UNDERGROUND MINING ENGINEERING 22 (2013) 63-70 UDK 62
FACULTY OF MINING AND GEOLOGY, BELGRADE YU ISSN 03542904

Professional paper

THE SAFETY OF THE NATURAL GAS USE

BEZBEDNOST KORIŠĆENJA PRIRODNOG GASA

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Abstract: Having many positive characteristics which make the gas competitive in relation to other fuels, a number of natural gas users is constantly rising. During a selection of the methods of natural gas usage, the energetic, economical, environmental and the other factors which influence the optimal choice are analyzed. Definitions, terms and the safe aspects of the natural gas usage with special reference to the safety of the gas usage in the urban areas will be analyzed in this study. A model for analyzing the suitability of using natural gas for heating, according to the safety factor, the size of the urban area and a specific heat load is presented in this paper.

Key words: natural gas, safety, heating system

Apstrakt: Zbog velikog broja pozitivnih osobina prirodnog gasa, koje ga čine konkurentnim u odnosu na druga goriva, broj korisnika prirodnog gasa je u stalnom porastu. Prilikom izbora načina korišćenja prirodnog gasa analiziraju se energetski, ekonomski, ekološki i drugi faktori koji utiču na optimalan izbor. U ovom radu se analiziraju definicije i pojmovi kao i bezbednosni aspekti korišćenja prirodnog gasa sa posebnim osvrtom na bezbednost korišćenja gasa u urbanim sredinama za potrebe grejanja. U radu je prikazan model koji daje analizu u smislu da li je preporučljivo i u kojoj meri korišćenje prirodnog gasa za potrebe grejanja, u zavisnosti od bezbednosnih faktora ali i veličine urbanog područja i specifičnog toplotnog opterećenja.

Ključne reči: prirodni gas, bezbednost, sistem grejanja

1. INTRODUCTION

Natural gas is the most used gaseous fuel. There are different users of natural gas, beginning with the biggest ones such as the heating plants and power plants, from various industrial users which can use it both as an energy substance and a raw material, to the smallest ones such as the households. Nowadays, the issue of the most economical fuel usage is very common, and the natural gas is becoming more

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important thanks to its physical and chemical characteristics which enable the best usage of energy accumulated in the fuel.

The natural gas advantages over the other fuels are very important, and they are:

- less costs of extraction, modification and transport;
- possibility of the usage for the technological and energetic needs;
- less environmental pollution during combustion;
- a simple automation of combustion;
- a high efficiency of burners ($0.85 \div 0.95$) and
- a longer duration of the natural gas devices and installations.

Except for the great number of the certain advantages in relation to the other fuels, natural gas has a few imperfections. Mains of them are:

- danger from the explosion and fire;
- need for the building of the expensive underground storehouses for the equalization of the use.

The greatest shortcoming during the usage of natural gas is certainly the danger of the explosion and fire which could appear as the consequences of the defects of the gas installations, i.e. the uncontrolled gas flows in both closed and opened areas. This study will analyze the safe aspect of the natural gas usage through the production of the models for the choice of the heating systems which use natural gas in the urban areas.

2. THE USAGE OF NATURAL GAS IN THE URBAN AREAS

Using energy in the urban areas could be sorted into the sectors on general usage, industrial usage and traffic usage.

In the sector of general usage, energy is used for providing heating needs, a consumable hot water preparation, cooking, lightning and the power of the electric appliances (Prstojević et al. 2005). According to a used concept and a degree of the pipeline gas transport construction, natural gas could be used for providing the mentioned needs in general usage. However, in Serbia it is common that natural gas is used for providing heating needs, the consumable hot water preparation and cooking, while the needs for electricity are mostly provided from other energetic sources (coal and hydro potential) (Jovančić et al. 2011). Currently, there are three power plants which use natural gas (Ivezić et al. 2013). Local cogeneration in Serbia is not seriously assumed, too, so its influence on the general energetic usage could be neglected.

The local systems of natural gas usage include the systems in which the gas consumption is done on the individual objects (residential and business) in one area. According to a character of the energetic transformation, the local systems could be classified into the direct and indirect ones. The direct transformation includes a transformation of natural gas chemical energy into the heat which is directly transmitted to the object of heating (those objects could be rooms heated by gas stove, water in a rapid water heater, or dishes during cooking). The indirect transformation includes a multistages heating transfer from the combustion place to the heating object.

