Features of construction of sea gas pipelines in difficult characteristics of compressors hydrological conditions. analysis of gas transportation technologies

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Abstract. One of the problems at the operation of sea gas cross-country pipelines is connected with pressure drop during gas transportation. The analysis of the applied technologies of gas flooding is carried out. The description of standard plan for the implementation of compressor and natural pressure technologies are given. The merits and demerits of the considered technologies of gas transportation under difficult hydrological conditions are revealed. An economic success on the gas compression operation substantially depends on the operation of the involved compressors at considering gas compressor stations for pipeline projects. In the article the major factors are emphasized, having an impact on the efficiency of main designing solutions at the construction of gas cross-country pipelines; it particularly focuses on the interaction of a pipeline and a compressor station.

1. Introduction
Growth of the world demand for raw hydrocarbons and its fuel exhaustion in the onshore production sped up the exploration in water areas of seas and oceans which has led to the essential extension of sea oil and gas production in the last decades. In recent years fractional oil content of sea oil and gas exceed 30% in relation to the world volume production.

Russia possesses about 21% of the World Ocean shelf (over 6 million sq.km). At the same time the largest volume of hydrocarbons (about 90%) is concentrated in the Arctic seas.

2. Relevance
This article mentions a number of publications in which authors consider the using of the known and new technologies in the construction of the sea gas pipelines towards the peculiarities of difficult hydrological conditions and strict ecological requirements.

3. Setting of the problem
At the present day the construction of the Arctic area sea pipelines requires the solution of a set of problems (technical, technological, organizational) and it is connected with the considerable complexity caused by an environment, remoteness from industrially developed areas, lack of the developed infrastructure and strict ecological requirements. The complexity of an environment is the major factor identifying a need of search new technologies and methods of sea pipelines construction.
4. Theoretical part

One of the problems requiring the solution is a pressure drop as a result of hydraulic resistance at the big extent of sea gas pipelines. The solution of this problem is possible as a result of application of one of two known technologies: compressor and compressorless pumping of a product.

The search for a solution to optimize the gas transportation models in the systems of the main pipelines is relevant for gas industry. Now the total extension of the Unified Gas Supply System (UGSS) of Russia is more than 170 thousand km in a single line pipeline calculation, process of construction and commissioning of new gas pipelines doesn't stop. Transportation of natural gas is provided by 250 compressor stations at which gas-distributing units with a general power of 46,1 thousand MW are installed. Both effective instruments of mathematical modeling are necessary for designing the new gas pipelines systems as well as for management of already functioning ones.

The work of compressor stations demands considerable energy consumption: while transporting natural gas on UGSS Russian Federation the consumption of fuel gas at compressor stations makes more than 10% of the volume of transit to the neighbouring countries, and at some modes reaches 20%.

An optimization of working hours of compressor stations allows to lower significantly costs while transporting and, in particular, at transit of hydrocarbons.

The current stage of development of UGSS is characterized by a limit loading of gas transmission capacities of a number of objects, a decrease in relation to the project of technically feasible productivity, a need of performance of the considerable amounts of works on reconstruction and capital repairs connected with natural degradation of gas transmission network capacities.

The choice of this or that technology depends on the whole complex of the tasks facing designers and builders, one of whom is the economic efficiency of the project.

An economic success on the gas compression operation substantially depends on an operation of the involved compressors. The Initial expenses, the operational costs (especially costs of fuel), the cost of life cycle of compressors and compensation payments for emissions belong to an important criteria.

At compressor stations there are: one or several compressor shops; a power plant or a transformer substation; a system of water supply with pump stations I and II of rise, a circulating cooling system of compressor units, a water tower, a cooler and a tank for storage of a fire water supply; a knot of long-distance and internal communication; an installation on regeneration of oils with a warehouse of fuel and lubricants substances; a chemical laboratory; a boiler room; a mechanical workshop; an installation of oil dust collectors; reception and delivery collectors of gas with the disconnecting fittings; a motor transportation park and material warehouse.

Decisions on configuration of compressor stations, that is the quantity of units, reserve requirements, driver type, type of compressors, fuel consumption, operational flexibility and also existence of the station, all these indicators exert impact on the cost of projects. The considerable part of the park of gas-distributing units of compressor stations is in a stage of significant development of a resource and demands replacement. More than 70 thousand km (42%) of the main gas pipelines in UGSS are in operation more than 30 years and approach exhaustion of a technical resource. The compressorless way of gas pumping could become the solution of a number of problems.

The essence of this technology lies in pressure is created (220 kg on 1 sq. cm) capable on an entrance to the main gas pipeline through adjusting powerful compressor station, for example, as in the Nord Stream project to transport gas on distance of 1224 km. Such results are achieved by means of the variable diameter of a pipe: external diameter on the route course gradually decreases according to gas pressure drop. On each of sections of the pipeline the wall of a pipe has various thickness, such segmentation has allowed to save expenses on production of pipes without prejudice to reliability of a design). Besides, for reducing friction pressure losses because of gas flow in a pipe, the internal surface of a pipe is processed in such a way that the roughness of metal becomes lower than six microns.

At operation of the main gas pipelines while using of both compressor, and compressorless technologies of gas pumping, the main element without which it is impossible to present work of the
highway are compressors. Based on an operation of compressors, we will also make the analysis of two technologies.

