ISSN: 2219-8229
E-ISSN: 2224-0136
Founder: Academic Publishing House *Researcher*
DOI: 10.13187/issn.2219-8229
Has been issued since 2010.

European Researcher. International Multidisciplinary Journal

Natural Gas Container Transportation: the Alternative Way to Solve the World's Energy Transportation Problems

[1] A.M. Shendrik
[2] M.I. Fyk

[1] Shebelinkagasdobycha, Ukraine
64250, Kharkov region, district Balakleevsky, Chervony Donets, Oktyabrskaya St., 9
PhD
E-mail: oilgasua@mail.ru
[2] Kharkov polytechnic university, Ukraine
61002, Frunze street, 21
E-mail: mfyk@yandex.ru

Abstract. The container gas transportation for low and medium level consumers as an alternative to pipelines is considered. The options for gas supply schemes, based on road and rail transport are given. The advantages and disadvantages of both types of gas transporting are described, the areas of their effective using are separated in the article. Promising implementations of technology in environment of economic crisis and also considering world trends of energy development are presented. The most advanced organization of compressed gas condensate transportation of unprepared gas fields in large diameter universal cylindrical balloons (up to 1000 mm) are reasoned.

The problem of compressed gas sea transportation are well disclosed, but the alternative ways of gas transportation by land are not investigated enough. Compressed Natural Gas (CNG) Technology - is new promising technology for natural gas transportation by specially designed vessels – CNG-vessels. The feature of this technology is that natural gas can be downloaded directly near gas deposits and unloaded - directly into the customer's network. This eliminates significant capital investments in underwater pipelining or gas liquefaction plants. The main objects of investment are CNG-vessels themselves.

The most attractive places for implementation of CNG-technology are sea (offshore) natural gas deposits. Numerous international experts estimate the natural gas transportation by CNG-vessels in 1.5-2.0 times more cost-beneficial in comparison with offshore pipelines transportation, or in comparison with LNG (Liquefied Natural Gas) shipping with natural gas transportation volume between 0.5 and 4.0 billion cubic meters per year on the route from 250 to 2,500 sea miles. This technology makes possible to provide gas supplement to the mountain and abounding in water areas, remote and weakly gasified regions. Described technology deserves special attention in the case of depleted and low-power oil and gas deposits development.

Keywords: gas production industry; compressed natural gas container transportation; technology; construction.

Introduction.

Natural gas quickly becomes the basic fuel of the world. It provides relatively ecologically clean combustion, it is cheap, occurs in abundance, gradually retrievable and could be obtained from the organic feed.

Currently, about 25 % of the world energy balance is formed by natural gas consumption. Natural gas is used for heating homes, cooking, electricity production, as fuel for cars and trucks, as a raw for chemical processing plants. Only in single industry sector - natural gas for vehicles (NGV) - natural gas consumption grew by 20 % last year and will grow by at least 10 % per year for the next 10 years. A lot of analysts predicted that in 2020, 30 % of the world energy will be obtained from the natural gas.

The gas production industry progress is closely linked not only with the history of the discovery and development of gas deposits, but also with the formation of gas consumption markets, creation of new transportation and consumption technologies.

In the early stages of the gas production industry the main consumers of natural gas were domestic sphere and production facilities which were located near the gas deposits. The pipelines diameters were small - Ø 520-730 mm and conducted within a single state. Gas production volume dynamic were ahead of consumption. Then have been developed powerful pipelines Ø1020-1420 mm of continental importance, so new consumption market began to form. The most powerful players among them – European states, USA, China.

Versatility, environmental friendliness, ease and relatively safe using in comparison with such energy as coal, uranium and oil are the reasons for industry reorientation and creation of brand new technologies based on the natural gas using. Natural gas consumption growth has become the key to competitiveness and energy security not only for single manufacture, but also for entire states, so the tasks of effective and reliable natural gas transportation to the customer gaining strategic importance. Moreover, the depleted gas fields problem has become exacerbated due to impractical transportation by powerful pipelines. And the number of such depleted deposits is constantly growing in gas-producing countries.

