To analyze the trends of hydrogen engine building, gaseous and liquid hydrogen storage systems are compared. The advantages and prospects of running Stirling engines on hydrogen are noted. The concept of building infrastructure of KrioAZS cryogenic fuel filling complexes for motor vehicles is proposed.

Since 2001, industrially developed countries have been adopting massive state-sponsored R&D programs in the field of hydrogen energy, which are projected for a period until 2020 and aimed at reducing dependence on energy import, finding solution to a host of ecological problems, and developing new renewable energy utilization technologies.

The main thrust toward introduction of hydrogen energy technology is the use of hydrogen as a fuel for motor vehicles. The source of hydrogen is unlimited. Water vapor is produced when hydrogen is burned (oxidized), so it can be claimed that hydrogen is ecologically the cleanest motor fuel. The only toxic substances are nitrogen oxides, which are contained in the exhaust of the hydrogen engine in very negligible amounts and are easily rendered harmless in the catalytic converters.

Being well aware of the potential of hydrogen fuel, the governments of the USA, European Union, Japan, and other countries have since long been investing billions of dollars in R&D and introduction of commercial hydrogen technologies.

A serious problem in using hydrogen as a motor fuel is how to store it aboard the motor vehicle. Hydrogen is the lightest of all chemical elements, so a much smaller amount of hydrogen can be held in a given space than other types of fuel. For instance, at room temperature and normal atmospheric pressure hydrogen occupies roughly 3000 times larger space than gasoline for the same amount of energy generation. So, for fueling vehicles, it is necessary to compress hydrogen under high pressure, or use it as a cryogenic liquid, or equip the vehicle with highly complicated fuel systems.

Supplying filling stations with compressed hydrogen and filling up bottles placed in the vehicle is technically simple. The currently available high-strength materials guarantee high reliability of the bottles. But then the weight of the vehicle increases and its useable space decreases since the capacity of the bottle that holds 1 kg of hydrogen compressed under a pressure of 70 MPa is 7.5 times greater than the capacity of a tank containing an energy-equivalent amount of gasoline.

But if restrictions of mass and volume are imposed on the hydrogen storage system, which is typical for vehicles, cryogenic hydrogen (in liquid form) storage system is more preferable.

Liquid hydrogen, whose production is growing in the world at a rate of 5% annually, is a vital element of the infrastructure for hydrogen supply to consumers. The USA have production capacities for getting as much as 120,000 tons of liquid hydrogen annually, 15% of which is used for production of space rocket fuel. The rest is used in chemical industry (37%), metallurgy (21%), electronics (16%), and glass industry (4%).
Almost all automobile companies are engaged in introducing cryogenic hydrogen storage system aboard the vehicle. In the beginning of 2004, two of the largest automobile companies, General Motors Corp. and BMW Group, announced their intention to start joint development of equipment for fueling vehicles with liquid hydrogen. The following figure indicates the scale of the undertaking: in Germany alone a plan is afoot to build 10000 cryogenic hydrogen filling stations.

In this context, it is necessary to standardize the liquid hydrogen filling equipment, which will be available after the preliminary specifications are worked out within the framework of the European Integrated Hydrogen Project (EIHP). Right now the EIHP specifications are at the consultation stage and are the base for the standard of the European Economic Commission of the UNO for hydrogen-run vehicles.

The agreement on joint development signed by General Motors, world’s largest motor vehicle manufacturer, and the BMW Group, world’s only company specialized exclusively on manufacture of premium class vehicles, is a significant step toward creating and standardizing hydrogen fuel technologies.

In the mid-1990s, many automobile companies began to develop electric cars with fuel cells (FC) that have no moving parts, which precludes possibility of explosions. Hydrogen does not burn the way burning occurs in heat engines but dissociates inside the FC into oppositely charged ions and electrons. The electrons turn into useful electric current, which feeds the network of the onboard power system, and the hydrogen ions bind the oxygen contained in ordinary air supplied to the FC, producing water vapor as exhaust.

Research showed, however, that FCs have a host of serious flaws, such as high cost, short life, low efficiency (theoretical efficiency is about 70% but the actual efficiency even of the best Japanese FCs is not higher than 30%), substantial increase in mass and size of the car, etc.

A more promising direction of liquid hydrogen use in motor vehicles is burning it in internal combustion engines (ICE). BMW has built a test car, 745H, in which liquid hydrogen is stored in a cryogenic tank and the gas is injected into the cylinders by specially designed electronically controlled injectors. Practically no toxic nitrogen oxides (carcinogens) are formed in the combustion chamber when the hydrogen-air mixture is leaned by more than two times compared to the stoichiometric composition; no other pollutants are formed when hydrogen burns in air. So, from the exhaust pipes of the 745H car only water vapor is discharged to the atmosphere.

BMW has also built the fastest hydrogen-run car H2R (Fig. 1), which can develop a speed of more than 300 km/h. At this moment, the traditional ICE is not completely replaceable, but obviously a new line of engine building, i.e., development of engines running on hydrogen fuel, will appear soon. One of such engines is Stirling engine, which has not yet come into wide use in automobile transport because of more complex (compared to ICE) design, greater materials consumption, and higher cost.

However, experts on energy conversion engineering consider Stirling engines as the most suitable for use of hydrogen as a motor fuel. Thanks to such parameters as low noise level, long life, comparable size and mass, high torque, etc., Stirling machines will soon dislodge ICE and FC from the hydrogen energy field. Lately, several foreign companies have been building anaerobic energy units for space (flying) vehicles and submarines where initially used electrochemical generators in fuel cells (FC) have been almost completely replaced by Stirling generators.