Various concepts, such as number of the installed blocks, efficiency of their work as certain stations on all extent of the gas pipeline, including installation of reserve blocks are discussed. The number of the compressors which were installed at each compressor station of the pipeline system have a significant impact on fuel consumption and productivity of system, depending on a profile of loading of the station.

The working point of the compressor is defined by a balance between the available engine capacity, the characteristic of the compressor and behavior of system. If management of variable speed is available, for example, because the operator can easily operate the gas turbine or variable speed of the electric motor, then it is a preferable method of management.

The typical compressor with the card of adjustable frequency of rotation of the compressor is shown in the figure 1. It shows the area of possible working points of the compressor. The lowest possible gas supply is defined by the line of a pulsation. If the station demands lower gas supply, then gas has to be recirculated. In any point of the card the speed and energy consumption of the compressor are various. The line B has shown a system in which pressure of absorption and a discharge is more or is fixed and, thus, changes very insignificantly at changes in gas supply. Examples are refrigerating systems or systems where pressure of absorption is fixed by the required separator pressure, and pressure of forcing is fixed by need of supply of this gas in the existing pipeline. The line A shows the typical behavior of gas where any change in gas supply is densely connected with pressure drop because of friction in the pipeline.

![Characteristics of compressors.](image)

The line C is typical for application, for example, of left-luggage offices where pressure in a cavity of storage increases with amount of gas which is stored. If the compressor is operated by the maximum force, then initial gas supply will be high. The more gas it is stored in a cavity, the above his pressure, thus, it becomes clear what necessary pressure is being forced out of the compressor.

In case of the gas pipeline, the working point of the compressor is always defined by driver power (figure 2.). In case of application of a compressorless way, the power of the gas-turbine engine is controlled by control of speed of the gas producer and characteristics of the pipeline. We find this point on the map of the compressor on crossing of the characteristic of the pipeline and available power. Increase in a stream of gas via the pipeline will demand more energy and a big compressor
head. It will demand use of new technologies of construction for installation on an entrance of the gas pipeline of more powerful compressor station.

Comparison of economic efficiency of compressorless or compressor ways application is possible only by consideration of the working draft.

![Diagram](image)

**Figure 2.** Working point of the driver.

At the same time it is necessary to consider that change of service conditions of compressor pumping of gas is connected with many reasons, such as pressure drop, wear of the pipeline that eventually leads to increase in power. Cycling of the gas pipeline will change his characteristic to provide more streams at the same requirement to a head. Any change in activity of the pipeline will influence requirements to power, the head of the compressor or coefficient of pressure. Operational changes can transfer a point of operation of the compressor to the modes with smaller efficiency over time. Fortunately, the centrifugal compressors put in action by gas turbines are very flexible, automatically adapt to some extent to changes. But it demands considerable rise in price of the project.

Recirculating forces the compressor to pass more gas, than it is necessary for process that demands more energy. Therefore, the electric motor for the drive with a constant speed has to be calculated on the big power, than the engine for the drive with a variable speed under the same conditions.

5. Practical part

As an example the international gas cross-country pipeline is considered. Total length of the route is about 7000 km. The pipeline consists of two lines. Design bandwidth of the gas pipeline is 30 bn/Nm3 ar with the maximum working pressure in the pipeline of 9.8 MPas.

We will compare two ways of gas pumping for the specified conditions. For this purpose we will accept the following assumptions: in one case, we will consider operation of bigger blocks of a turbo compressor (a case And, 2 big blocks), in another - the bigger number of small blocks of a turbo compressor (a case of B, 4 small blocks). At the choice of this or that option it is necessary to consider the following factors.

At assessment of reliability of system and the maximum capacity it is necessary to consider influence of interruptions in operation of the unit (figure 3). So during the operation of two 30 MW big blocks, the refusal of one of them will lead to 50% to power deceleration. Whereas if we consider 4 smaller 15 MW blocks, the refusal of one of them will lead only to 25% to power deceleration. At the same time, if the escaped blocks work at full loading to pump over as much as possible stream, the
working point for a case of B will be close to a point of the highest efficiency. The compressors which 
have remained in working order will work more effectively in comparison with a case And. Obviously 
that restoration of supply of gas on the pipeline for a case In, will require less time.

![Diagram](image)

**Figure 3.** Influence of interruptions in operation of compressors.

Besides, the amount of gas which will process one remained 30 MW compressor is so high that it 
will put the block in a throttle. So, practically, when one larger turbocompressor fails, the second 
should be closed and the station will be bypassed. However the configuration of the station with a 
single superdimensional turbocompressor is applied rather often. Arguments in favor of this method 
are very high availability of pipelines (99,5%) and high efficiency (40-42%) of the 30 MW 
turbocompressor installations.

Also it should be taken into account the bandwidth of the pipeline at uniform approach to a 
turbocompressor. Many pipelines transport the gas belonging and extracted by various commercial 
organizations. Thus, terms of development of gas fields and availability of gas depend on many 
technological and, recently, political factors which can potentially exert negative impact on the 
predicted growth of power of the gas pipeline. In these conditions one oversized turbocompressor or 
will work in the mode of deep processing until there is an expected amount of gas, or begins work 
with compressor steps, smaller on power that can demand subsequently expensive replacement of an 
internal set.

6. Conclusions
As a result of the carried-out analysis of technologies of compressor and compressorless transportation 
of gas under various conditions, both advantages and disadvantages of these technologies have been 
found out. It is possible to draw a conclusion that the choice of technology depends on many factors 
therefore each specific project requires the technical solution.

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