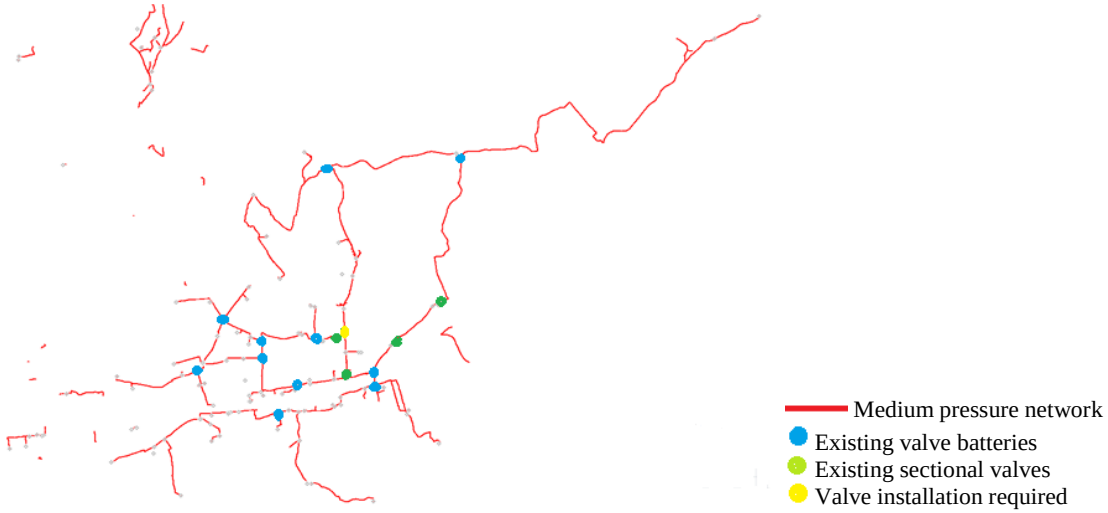


Figure 7. Detail of DGM - valve battery on medium pressure ring - PSP [8]

Such reconstruction would require a longer period of time due to construction and mechanical preparatory activities. The reason is that for the blocking stations installation, it would be necessary to carry out a larger excavation around valve battery to accommodate equipment and blocking devices, as well as accompanying installations, then mechanical and electrical work to connect all elements into one unit, and

finally, testing the system before backfilling. Bearing in mind the increase of safety level, the installation of blocking stations on all valve batteries and on sectional intervention valves on the network of pressure 3 [bar] is fully justified.

From this part of the gas network, gas is further supplied to regional - regulation and receiving regulation stations, which reduce the pressure from 3 [bar] to 0.1 [bar]. Regional-reduction stations supply gas to the general public, i.e. citizens, while receiving-reduction stations supply gas to large consumers such as boiler houses and some businesses.

2.2 INSTALLATION OF BLOCK VALVE STATIONS ON THE 8 [BAR] NETWORK

Given that there are 33 valve batteries on the 8 [bar] pressure gas pipeline, which is much longer than the 3 [bar] pressure pipeline, the installation of blocking stations on all valve batteries would be a large and expensive investment. Also, for some sections with valve batteries there is no justified need to install a blocking station. A certain number of valve batteries and part of the gas system are located in the area of agricultural property and other "green areas" that are outside urban areas. The possibility of damage due to construction activities is low, and it can be concluded that the installation of a blocking station is not a priority in this part of the gas system. It should be noted that the valve batteries on the 8 [bar] gas system are designed so that on most of the sections, besides the branch valve, there are breathers and breather valves. The position and location of valve batteries, their importance in supplying consumers, but above all the importance of individual branching, as well as the reduction of section lengths, were taken into account as criteria for the installation of blocking stations in this paper.