The existing gas transferring system most of the gas exporting countries of the Eurasian continent is based on pipelines system, which in most cases was built by former USSR. Recent events have demonstrated not only the need for modernization and restoration of the system, but also the vulnerability of "collective gas pipe" on the relationship between the transmission system operators. At any time, all of gas transporting participants (exporters and importers) could become hostages to force majeure, which are formed on any pipeline section. In addition, there is the formation of new powerful markets of natural gas consumption - such as China and India, where the gas supply has not only financial but temporal aspects.

The problem of transporting and consuming of natural gas huge amounts has increasingly quantitative and geographic dynamics. Sources, delivery destinations and even the most modern gas markets could be classified as dynamic. Therefore, the diversification task of ways and means of gas transportation is very relevant in today's natural gas industry.

The most known alternative to "gas pipe" is the compressed gas container transportation. Development of this kind of gas transportation service directly connected with relatively small and specialized gas markets - motor transport refueling, gas providing to remote and difficult accessible areas with relatively low consumption levels. But present economic environment with periodic crises, energy prices growth and increased competition between the world's leading economies, makes container transportation method acquires potentially a viable alternative for small and medium energetic.

The consumption structure of natural gas displays the main consumers: electricity production and major industry which are occupying respectively 24.4% and 32.3% of the total gas market. Typically, these segments are represented by large power plants and powerful plants which have no alternatives for gas pipelines. The only exception are the powerful supply systems of liquefied gas. But two other segments of the gas market - commercial and residential (14% and 21.8%, respectively) don’t have such tight restrictions and can be attributed to small and medium consumers.

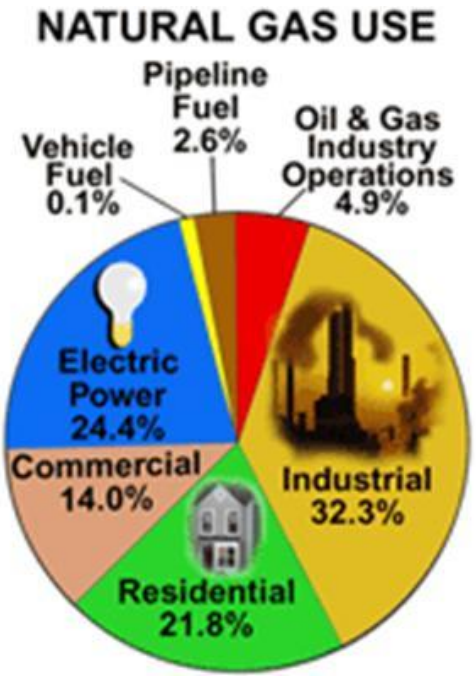

Figure 1. Natural gas use pie chart.

The features of commercial and residential domestic gas using segments are: significant seasonal and other consumption fluctuations, high gradation levels and geography of supply, significant sensitivity to pricing of gas traders. All mentioned above makes gas pipelines not a very convenient way of supply and, in some cases, moves the container gas transporting ahead.

It should be noted that technology of gas container transportation to the European continent very underestimated today. Against the background of the significant achievements of the container type gas transportation across the both Americas and the states of Eurasia, this technology has considerable investment and innovation potential. Usually, in Europe, the containers are used to transport liquefied petroleum gas (LPG) - propane-butane mix, but it production requires considerable capital expenditure on the construction of propane liquefaction and decontamination. But experience has shown that this technology can not override the seasonal demand fluctuations of energy consumption. A transportation of compressed methane usually provide supplementation of automobile CNG filling stations network (Fig. 2a) and individual gas consumers (individual small settlements and industries) due to relatively small fleet of gas containers, small capacity containers (Fig. 2b) and the significant cost of natural gas from traders.

Figure 2. Equipment for mobile CNG stations: a) mobile methane refueling, b) CNG cylinders for CNG stations, c) methane transporter.

