NATURAL GAS AS MOTOR FUEL IN UKRAINE

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1. HISTORY OF COMPRESSED NATURAL GAS REFUELING STATIONS DEVELOPMENT IN UKRAINE

Ukraine is one of the world’s leaders in using natural gas as motor fuel.

The first domestic refuelling stations were built, and the first vehicles were converted to use liquefied petroleum gas, as early as 1936. In the following year, Ukraine’s first compressed natural gas refuelling stations (CNGS) was commissioned to use gas from Priazovskoie Field. Its capacity was 180 cum/hour, enough to refuel nearly 76 gas vehicles (lorries).

After the end of the WW2, mass vehicles conversion effort continued. In 1946, motor race Berlin-Kyiv-Moscow featured virtually all vehicle types ranging from 0.5l midgets to 7.4l hundred-seat buses. The rout of 2,603km was covered over 14 days (including 11 days of actual races) by 18 vehicles that included 5 natural gas and 13 liquefied petroleum gas ones (see Fig. 1 below).

![Figure 1. Gas vehicles of the 1930s](image)

In 1949-1953, natural gas vehicles (NGVs) were designed and launched into production. A network of nearly 30 CNGSs was set up for these vehicles refuelling. The CNGSs used 3- and 4-stage compressors and capable of filling various kinds of trucks.

Years of rapid development were followed by a period of stagnation. Large oil reserves were explored, and oil refineries became capable of covering the existing demand.

Petroleum crisis of the 1970s once again made NGVs topical. At that time it became clear that oil reserves were not as large as expected, and that an alternative to liquid fuels was required. On the other hand, large gas reserves had been discovered. Thus, the early 1980s gave a start to another era in CNGSs development.

Compressed gas refuelling programme was launched in Ukraine in 1984 with commissioning of 4 CNGSs. Another 9 were completed during the following year. All in all, 48 stations were put into operation.

These stations were assembled directly on site. Equipment was delivered from different countries: Ukraine, Russia, Germany and Italy. Stations were capable of refuelling 500 vehicles per day and were fed from gas distribution grid under the pressure between 4 and 12 atmospheres.

Implementation of second-generation modular container-enclosed CNGSs rated for 500 refuelling operations daily was the next step. These stations that came in a number of versions were launched in 1987, and the total of 39 was commissioned.
Both the first- and the second-generation CNGSs were dependent on availability of a large NGV fleet in the immediate vicinity, which was their common disadvantage. Furthermore, stations’ excessive capacities and severe (at least 100 m) safety zone requirements prevented them from being located in the areas with dense population.

The third-generation, the so-called “garage”-type, CNGSs came next. They were rated for 100 NGVs and could be accommodated in 1 or 2 containers. This minimised the scope of installation and completion works, and stations could be placed within motor depots or as attachments to petrol stations.

2. PRESENT-DAY STATUS OF CNGSS DEVELOPMENT IN UKRAINE

The Ukrtransgas Affiliated Company CNGS network as of 01/01/2003 comprised 87 stations, covered 66 towns, and was capable of refuelling the total of 70 thousand NGVs, releasing 625 thousand tones of liquid fuels (see Figs. 2).

![Figure 2.](image)

Size and capacity of Ukrtransgas’ CNGS network and the magnitude of its sales have for a meaningful time been making the Company one of the CNG business leaders in the CIS (see Figs. 3 and 4).
Ukrtransgas’ network is able to capture not only local transfers, but as well long-distance transits along Ukraine’s major highways connecting Eastern Europe with Ukraine, Russia, Belarus and other countries. Ukraine has an extensive experience in motor fuels quality assurance that was confirmed at the international symposium Use of Compressed Natural Gas and Liquefied Natural and Petroleum Gas as Motor Fuels held in Kyiv.

The symposium opening event was an NGV race that started in Rome. The race covered over 10,000km across a number of European states and ended in Kyiv, Ukraine. Between Uzhhorod and Kyiv, 50 vehicles representing various nations were refuelled at Ukrainian CNGSs.

Ukrtransgas continues to expand its gas refuelling stations network. Last time 18 new stations were commissioned. We are planning to expand CNGSs network in the future.

Economic and environmental benefits from the use of gas motor fuel made Ukrtransgas undertake development of a concept suggesting new approaches to expansion of CNGS network and
the entire motor vehicles conversion related infrastructure. The concept addresses the following points:

- building of multi-purpose CNGSs serving compressed gas, liquefied gas, petrol and diesel and providing gas tubes refill (GTR) and other services;
- development of "garage"-type CNGSs to refuel natural gas vehicles locally;
- equipping existing stations with service centers for GTR;
- setting up the own equipment production in Ukraine to support compressed gas refuelling stations;

Adequate service support of the existing CNGSs is among the Company's most important priorities. Apart from regular maintenance and repair, the Company retains assistance of research and engineering institutions to exercise equipment upgrade and replacement efforts. New technologies are being implemented in production of gas filling pumps, gas coolers, power engines, etc. to replace the obsolete ones.

Company’s dedicated division is involved in diagnosing CNGS equipment to prolong its service life. These works are part of the Programme for CNGS development.

Programme's initial task is to identify actual condition of CNGS equipment that is 10 or more years old. This effort will spot the items needing replacement and the equipment whose life may be extended through certain renovation routines (see Fig. 5).
The next objective is development of instructions and manuals for equipment audit, rehabilitation and service life extension based on the available diagnosis data and using services of specialist research institutions.

The third step is practical implementation of the above developments.