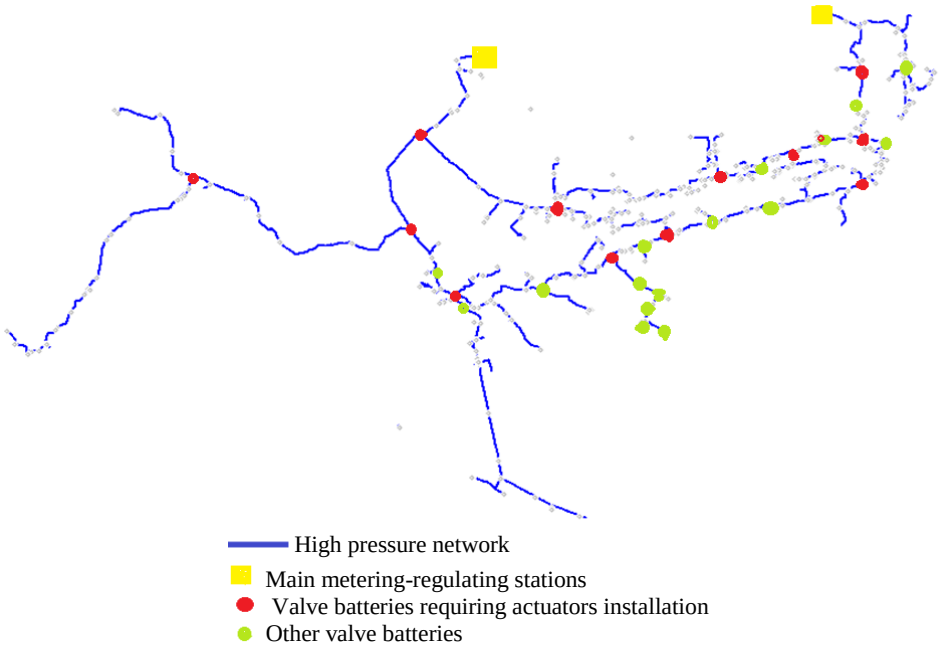


Figure 8. Detail of the DGM - valve batteries on the high-pressure ring [8]

At the end of the analysis, it is concluded (Figure 8) that it is necessary to install remote control systems on 13 batteries, and on the B8-02 battery an actuator would be installed on only one valve, on the branch of the battery that leads the gas to the B8-33 battery. Also, on battery B8 - 33, actuators would be installed on branches for Municipality of Hadzici and settlement of Rakovica, and since it is not supplied on both sides, no actuator would be installed on the valve for the branch towards battery B8 - 02. Actuators would be installed on all other valve batteries, which have three branches each and valves on each branch, i.e. on all valves located on the battery.

3. CONCLUSION

Procedures for accidental situations on the gas system of Canton Sarajevo, in terms of the organization itself, are carried out on the basis of internal documents. Technical measures and practical handling in the event of accidents depend on several factors, the most important of which is the pressure in the damaged pipe. At pressures of 3 [bar] and 8 [bar], it is necessary to cut off the gas flow to the place of damage. If the pipe is possibly made of polyethylene, and if it is accessible enough, it is possible to stop the gas flow by placing a clamp, crushing the pipe, although these situations are very rare. If the pipe is made of steel, the only way to stop the gas flow is by closing the valve. This is possible on valve batteries or on sectional valves if they exist on that part of the pipeline.

When the gas system is damaged, it takes a certain amount of time for the emergency teams to arrive, which directly depends on the traffic conditions. Sometimes an emergency intervention team cannot adequately and quickly respond to the gas accident. All this leaves the possibility that the gas will leak out uncontrollably for a certain period of time and thus represent the possibility of a fire or possibly entering nearby buildings, which would be very dangerous, because an explosive mixture could be created in a short time due to the pressure in the pipe. In addition to the above, the noise that appears due to gas release under high pressure causes panic in people. In order to improve the action in the event of damage and accidents on gas network, the proposal is to install block valve stations on networks 3 [bar] and 8 [bar]. This way, a step forward in terms of safety would be made, as it would be possible to close the valve in the shortest possible time. Block valve stations with blocking devices are preventive measures, but they are repressive in nature. They provide the possibility to automatically or remotely control the gas from the dispatch center on the closest valve batteries to the accident site, thus preventing further gas leakage that would endanger human life and property. The valve closing this way takes place within a few minutes from the moment of damage. In this regard, it is necessary to make a step forward and start installing block valve stations with one long-term project. This way, until the arrival of the first emergency teams, the gas supply would be closed, and the employees of the emergency intervention team would have time to secure the area around the accident site, without wasting time on finding the valve and closing it. Analyzed gas accidents from the past testify that only with a serious approach, good organization and professional action accidental situations on gas system can be maximally controlled and ended without human and material losses. It is also necessary to carry out a thorough analysis of the protection and rescue services functioning, as well as to ensure professional management of the competent institutions of this system. It is also necessary to form specialized response teams from various dangers, establishment of continuous training for professionals who would manage operations in gas accidents, as well as members of specialist teams who would represent the operative base for protection and rescue in the field.

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