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Russian R&D in Hydrogen and Fuel Cells

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1 Introduction

Russia has been developing and using hydrogen technologies in practice for many years, starting from the time of its first space program. Among its achievements are experimental liquid-hydrogen fuelled airplane-laboratory TU-155, which was tested back in 1986-1987, air and space hydrogen-fuelled engines, including an unparalleled engine RD-0120 with a forward thrust of 200 tf in each booster of “Buran-Energy” complex, experimental hypersonic ramjet engine (SCRAMJET) 58L that was successfully fly-tested with hypersonic flying laboratory (HFL) with Flight Mach number from 3 up to 7 , a fleet of demonstration taxi-cars fuelled by a mixture of gasoline and hydrogen which were successfully run in Kharkov in 80-ies, hydrogen forklifts, systems for liquid hydrogen production, storage and transportation, 250 kW AFC-based power generation units and many others which brought about R&D activities carried out at the end of the 20th century. The results of these works are presented in 8 volume collection of scientific papers entitled “Nuclear and hydrogen power and technologies” and in a number of monographs, published in 80-90-ies in the Russian language. In the nineties the hydrogen R&D program was considerably curtailed because of the political situation in Russia. At the beginning of the 21 century the Russian Ministry of Science and Education and Federal Agency for Science and Innovation (FASI) have re-initiated an R&D program in the field of hydrogen technologies by starting to fund R&D projects for power sector and transport. In 2008-2009 the Russian hydrogen program funded by federal budget comprises more than 40 research projects.

2 Policy and Legislation

By decree of the Russian president in May 2006, hydrogen energy technologies were given the status of critically important for further development of the national economy, which means that they are to be developed on a priority basis. The national programs through which research, development, and demonstration (RDD) projects were funded from 2002 to 2006 have been successfully completed. Since 2007, the projects aimed at development and deployment of hydrogen energy technologies, including projects related to fuel cells (FCs), are funded by the Russian government mainly through two national (or special federal) programs: (1) “R&D in the Priority Areas of the Russian Scientific and Technological Complex Development for 2007–2012” and (2) “National Technological Basis for 2007–2011.” The main objective of the first program is to accelerate research and development in the priority areas of science and engineering, while is the focus of the second program is to accelerate commercialization of innovative technologies and new products. Some H2-related

basic research is also funded through the programs of the Russia's Academy of Sciences and the Russian Foundation for Basic Research (RFBR).

3 Research & Development

Current directions of research and development in the field of hydrogen energy are determined by social and economic targets set by Energy Strategy of Russia for the period up to 2030 confirmed by the government in 2009. For example, increasing of the role of nuclear and coal fuelled thermal power stations and renewables in energy balance stimulates R&D in hydrogen accumulation of energy for load management and environmentally friendly hydrogen based technologies for autonomous power supply, also deep crude oil refining processes and increasing of quality of oil products requires R&D in large scale hydrogen production (up to 3-4 millions of tonnes in 2030) for oil industry.

In 2007-2009, over 60 organizations were involved in hydrogen projects implemented within the framework of the special federal program "R&D in the Priority Areas of the Russian Scientific and Technological Complex Development for 2007-2012 " Among the project coordinators are leading Russian research organizations: 8 federal scientific centres, 19 institutes of the Russian Academy of Sciences, 14 universities; as well as innovative SME, branch research institutes and design engineering departments. R&D carried out by them covers all aspects of hydrogen technologies.

4 Hydrogen Production Technologies

Within the framework of the Russian R&D program efficient compact units (including portable one) for catalytic conversion of hydrocarbons, PEM electrolysers operating under pressure of up to 13 MPa with productive capacity over 10 nm^3/h, stationary and on-board plasma-chemical converters for converting hydrocarbon fuels into syngas, hydrogen production units with systems of hydrothermal oxidation of Al and Mg-based solid materials , as well as some basic R&D in new catalysts (including nanostructured one) for thermochemical and electrochemical processes, of hydrogen production are being developed by Boreskov Institute of Catalysis, Russian Research Center "Kurchatov Institute", Joint Institute for High Temperatures, Frumkin Institute for Physical Chemistry and Electrochemistry, Moscow State University, Moscow Power Engineering Institute, Gubkin Oil and Gas University, Novosibirsk State University and others.

5 Hydrogen Storage Technologies

Hydrogen Storage Technologies are being studied and developed due to effort of more than 20 national research institutes and universities. New materials (including nanostructured and composite one) for reversible hydrogen storage systems and purification, hydrogen storage in non-equilibrium and regenerable systems, reversible solid storage systems integrated with stationary power generation units based on low temperature fuel cells with capacity of up to 5 kW(e) compact and safe metal hydride hydrogen sources for portable (mobile and transportable) power supply units, equipment and apparatus are being developed by Institute for Problems of Chemical Physics, Moscow State University, Joint Institute for High

Temperatures, Novosibirsk State University, Ural Institute for Physics of Metals, Moscow Power Engineering Institute, RRC “Kurchatov Institute” and others.