The Company has already initiated phases 1 and 2 of the Programme. CNGS equipment inspections have been triggered within the framework of the respective research programme and based on available global equipment audit instructions. In parallel, equipment service extension terms are being discussed with manufacturers, along with the required efforts.

Ukrtransgas came up with the initiative to launch an NGV programme for Kyiv for the period until 2010, which was developed by VNIPITransgaz Institute.

The programme included analysis of the available fleet of motor vehicles by types and operating ages. In found that between 1992 and 1998 the number of trucks dropped by 16%, whereas the fleet of cars experienced a 2.4 time increase. The 2010 forecast was a minor growth of the truck fleet and the 1.5 times increase of the number of cars. Reduced mass of noxious discharge in Kyiv alone was estimated to grow from 43.1·10⁶ conventional tones/year in 1990 to 66.0·10⁶ conventional tones/year in 2010.

Mitigation of the harmful effect on the city's environment could be achieved through NGV technology implementation. The programme assumes conversion of approximately 55,000 vehicles by 2010. About 10 thousand vehicles of various kinds are planned to be converted to binary fuel. Nearly 50 conversion outlets are planned to be set up to complete the massive effort, whereas refuelling will be provided by nearly 300 CNGSs. These actions are expected to increase overall compressed gas consumption in Kyiv to 535.5-10⁶ m³/year and reduce aggregate noxious discharge by 96,500 tones per year.

International experience proves that practically in every country where the effort of liquid fuels replacement with compressed natural gas was successful (Italy, New Zealand, France, USA, etc.), a leading role was played by the government who pursued appropriate environmental policy and established the respective legislative support.

3. PROSPECTS OF CNGS DEVELOPMENT IN UKRAINE

Environmental and economical efficiency of CNG use could be sustained by bringing CNGSs closer to consumers, i.e. to residential areas.

The practice of using mobile refuelling vehicles (MRVs) designed to transfer compressed natural gas is a possible technological solution to bring filling stations closer to their clientele in Ukrainian environment. A MRV is a truck equipped with vessels containing CNG under pressure of 20-25·10⁶ Pa or 32·10⁶ Pa, depending on a vehicle version.

MRV may carry a minimum of 7-8 spherical cylinders of 1 cum geometrical each to a maximum of 50-100 cylinders of 50 litres geometrical. Vessels are grouped in sections, which is needed to increase overall amount of gas available for refuelling. If no such sectioning is applied, the amount of released gas will be dependent only on pressure difference (between initial pressure of 20-25·10⁶ Pa and terminal pressure of 20·10⁶ Pa) and geometrical volume of vessels. In such event, useful capacity of a MRV would not exceed 10% of the total amount of gas carried by the vehicle.

Due to the sectioning and employing one section consecutively after the other in the refuelling process the useful amount of gas may be driven up to 40-60% of the total compressed gas volume carried by a MRV. After the refuelling is over, pressures in each MRV section will range between 25-50·10⁶ Pa in the first section and 20·10⁶ Pa atmospheres in the last one. The optimum number of sections is 4 to 5. Any further increase of sections number would not result in any material growth of useful gas output, however will make the refuelling process more complicated.

Another factor governing the useful gas amount is initial pressure in the sections. Pressure increase to 32·10⁶ Pa results in larger overall gas output during the refuelling exercise because more gas is originally pumped into the MRV vessels. Useful gas output ratio is also larger: 80% of the total gas volume.
However, the use of MRVs designed for the 320 atmospheres is prevented due to insufficient pressures at CNGSs. Under technological requirements, CNGS receiver tanks contain gas at 20.5-24.5·10⁶ Pa. Additional booster compressor would be required to increase gas pressure to 32·10⁶ Pa.

One of the possibilities to increase useful gas volume is to apply stationary (at MRV area of operation) or mobile (MRV-mounted) booster compressors. This solution could result in almost 100% ratio of useful gas output, yet, on the other hand, it would increase gas price to reflect the cost of pressure boosting.

MRV-based refuelling process developed by our Company allows for both billing the sales, automating the refuelling process, and metering gas pumped into a MRV (see Fig. 6 below).

![Figure 6. MRV computer-aided process diagram, including automatic refuelling control, gas sales billing and MRV filling meter functions](image)

A dedicated MRV filling outlet connected directly to receiver tank at 25·10⁶ Pa should be provided at a CNGS (see Fig. 7 below). Connections should be established with both gas transmission lines (MRV hoses) and interface channels to CNGS centralised automatic control system (CACS), a computer-aided device governing CNGS electronic meters and monitoring the overall gas balance at the CNGS.

Prior to MRV filling, its meter will forward to CACS its overall sales statistics, including card sales, and inform the system on MRV availability for the filling. Upon receipt of the above data, operator will issue filling authorisation. Filling progress data will be transferred by MRV meter to CACS in a real-time mode. In this way, CACS would keep a complete record of gas availability within the process line between the inlet meter and the client NGVs.
Figure 7. Suggested CNGS – MRV interface scheme
In the future, MRV efficiency increase could be achieved though including extra booster compressors in MRV refuelling scheme. This will allow filling MRV vessels at 320 atmospheres. The refuelling process itself will not be affected; however CACS scope of functions will have to additionally include control of the booster compressor operation.

The above CNGS-MRV interface scheme can serve as a viable solution for selling compressed natural gas at the accuracy rate of 1.0 in compliance with Ukrainian codes and monitoring overall gas balance throughout the entire CNGS process line.

REFERENCES