Therefore, it is necessary to consider separately these obstacles for CNG container transport development. It should be noted that preparation of methane to pipeline transportation requires significant costs for manufacturer as much as gas preparations to liquefaction. Actually, spending directly connected with the preparation precisely for transportation, because, in the LPG case, gas should first be converted from a gas to a liquid state and then, using sophisticated refrigeration and thermal vacuum chambers, should be delivered to the special equipment stations which are prepared it for realization. In the pipeline transportation case - gas should be not only cleaned from the hydrate forming impurities [1], but also should be compressed many times by powerful gas compressor stations (hereafter GCS) along entire pipeline. Container transportation of compressed methane doesn't require such preparations. And this is the main advantage of this type of transportation because quality requirements defined by the consumer can be significantly reduced. Really, the presence of the higher hydrocarbon impurities in methane only increases its caloric content, water and liquid impurities could be easily removed from the gas by draining the container and that operation doesn't need even additional equipment, and the formation of hydrates could be easily prevented with addition of small amounts of methanol or by simple heating of gas reducing system elements. The only exception is dangerous or harmful impurities - hydrogen sulfide, sulfur or carbon monoxide.

Therefore, compressed natural gas container transportation (mostly methane), can use technology of raw (unrefined) natural gas transportation [2]. This gives a great advantage over the other types of CNG gas transportation because there are appear an economic reasons for the development of small and depleted gas fields, simplifies transportation of associated gas of oil fields, significantly expanding the geography and gas supply ways of the gas transmission lines. Currently had already been created a series of compressors for CNG (Fig. 3).

Jordair Compressor inc.

Chongqing Gas
Compressor Factory Co., Ltd.

Figure 3. Worldwide samples of equipment for natural gas compressing.

Modern gas containers industry uses high-pressure pipes with a diameter of 0.3-0.5 m. This limits, to some extent, as volumes of transportation as consumption of compressed natural gas. The main task for the final formation of CNG technology in Ukraine and some countries in Europe now is to design a universal CNG container of large capacity based on large diameter steel pipes (0.5-1 m), or other modern materials that could be used for road transportation, rail or by sea transport.

Figure 4. Worldwide samples of methane transporters.

It should be noted that compressed natural gas container transportation is quite well-known technology in the world (Fig. 4). It is already exist at international standard on 20- and 40-foot containers with pressure up to 2.5 MPa - ISO 11120 and for cylinders up to 200 atm. - DOT 3AAX 2900. The standard contains specifications for the container units production based on marine and railroad containers, which are fit for transportation by vehicles (usually van-TIR). On the basis of these standards, the Korean firm NK CO., LTD Korea has already started containers producing for compressed gas transport CNG. Also, recently appeared large diameter pipes (1220 mm) designed for high pressure (working pressure 22 MPa). That type of pipes was produced in order to reduce transportation costs for projects like Nord Stream. Therefore, the opportunity to increase the capacity of the CPG – containers has appeared.

Figure 5. 20-foot and 40-foot containers produced by NK Co. Ltd.

Now, let's consider the example of universal containers used under high pressure (up to 25 MPa). Fully loaded containers produced by NK CO., LTD Korea can transfer by car up to 5300 m3 (Fig. 5). This corresponds to a month gas need of a small village in the summer time or daily gas production by marginal wells. Using such methane carriers allows developing small gas deposits with a small number of wells. Equipped with small gas compressors, odorizator and methanol facility on container frame, mentioned gas deposits could operate without stationary gas preparing systems at all [3]. Such systems could provide not only the gas production, but generally its transportation and sales to small consumers (settlements, camps, expeditions etc.), could provide gas supply to the refugee camps, mobile construction and military brigades, drilling stations, etc.

By the way, experience using close analogues-prototypes is already known in different parts of the world. Argentine company "Galileo" uses high pressure gas containers for gas supply in those remote areas of the country where construction of the pipeline is beside the purpose (Fig. 6). But containers which they are using, collected from a large number of small capacity items and,

moreover, they use already prepared and compressed natural gas from pipeline. This technology is called "virtual pipe" revealed very good practical results.

