ECOLOGICAL ASPECTS ON EXPLORATION AND EXPLOITATION OF SHALE GAS

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Abstract
Exploitation of shale gas wells requires the use of millions of gallons of water. Water is mixed with sand and chemical additives in order to obtain a fluid which will be injected among the walls of the clay crack formation [1, 2]. Some chemical additives include biocides, lubricants and detergents.
Hydraulic fracturing operation may have adverse consequences on the environment: pollution of groundwater and soils, landscape degradation or noise [3]. These issues without taking into account gas leakage, may contribute to the greenhouse effect.
This paper presents some specific responses for shale gas exploration and exploitation.

Keywords: shale gas, environmental impact, greenhouse effect, hydraulic fracturing, additives

1. Introduction

The current global volume of unconventional gas resources exceeds 32.560 tcf (trillions cubic feet), and there is no doubt that, as specific technologies will progress, these estimates will be reviewed [1-8]. Table 1 present the shale gas production around the world In particular, the discovery of new shale gas formations and their production development within the sandy-clay sections (tight gas sands) in the future, will play a major role in this field. The term of unconventional natural gas refers to the natural gas resources accumulated in complex geological reservoirs with low permeability, of which their commercial exploitation can be achieved only through the application of oil sophisticated operations and often expensive. There are three types of unconventional gas resources: gas from reservoirs (*sands*) tight (*tight gas sands*), gas from argillaceous rocks or shale gas and coal gas (*coal bed methane*).

Figure 1 shows a diagram of a geological section with the three types of unconventional gas resources.

Currently, for shale gas exploitation, are used vertical drillings or horizontal drillings (controlled). The trend in the future, is based more on horizontal drilling, taking into account the optimized expansion and exposure of the geological formation in this case. Currently, combination of the horizontal drilling with the hydraulic fracturing operation, carried out in several stages, has led to a significant increase of shale gas well productivity.

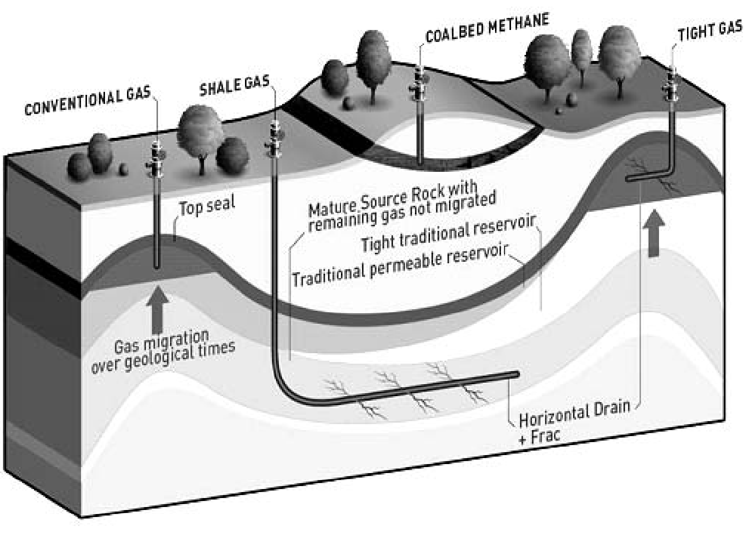

Fig. 1 *Geological section (unconventional resources) [1]*

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Table 1 *Shale gas production around the world*

Region	Coal mist, tcf	Shale, tcf	Gas-tight reservoirs, tcf	Total, tcf
North America	3.017	3.842	1.371	**8.228**
Latin America	0.039	2.117	1.293	**3.448**
Western Europe	0.157	0.510	0.353	**1.019**
Central and Eastern Europe	0.118	0.039	0.078	**0.235**
Former Soviet Union	3.957	0.627	0.901	**5.485**
Middle East and North Africa	0	2.548	0.823	**3.370**
Sub-Saharan Africa	0.039	0.274	0.784	**1.097**
Central Asia and China	1.215	3.528	0.353	**5.094**
Pacific (O.C.D.E.)	0.470	2.313	0.705	**3.487**
Other Asia-Pacific countries	0	0.314	0.549	**0.862**
Southeast Asia	0.039	0	0.196	**0.235**
Around the world	9.051	16.112	7.406	**32.560**