District heating includes the system in which the chemical energy transformation from natural gas is transformed into heating energy in power plants by combustion. During this process, the obtained heating energy is transported to the final users by the adequate means.

3. SAFETY - DEFINITION AND INFLUENTAL FACTORS

Safety is an important aspect of the natural gas usage in every part of consumption. The term "safety" is a complex term which contains various numbers of phenomena. The most recognizable phenomenon is reliability. Reliability is a probability, on a certain level of confidence, that a system will successfully fulfill its function, without failure, and within the given functional boundaries during wanted period when the system is appropriately used. Reliability is expressed as a number between 0 and 1 or between 0 and 100%. Reliability can be presented as a relation between the number of successfully done tasks and the total number of the system tasks (Ivković, 1997). If the system fulfils all the tasks, the reliability is 1, i.e. 100%. Safety and reliability are two connected terms, i.e. if reliability grows, safety grows, too.

Every system has its working (real, current) and critical conditions which are defined according to proper working parameters. The critical condition is usually a constant for the given system and has a static character. The difference between these two systems is dependability of the system. That is, as the working condition parameters closes to the critical condition parameters, a dependability system level declines. Safety is usually presented as a relation between critical and working parameter value, when, theoretically it has to be equal or higher than 1. The system could be very reliable for a projected function and working conditions, but if the parameters which form the working condition are obviously damaged, its dependability could be very low. The systems which work with higher dependability could be considered safer for using.

Quality is a characteristic of the final system product which shows at what degree it fulfils the given tasks. Quality is a complex, comprehensive index of system functioning; for reaching quality, an appropriate compliance with the tasks and expectations is needed. The system which is reliable and safe does not have to give a qualitative final product if it is not functionally adequate for usage. Reaching the high quality without any doubt requires permanently rising of a reliability and dependability level. A quality system is definitely a safe system.

Bearing in mind the safety aspect, there are some advantages of the district heating system to the local system:

- gas does not come to a housing estate; its combustion is done in a power plant out of the housing estate;
- in power plants, educated personnel operates the gas installations, while in the local gas system, all habitants operate the gas installations, and those people are mostly uneducated for safe operating;
- in the densely populated buildings with gas installations, there is higher danger from possible accidents and importance of possible consequences for the inhabitants and
- there is a greater possibility for uncontrolled gas flow out from underground pipeline constructions in the local gas heating system.

There are various factors which affect the safety of natural gas usage in urban areas:

- the age and method of an object building in the housing estate;
- a number of object's floors;
- a number of flats in buildings;
- the age structure of a population (a greater number of population younger than 15 and older than 65 increases a risk of the possible accidents);
- educational structure of a population and
- a possibility of investments in safety.

The age of an object in one housing estate mainly defines the method of building, i.e. which constructive elements were used during its building. The constructive characteristics affect the object safety in case of gas distribution (local heating). The older objects which have the brick walls as the vertical construction elements are more prone to collapse in case of explosion in some parts of these objects. The newer objects which have ferroconcrete walls and pillars as the construction elements, and which were built according to the regulations of building in the seismic active areas, are more reliable in case of possible explosions which could happen in the object.

The other issue in a relation to gas usage, a method of building objects concerning to gas distribution safety is if the gas network was planned during the object projecting, or if it was done after the building process. It is surely better to know that gas distribution will be done while the building project is being written, because the object is being prepared for using gas and some of the safety issues in the future exploitation are being solved. It includes a solving of the safest method of installation, projecting safety rooms for putting the gas devices, solving the problems of ventilation and adequate flue of burning products, etc. When the object has already been built, those problems are hardly solved, and it is often impossible to fulfill all recommended security measures.

A number of floors and flats in buildings, i.e. a number of flats per floors, affect the safety. The greater number of floors increases the number of the gas installation users and their gas devices, which increase the number of consequences for the inhabitants.