But that technology is useless for the "wet" gas, due to large amount of the fuel cells that obstruct drainging the condensate and impurities. Road transport of compressed natural gas is suitable in the case of relatively small operational gas consumers and low volumes of gas transportation. Also, similar technology has got significant development for small gas supplementation along all main gas pipelines.

Figure 6. "Virtual pipe" technology equipment by Galileo company.

To provide a more powerful CNG supplement it is suitable road trains, rail and maritime transport way. Highly developed railways network, low level costs for traffic management make this method a very attractive way to transport gas to commercial consumers and housing segments of the gas market. In addition, there is the possibility for organization of some specialized gas transport railways for large consumers with lifetime limitations or technological seasonal cycles. The advantages of such railways are low construction costs (consider road constriction, flatcars, locomotives and containers) – cheaper in 1.5-2 times.

Rail transport usage allows significantly reduction in cost he cost and increases the speed of construction, reconstruction, and repairing of hydrocarbon transport line. After deposits exhaustion, prepared gas railroad can be easily disassembled, logistics could be reorganized or used for other purposes. And if trains would use methane as fuel, the costs for materials and power supply rail can be almost eliminated.

Loading a single platform with two containers (container height 1.4 m, width 2.4 m), and one train with 80 platforms, will obtain 850 thousand m^3 of natural gas per train. Consider a maximum railroad load as 1 train per a half hour – will transfer 41,487 million m^3 per day, that means about 15 billion m^3 of CNG per year – this is approximate power of such gas artery. In respect that train will spend about 300 m^3 of methane per 100 km, will get gas outlays equal to 0,035% of total gas volume. Comparison with pipelines revealed: the gas transportation through 10,000 km of pipes would required the construction of more than 50 pump stations and, depending on the hydraulic pressure losses and a good selection of power stations (Fig. 7), the number of stations can be much higher [4]. Therefore, when comparing the cost for the equipment, construction and maintenance of these types of gas transportation, railway transportation demonstrates its advantages, especially for irregular and unsteady hydrocarbon stream traffic. Also, technical problems (accidents, repairs, maintenance) will show significantly less loss of natural gas with higher security. CNG railway management is more flexible, so, consider the economic crisis, it can be a decisive factor as for gas producers and traders as for consumers.

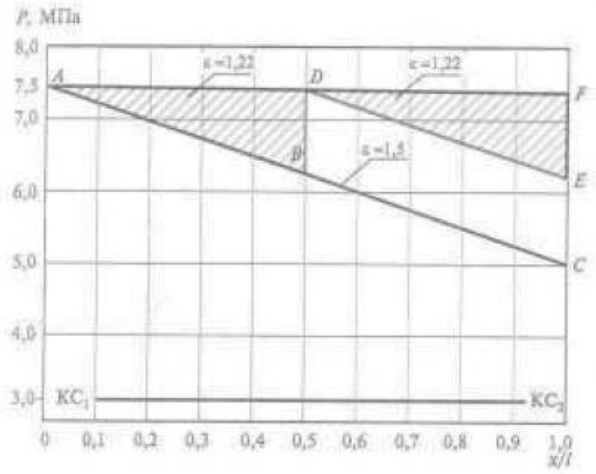

Figure 7. Energy loss due to the gas transportation by the pipeline at an initial pressure of 7.5 MPa and various degrees of compression

Return run efficiency of the train could be increased by loading natural gas purification products (such as gas condensate, oil, water) and with other goods and materials (raw materials, local produce, military, scientific and technical equipment etc.).

Maritime transport using has always been distinguished from other types by low cost. Besides classical [5] gas vessels and container transporters for LPG it is possible to tow containers assemblies directly by the water (Fig. 8).