2. Hydraulic fracturing

The aim of hydraulic fracturing operation consists in the intersection and opening of the existing cracks in a reservoir and also in generation of new cracks. This system of cracks is necessary to create new channels through which natural gas can enter into the well. In this sense, in the system it is injected a fluid that is composed of water, chemicals and sand.

Granular materials (sand and chemicals) will lead to formation explosion in such a way to obtain cracks for the release of gas which will then go on the surface through the well (fig. 1). At the same time, the sand is injected in order to prevent the reblocking of small dimensions cracks (of the order of millimetres).

Among in this operation we can enumerate: [3]: 1,2 benzisothiazolin-2, 1,2-benzisothiazolin-3, 1,2,4 tri methylbenzene, 1,4-dioxane, 1-eicozen 1-hexadezen, 1-octadezen; 1 tetradezen, acetic anhydride, acetone, acrylamide, etc. (composition and content of each product or mixture were kept secret by the manufacturers and users of American who expressly asked the Senate that the law not to require them to disclose the names of those products).

According to experts from Halliburton and other operators in the field [2], more than 99.5% of the fluid used in hydraulic fracturing consists of water and sand. Sometimes sand may be coated with resin or replaced by ceramic balls.

You must start from the observation that the role of water in fracture is crucial. A well exploitation requires the employment of millions of gallons of water (an average of 8-35 million for each fracturing operation).

It is also believed that a hydraulic fracturing operation may have adverse consequences on the environment: pollution of groundwater and soils, landscape degradation, noise, etc. This aspect, without taking into account the leakage of gas, may contribute to the greenhouse effect accentuation.

Progresses realized in monitoring and control of hydraulic cracking in rich-gas layers (typically, at more than a kilometre and a half below the underground water network) make the risk of direct communication between the exploited layer and groundwater networks to be unlikely. Moreover, we believe that it should be more enforced on achieving a proper well consolidation (casing and cementing), achieving a control geophysical logging etc. [4, 5, 6].

It is also true that ground waters may be affected in an indirect manner: waste water production or uncontrolled outflow of fluid from the surface; risks related to the management of the settling basin; risks related to wastewater and chemical additives transport by tank trucks; risks related to contaminated water treatment.

To reduce the risks of groundwater pollution in the first place it is need to optimize the casing and cementing programs of horizontal wells. At the same time, for the protection of ground waters, of reservoirs and environment it must be reacted on the nature and composition of chemicals products used in the fracturing operation.

At the same time, at the beginning of 2012, an interdisciplinary team of researchers from the Energy Institute of the University of Texas in Austin [6] announced the results of the scientific research results on various aspects of the activities related to hydraulic fracturing: groundwater contamination; fluids leaks on the soil surface; emissions into the atmosphere; the use of the water resources; residues resulting from drilling activity; free eruptions; cars traffic; noise.

The researches covered all the development phases of the main reservoirs of shale gas in Barnett, Marcellus and Haynesville USA.

The main findings are:

• there were not found contaminations with chemicals neither of the aquifers nor deep fracturing fluids leaks;

• there have been identified many contaminations within the conventional operations with no connection with the hydraulic fracturing having as cause the loss of cased columns tightness and failures of their cementing;

• soil and water contamination risk with fracturing fluid is due to incorrect handling them at the surface than the one determined by the injection of these fluids in shale gas formations etc.

These findings are somewhat confirmed by the concerns of the recent years in order to find technological solutions to stimulate the compact formations and the shale gas to reduce the drawbacks highlighted above.