A greater number of populations younger than 15 and older than 65 in one housing estate have also got negative influence on the safe usage of the gas installations, which should be considered during choosing the heating system. Bearing in mind inhabitants, the education structure of these people in one housing estate should not be forgotten. Less educated inhabitants hardly understand and use the procedures for gas installations use and maintenance, which directly influences its safe usage.

Finally, the possibility of investment in safety in one housing estate whose gas distribution is being planned should be mention. This is related to the investor's material supplies, i.e. inhabitants', which enable a usage of modern safety devices and procedures, and their availability on the market.

4. CASE STUDY: CHOICE OF HEATING SYSTEM ANALYZING SAFETY FACTORS

In order to create a model for a choice of a heating system based on the safety factors, a defined heat load analysis and a number of buildings in one housing estate which were used in the paper (Ivezić et al. 2009) should be considered first. The choice of the heating system is done for nominal urban area (NUA), defined as a rectangular area size of 0.05 km^2. The main parameters for NUA are the number of buildings and the size of buildings. The size of a building is defined by its heat load. The sum of building heat load on NUA is the maximum NUA heat load. For the analysis and formatting a model, nominal urban areas are presented as the ideal areas of 4, 8, 16, 32, 64 and 128 buildings, having the maximum heat load of 10, 20, 30, 40, 50, 75, 100 and 125 MW/km² (Prstojević et al. 2004, 2005). Considering the building heat load 144 W/m² and an average floor area of 60 m², it is concluded that the average heat load is:

$$Q_s = 0.144 \cdot 60 = 8.64\,\mathrm{kW} \tag{1}$$

A number of flats per buildings in some urban areas is:

$$N_{SZ} = \frac{Q_N \cdot 1000}{Q_s \cdot N} \tag{2}$$

where:
Q_N - heat load of NUA [MW],
N - a number of flats on NUA.

In Table 1 is shown the average number of flats per buildings for every previously defined situation.

Table 1 - The average number of flats per building on NUA

	MW/km^2							
	125	**100**	**75**	**50**	**40**	**30**	**20**	**10**
N = 4	1809	1447	1085	724	579	434	289	145
N = 8	904	723	543	362	289	217	145	72
N = 16	452	362	271	181	145	109	72	36
N = 32	226	181	136	90	72	54	36	18
N = 64	113	90	68	45	36	27	18	9
N = 128	57	45	34	23	18	14	9	5

How to introduce a safety aspect in the model?

One of the simplest methods for defining a choice of energy supply based on the safety factors is defining the maximum average number of flats in buildings in housing estates where installation of gas grid cannot be done. For example, the settlements which have on average more than 20 apartments per building cannot use gas, regardless of economic and other factors.

In Table 2 is shown a supply choice in a case that the previous condition "the settlements which have on average more than 20 apartments per building can’t use gas" is realized:

Table 2 - A choice according to the average number of flats per buildings ("T" if $N_{SZ} > 20$) (T-district heating, G-local heating)

	MW/km²							
	125	**100**	**75**	**50**	**40**	**30**	**20**	**10**
N = 4	1809/T	1447/T	1085/T	724/T	579/T	434/T	289/T	145/T
N = 8	904/T	723/T	543/T	362/T	289/T	217/T	145/T	72/T
N = 16	452/T	362/T	271/T	181/T	145/T	109/T	72/T	36/T
N = 32	226/T	181/T	136/T	90/T	72/T	54/T	36/T	*18/G*
N = 64	113/T	90/T	68/T	45/T	36/T	27/T	*18/G*	*9/G*
N = 128	57/T	45/T	34/T	23/T	*18/G*	*14/G*	*9/G*	*5/G*

For more precise defining of a model, it is recommended to consider the previously mentioned factors which have an influence on safety gas usage. One of the methods is defining the criteria for evaluation of the given factors. Depending on the obtained mark, the maximum number of flats where gas cannot be used should be increased or decreased. The influence of the criteria on a choice of a heating system would be marked from 1 to 5. The average mark would define sensitivity of the housing estate in a relation to gas distribution. One of the possible evaluation methods will be shown below.

The idea is to mark each of the given factors from 1 to 5 according to established criteria written below.