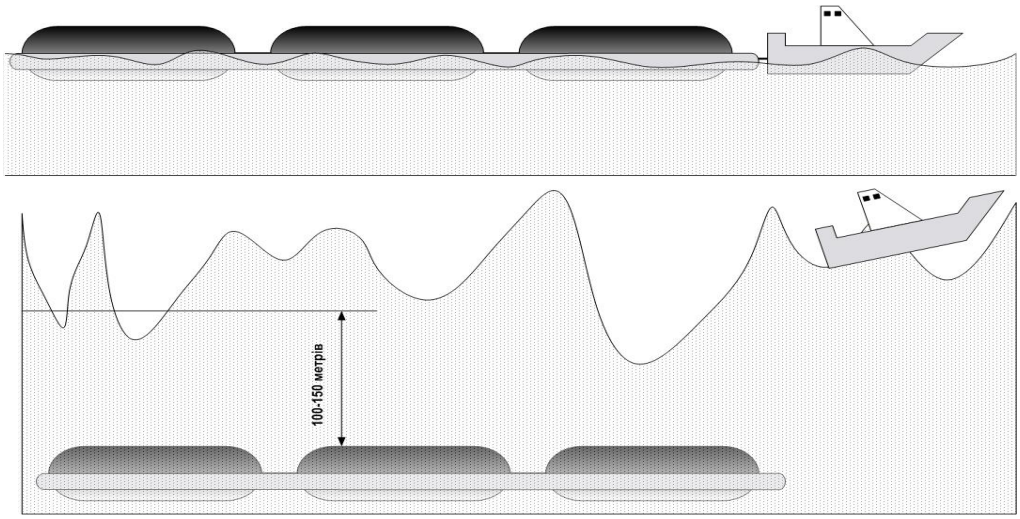

Figure 8. Towing containers by sea.

This method has got a lot of advantages:

- unlimited number of containers;
- in the case of an accident or storm, container assembly could be detached then programmed to dive under the ocean waves;
- vessel could carry additional loads;
- could be used on small waterways with shallow depth, swamps and small offshore gas deposits (Fig. 9).

Figure 9. Gas transportation scheme for the offshore gas deposits.

Such technology is acceptable as for powerful offshore gas fields (Shtokman, North/South Pars) as for small, depleted wells with presence of oil associated gas.

Main pipeline construction for natural gas, oil or other liquid (gaseous) product transportation needs an assurance that such a product exist or will soon appear at one end of the pipeline, and that there are it customers on another end. Such pipeline construction is not a cheap thing. In addition, pipelines with flammable gaseous substances can explode causing physical damage to people and the environment. So, pipeline construction costs should include costs for potential disasters. But the most important: gas pipelines built to make a profit. Primarily, it should bring profit to those whose owns land with pipelines laid. So, every oil or natural gas trading begins with picking on transportation way to the consumer in accordance with different technical and economic options [6]. And a significant component of the oil and natural gas price, except their production cost, is the cost of their transportation. Therefore, optimal choice is only possible under conditions of a wide selection of options and possibilities of their implementation.

Let's make assumption that we need to transport gaseous hydrocarbons in a volume of 100 thousand m3/day by existing main and distribution pipelines on a distance at 100 km and then, by a local means of transport carriers and low-pressure gas pipeline networks, also, on a distance at 100 km. Gas expenditure for hydrocarbons transportation by pump-compressor equipment on standard pipelines is about 8-12 % (mean rate - Wmr_pl -10 %) of the total energy flow through the distribution networks. Gas expenditure on the networks of low pressure is about 3-5 % (mean rate - Wmr_nw – 4 %). So, the overall cost of standard fuel are on average 15 % in the former Soviet states according to the evidence of classical textbooks for oil and gas business and according to expert judgment of the authors and their colleagues, who have industry experience of three decades of work in that area. During gas transportation to the total distance of 200 km (100 km by pipelines and 100 km by local networks) of hydrocarbons with preparation, intermediate cleaning and pressure increasing, the percentage of costs will be:

$$Wmr\_pl + Wmr\_nw = (10 + 4) / 2 = 7\ \%$$

Container transportation spending includes the costs for purchasing, maintenance of vehicles and fuel costs for trucks / railway wagons. Polls of trucking companies, engaged in transportation of petroleum products in Ukraine, have provided averaged fuel costs (V_fuel) as 30-50 L. per 100 km. path in terms of light crude petroleum. With an average of 10-30 th. km / year, the cars renewal cost (V_amort) at level of 100-140 L. per 100 km. of the truck path in terms of light crude petroleum. Average operating costs (V_ekspl) is 30-70 liters per 100 km. path. So, making the overall average estimates in natural units will get:

$$V\_fuel + V\_amort + V\_ekspl = 20 + 120 + 50 = 190\ L./100\ km.$$

Container transportation up to 200 km. will require standard fuel (V_av_st_fuel):

$$V\_av\_st\_fuel = 190 \times 2 = 380\ L. / day$$

When ordering the transportation of 100 thousand m^3/day (V_day) of standard fuel (it may be seasonal or urgent need of a small domestic or industrial consumers) consumption of fuel

equivalent is multiplied by the number of trucks needed (wet natural gas transportation will need two) or rail wagons (N_truck):

$$V\_aver\_st\_fuel\_sum = V\_av\_st\_fuel * N\_truck = 380*2 = 560 \text{ L. / day}$$

Recalculation of light crude oil (stabilized condensate with propane-butane fractions) on the price of natural gas with an average caloric standard market prices at the gas station and CNG filling stations in Ukraine in 2010-2012 is V_fuel_st_day / V_fuel_day = K_fuel_eq = 1:3.5. Let's calculate an approximate consumption of natural gas per 100 kilometers of container transportation, excluding the costs of industrial gas compression:

$$W\_av\_comp = V\_aver\_st\_fuel\_sum / V\_fuel\_day / K\_fuel\_eq = (560 * 3.5) / 100000 = 2\%$$

For this example, let's assume that the costs (W_av_ks) for compressing of 100 thousand standard m^3/day of raw natural gas with the wellhead compressor (from 10-20 to 40-60 atm) are equal to 3-5 % (industrial practice in Ukraine – "Shebelinsky" gas deposit, compressors "Gazdzhak").

Total percentage:

$$W\_total = W\_av\_comp + W\_av\_ks = 2 + 4 = 6\ \%$$

That is, if there is urgent and seasonal changes in unprepared gas transportation logistics to the consumer with a volume of 100 thousand standard m^3/day at distance of 200 km, described technology becomes competitive and even better on individual technological and environmental aspects. In addition, when using discrete and target gas providing systems, the risk of a contracts preparations mistake (for the gas supply planning and gas streams) are significantly reducing. Therefore, mobility and dynamism of this transportation form, as well as considerable flexibility of the gas volumes to be transported, makes container transportation method competitive with pipelines systems.

In addition, you should consider the costs and technical risks associated with the diagnosis, repairing and modernization of the "gas pipe" and all the equipment on it. Any technical problem can bring out of order very significant part of pipeline system and complicate the contractual obligations fulfillment, but container shipping is much less vulnerable to complications, because the repairing even the whole train will not affect as much on the overall transportation as a whole stop of the pipeline.

All over the world (exception is state-owned companies) on the gas market more and more weight gain independent financial players - commodity exchanges, gas traders, gas transportation consortiums. This is very conducive to the intensive development of financial instruments such as swap agreements, the stock market, investment funds.

Flexibility of technical gas supply system, efficiency of new capacities and the possibility of gas flows rapid reorientation are crucial for such agents.

It should be noted that the very form of production, preparation and transportation of natural gas in containers of various capacities brings great diversification potential of routes, transport means and utilization of gas, greatly enhances the commercialization of gas supplementation of Europe, allows the use of such funding options, which are not suitable for giant gas transportation contracts.

All mentioned above allows us to extend the gas industry geography, allows to increase the development of a "classic" gas deposits and deposits with difficult mining stocks (such as shale gas deposits). It allows to open access to small businesses (e.g. manufacturing lighters or sprays) and to medium-sized businesses (thermal systems) or to state purpose facilities (gas supply services in disaster areas).