Hydraulic fracturing technology is individually designed for each well in part, taking into account the construction of the well, its depth, the nature of the geological formation to be cracked and of course, the purpose of the operation. The operation project mainly envisages: the depth of the well; the diameter and wall thickness of the cased column; the cement level behind the cased columns, the depth and their attachment mode; the initial and current bottom pressure; bottom temperature; composition of extracted / formation fluids; the nature of the formation to be cracked (type of minerals), mineralogical analysis, the nature of the cement, gram – meter – metrical composition, porosity, permeability etc.

The practice of the hydraulic fracturing / cracking in Romania in order to increase the productivity of the wells that exploits the reservoirs clustered in low permeability geologic formations (sandstones, marls / clays, sand, etc.), dates back over 40 years, during which there were successfully executed hundreds of such operations.

3. Fracturing by controlled pulsations (impulses)

In the American literature the process is known as *Dynamic Pulse Loading* or *Controlled Pulse Fracturing* [7, 8].

Since in unconventional gas reservoirs the porosity and permeability of the matrix are very low, and the addition of the support agent of the artificial fractures is not used, obtaining good results with this method depends on how the created fractures intercepts the natural ones.

The stimulating method itself consists of the ignition of propellant charges in the place of the production formation followed by the development of some high pressure pulses (impulses). After ignition, the propeller is subjected to a controlled burning deflagration. High-energy gas pulses generate a fractures system which radially enters into the adjacent rocks up to a distance of 1.5 - 6 m [7].

4. "Super Fracking"system - Schlumberger [5]

The system consists of a successive pumping of the supporting suspension agent and fracturing fluid containing fibres. There are realized fractures which have areas with supporting agent uniformly distanced towards areas which form part of a ducts system (fig. 2). During the periods when the pumped fluid does not contain supporting agent, are placed fibres in order to prevent uncontrolled spreading of the already introduced one and to maintain the desired flow channel system.

The company reports the reduction of water consumption by 60% and the supporting agent by 40% while the fracture conductivity is infinite and production rates increase by 20% compared to standard fracturing situation.

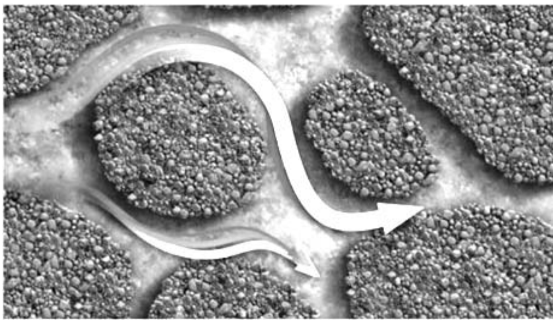

Fig. 2 *Positioning of the supporting agent and of the channels system inside the fracture*

5. The "Fast Frack" System - Halliburton [8]

The *Rapid Frack* system is dedicated to horizontal wells and uses a special bottom assembly hydraulically acted that allows the execution in one march of up to 15 selective and subsequent fracturing stages in more sections of the hole.

This system is used to shorten the execution duration of the hydraulic fracturing and reduce the water consumption. Thus, the water consumption is reduced up to 40% and the duration of operations is reduced from weeks to days and from days to hours.

In hydraulic fracturing there are a number of factors that determine the resulting geometry and therefore the overall productivity of the fractures system. Among them we mention the stress state of rocks under the reservoir, location pre-existing planes of least resistance, etc. All of these are difficult to control during the treatment. Contrary to the above, and in case of significant dimensions of the slots (tens of meters) which have a geometry and a controlled orientation can ensure good conduction and natural fractures communication systems.

In order to protect the environment, we can already think of alternative solutions such as cracking by liquefied methane, electric arc crack, cracking by laser etc.

Drilling activities achievement involves a permanent consumption of industrial water in appreciable quantities, necessary to carry out the drilling activities in good conditions. Among them, we mention the most important:

- drilling fluid preparation and conditioning;
- cement paste preparation;
- equipment and drilling machines maintenance and cooling, washing the rack etc.;
- intangible reserve for fire fighting;
- wells hydraulic cracking.