1. The age and method of object building in the housing estate (S):
- Before 1970, the vertical brick constructions (1);
- Before 1970, the vertical ferroconcrete constructions (2);
- After 1970, they were not projected for gas usage (3);
- After 1970, they were projected for gas usage (4);
- After 1970, they were projected for gas usage with special constructive measures (5).

2. A number of flats per floor (N):
- More than 5 flats (1);
- 4-5 flats (2);
- 3 flats (3);
- 2 flats (4);
- 1 flat (5).

3. Age structure- percentage of population younger than 15 and older than 65 (P):
- More than 50% (1);
- 40-50% (2);
- 30-40% (3);
- 20-30% (4);
- Less than 20% (5).

4. Educational structure of a population- percentage of highly educated (O):
- Less than 4% (1);
- 4-8% (2);
- 8-12% (3);

- 12-25% (4);
- More than 25% (5).

5. A possibility of investments in safety (F):
- Very low (maintenance on the permitted level) (1);
- Little (normal investments in current maintenance) (2);
- Middle (possible usage of usual safety measures and maintenance) (3);
- High (possible usage most of modern safety measures) (4);
- Very high (possible usage of all most modern measures) (5).

A final mark could be shown in many ways, but in this study, the average mark will be presented as an object safety statement.

$$F_b = \frac{S + N + O + P + F}{5} \tag{3}$$

Depending on the average mark, the previously accepted maximum number of flats per building where gas distribution is not allowed can be increased or decreased.

For average marks:
- $F_b \leq 1.5$ - mandatory decrease 60%;
- $1.5 < F_b \leq 2.5$ - mandatory decrease 30%;
- $2.5 < F_b \leq 3.5$ - no change;
- $3.5 < F_b \leq 4.5$ - allowed increase up to 50%;
- $F_b > 4.5$ - allowed increase up to 100%.

Considering the given safety factor, the tables according to an average number of flats with the coefficient $F_b \leq 1.5$ i $F_b > 4.5$ are presented (Table 3 and Table 4.):

Table 3 - A choice according to the average number of flats per buildings ("T" if $N_{SZ} > 20$) (T-district heating, G-local heating) $F_b < 1.5$

	MW/km^2							
	125	**100**	**75**	**50**	**40**	**30**	**20**	**10**
N = 4	1809/T	1447/T	1085/T	724/T	579/T	434/T	289/T	145/T
N = 8	904/T	723/T	543/T	362/T	289/T	217/T	145/T	72/T
N = 16	452/T	362/T	271/T	181/T	145/T	109/T	72/T	36/T
N = 32	226/T	181/T	136/T	90/T	72/T	54/T	36/T	18/T
N = 64	113/T	90/T	68/T	45/T	36/T	27/T	18/T	9/T
N = 128	57/T	45/T	34/T	23/T	18/T	14/T	9/T	*5/G*

Table 4 - A choice according to the average number of flats per buildings ("T" if $N_{SZ} > 20$) (T-district heating, G-local heating) $F_b > 4.5$

	MW/km^2							
	125	**100**	**75**	**50**	**40**	**30**	**20**	**10**
N = 4	1809/T	1447/T	1085/T	724/T	579/T	434/T	289/T	145/T
N = 8	904/T	723/T	543/T	362/T	289/T	217/T	145/T	72/T
N = 16	452/T	362/T	271/T	181/T	145/T	109/T	72/T	*36/G*
N = 32	226/T	181/T	136/T	90/T	72/T	54/T	*36/G*	*18/G*
N = 64	113/T	90/T	68/T	45/T	*36/G*	*27/G*	*18/G*	*9/G*
N = 128	57/T	45/T	*34/G*	*23/G*	*18/G*	*14/G*	*9/G*	*5/G*

5. CONCLUSION

The use of natural gas is becoming increasingly popular due to economic, environmental and other constraints which can occur with other conventional energy sources. One of the limitations posed by the introduction of natural gas use is the security aspect. A model for a choice of heating system in the urban area, which is presented in this paper, is based on an analysis of factors which affect human lives safety and material resources when natural gas is used. A similar approach could be used in the situations where the choice can be made between two possibilities, for example, by choice of a pipeline route or a location for pressure reduction station. Combining safety factors with economical, ecological and other important factors, a new model could be created, and it would enable more qualitative choice.

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