At the late stage of the gas fields development, as well as for remote marginal wells, minimum requirement for equipment is just specialized mobile compressors, which are, at least, quite widespreaded at oil and gas market, and had been made today by numerous companies.

It is very illustrative example of market processes in Ukraine: with an annual gas pumping through Ukrainian main pipelines of 179 billion m^3, fuel gas consumption is 6 billion m^3 (3.3 %). With successful using of alternative transport gas modes, this volume could be significantly reduced, because the structure of the consumer gas market is very versatile, and the pipeline system is designed for

transportation of huge volumes of gas. Successful integration of transport alternative modes into the gas supply system can complement the gas transportation system and makes it more competitive [7]. This is especially evident from the graphs of gas consumption levels fluctuations [7].

In Ukraine, these oscillations are overlapped with changing of gas storage facilities modes, but the pipelines power equipment is so great that it is very difficult to use it to respond to changes in demands of small and medium gas consumers. Also, the new dynamic gas sources and gas markets formation makes "gas pipe" very vulnerable to fluctuations of global gas demands. Therefore, the container transporting gas method with the reduced metal content (pipes of low diameter) has a significant market segment in the gas markets and good prospects for development in the world.

Conclusions.

1. Raw and compressed gaseous hydrocarbons transportation become more profitable not only by sea and road transport, but also by railways.
2. Most gas condensate fields in the late stage of operation could be served by transport carrying natural gas under high pressure, produced by the compressor at the gas producing fishery. Then, industrial consumer, mostly, only requires a gas pressure reducing device.
3. During exploration of new deposits or their remote parts, transportation of the compressed gas with trucks or retrofitting railroad became more profitable (in condition of the gas price increasing) than to burn it off with environmental fines deduction.
4. The development of container transportation universal means of hydrocarbon products acquires strategic importance for the producing and transit countries in the world.
5. Economically reasonable distance for gas container transportation increased to 200-500 km.

References:

1. Газы горючие природные для промышленного и коммунально-бытового назначения: ГОСТ 5542-87 [действует с 01-01-1988]. М. Государственный комитет СССР по стандартам 1988. 6 с. (Государственный комитет СССР по стандартам).
2. Пат. 34473 Україна. (19)UA (11) 34473 (13)U (51) 7 E21B43/00. Спосіб видобутку і підготовки природного газу / Фесенко Ю.Л., Фик І. М., Шендрик О. М:заявники та патентовласники. Фесенко Ю.Л., Фик І. М., Шендрик О. М. u200803684; заявл. 24.03.2008; опубл. 11.08.2008, Бюл. № 15.
3. Пат. 38010 Україна. МПК(2006) F17C 5/00 Пристрій для підготовки і транспортування природного газу / Фесенко Ю.Л., Фик І. М., Шендрик О. М.: заявники та патентовласники. Фесенко Ю.Л., Фик І. М., Шендрик О. М. - u200803681; заявл., 24.03.2008; опубл. 25.12.2008 Бюл. № 24.
4. Козаченко А. Н. Энергетика трубопроводного транспотра газов [Текст]: / А. Н. Козаченко. Учебное пособие М. ГУП. «Нефть и газ» РГУ нефти и газа им. Губкина 2001. - 400с.
5. Зайцев В. В. Суда-газовозы [Текст]: / В. В. Зайцев, Ю.Н. Коробанов. Л.: Судостроение 1990. 304 с.: ил.
6. Кологривов М.М. Інфраструктура і режими експлуатації систем газонафтотранспорту [Текст]: / М.М. Кологривов Навчальний посібник / О. Видавницькій центр ОДАХ. 2009. 60 с.
7. Фик І. М. До питання вибору базових стратегій технічного переозброєння газотранспортних підприємств із енергетичної точки зору [Текст] / І. М Фик., М. І. Фик Нафтова і газова промисловість. 2008. №6. С. 41-44.