When wells are put into production using hydraulic fracturing method, the quantities of water are significantly higher than those used in classical drilling.

Water resources that can be used in the drilling activity may come from surface waters and / or ground waters.

Depending on the geographical position of the locations where are located the drilling works and depending on the distance towards the water resources from the area in the vicinity, you can use different methods of supply and transport of water to the well. If the resource is derived from surface waters, if the distance is less than 3 km, you can use a pumping station and a pipeline transport. In the case where the distance to the source of the water is higher, water transport tanks can be used. In both cases it is necessary to make water storage basins, allowing the storage of water in the vicinity of the well, so that the use thereof for the drilling activities to be carried out in the best conditions. In all such cases shall be observed the legislation provisions in force.

Calculation of the necessary water, in case of drillings that dig for conventional oil and gas reserves, is performed upon the necessary drilling fluid and cement paste (used in cementing various technical or operating columns) and also upon the demands for other activities. To calculate the demand of water for cement paste preparation, depending on the preparation recipe, water consumption may vary from 750 dm^3 and 900 dm^3 per cubic meter of cement paste. Also, the quantity of water for preparing the drilling fluid depends on a number of factors among which we mention: the recipe for preparing the drilling fluid, cutting diameters, drilling depths for different diameters of cutting, the geological structures nature crossed by drilling (e.g. in case that cracked layers or with caverns are crossed, could be produced partial or complete losses of movement, leading to a significant increase of drilling fluid needs and, as a result, water consumption).

In case of drilling for the exploitation of non-conventional gases, at the water requirements calculated in a similar manner with that one for the wells drilled to exploit the gases it must be added the water necessary to achieve the hydraulic fracturing. If in the first case the amount of water used is relatively small (depending on the construction schedule of the well – foreseen in the drilling plan - the quantities of water can be of hundreds or thousands of m^3 order), in case of drillings that use hydraulic fracturing we can have a water consumption of the order of 15 000-30 000 m^3 of water.

Water use in the drilling process must take into account the legal provisions in force on water use. In this respect, drilling companies must appeal to local and national authorities with responsibilities in water management, in order to ensure a strict control on the measures against pollution. One of the major risks of pollution that may occur during drilling activity is polluting drinking water sources, both surface and underground. Because of this, both in the design of drilling as also through technical measures applied during the execution of drilling, it is necessary to take all necessary measures so as to avoid pollution of water resources. And within the activities of water supply, transport and storage shall be taken all the measures required by the specific working technologies and the legislation in the field, so as not to affect the water quality.

Resources of surface and underground water protection will consist of tubing some metal pipes columns, cemented, and other mechanical insulation measures so as to avoid pollution of water bodies and surface water, which are sources of drinking water. Isolation technical columns are designed to prevent communication between the layers of interest for exploitation of oil and gas reserves and the aquifer formations. In particular, when digging exploration, development and exploitation wells for unconventional gases, in which case the method of hydraulic fracturing is applied, the measures to ensure a perfect isolation of the area of interest towards the water bodies constituting drinking water resources must be developed with the greatest responsibility.

Throughout the execution of drilling works, it is necessary to monitor a number of parameters that allow the observation and control of any possible leakage of oil products to the surface in an uncontrolled manner. Some monitoring activities are specific for the drilling technology and are presented in the sections dealing with those issues and those related to environmental factors are monitored before, during the course of drilling activities and after starting-up the well.

An important aspect that arises in the process of using the technological water in drilling, is related to the way it is organized and carried the return (if possible) in the natural cycle of the waste water (if unconventional gas exploitation wells dug by hydraulic fracturing) or reuse of this water as process water to achieve another drill. In both cases must take all the appropriate technical, control and utilization measures so that such waters shall not affect the environment (soil, subsoil, surface water or groundwater, air).

Debris resulting from drilling activities should be stored properly to be treated before being stored in special places, to prevent environmental pollution.

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