6 Fuel Cells

The efforts are also taken to develop fuel cells of various types for portable and stationary power units (AFC, PEMFC, SOFC, MCFC) for autonomous power supply with capacity of up to 100 kW. Portable AFC-based charging devices with gradient porous structures are in the deployment and commercialization stage; AFC-based power units of new generation as well as stationary and portable power units with PEMFC and SOFC with capacity from 5 to 100 kW, new catalysts (including nanostructured one) and MEA with reduced content of platinum from nanostructured ceramic ion-conducting materials, reversible PEM and solid oxide FCs of 0,5- 1 kW are being developed by Central Institute for Ship Electric Engineering and Technology, RRC “Kurchatov Institute”, “Aspect” Association, Independent Power Technology, Ural Electrochemical Plant, KVANT, Institute for Problems of Chemical Physics, Moscow Power Engineering Institute, All-Russian Institute of Experimental Physics, All-Russian Institute of Technical Physics, Institute of Physical and Power Engineering and others.

7 Hydrogen Powered Vehicles

Automobile “Lada-Antel-1” (based on an alkaline FC) and “Lada-Antel-2” (based on PEMFC) have been displayed at various motor shows. A few types of automobiles with ignition engines in which hydrogen-gasoline fuels are used have been designed and tested. A switch locomotive with FC-based engine is under development. Hydrogen Powered Vehicles Projects are implemented by AVTOVAZ, National Auto-Motor Institute, RSC “Energia”, Ural Electrochemical Plant, National Association of Hydrogen Energy, All-Russian Institute of Railway Technologies and others.

8 Hydrogen Combustion Power Technologies

Experimental high pressure hydrogen-oxygen steam generators with thermal power up to 25 MW have been developed and tested, model high temperature steam turbine units with these combustors of up to 5 MW capacity have been designed and tested by Joint Institute for High Temperatures and JSC “Chemical Automatics Design Bureau”.

9 Hydrogen Safety

The R&D is aimed at developing technologies, methods and means expected to provide for safety of hydrogen production and its use as a energy carrier. They cover experimental and theoretical study of combustion processes (including combustion under non-stationary conditions) and explosion of hydrogen-air mixtures under ambient conditions, in large closed volumes of various geometry (including accumulative one), in jets coming out of high-pressure containers and others, as well as development of inhibitors and stabilizers, systems of diagnostics, prevention and liquidation of fire and explosion hazardous situations, research in hydrogen safety codes and standards and their harmonization with international codes and standards. A unique equipment is used for carrying out these works; among them is a 13 m

diameter explosion camera, with designed capability for explosion resistance, equivalent to 1000 kg of TNT. Due to R&D carried out in 2007-2008 a new phenomenon of abnormal increase in pressure under non-stationary combustion of hydrogen – air mixtures and in the situation when explosion waves enter into accumulative volumes is discovered; new methods and means of control over the velocity of hydrogen flame spread, means to prevent combustion from turning into explosion, safety valves for reduction of pressure in high pressure containers and some other devices have been developed. Some new national hydrogen safety regulations have been drafted, including those for liquid hydrogen. The work on hydrogen safety is carried out by Joint Institute for High Temperatures, Research Center "Kurchatov Institute", JRC "Cryogenmash" and others.

10 Education

Within the framework of Ministry Education and Science's project on hydrogen education a number of scientific and education centre have been established for training specialists in hydrogen energy technologies, they are functioning on the basis of the leading Russian universities and research institutes (Moscow Power Engineering Institute, RRC Kurchatov Institute, Joint Institute for High Temperatures, Moscow High Technical University, Novosibirsk State University, Ioffe Physical-Technical Institute, Voronezh Polytechnical University, Moscow Institute of Physics and Technology, Tomsk Technical University, St. Petersburg State University). A few text books and method guides in hydrogen technologies and fuel cells for high school students have been published.

In Moscow Power Engineering Institute a new department specializing in "Electrochemical and Hydrogen Energy Technologies" has been established, where specialists and post-graduate students undergo training. For educating elementary school children a few colleges have been established, such colleges function under the auspice of Moscow Power Engineering Institute, Moscow Institute of Radio Technology, Electronics and Automatics (MIREA), Ioffe Physical-Technical Institute (St. Petersburg), Novosibirsk State University and others. MIREA prepared a few text-books for school children. A few "hydrogen clubs" are functioning at some schools, as well as scientific and education centre "Sokolinaya Gora" set up with assistance of Moscow State University and MIREA.

References

[1] Mazurenko S.N., Malyshenko S.P., Reutov B.F. Russian R&D in the field of hydrogen energy and technology. 16 World Hydrogen Energy Conference, Lyon, France, CD-ROM. 2006.

[2] Hydrogen Technologies. Innovation Developments Catalogue. Moscow. 2007.

[3] II International Conference „Hydrogen Storage Technologies". Abstracts. Moscow. 2009.

[4] II International forum „Hydrogen Technologies for developing countries". Proceedings. Moscow. 2008 (in Russ).

[5] Special Federal Program "R & D in the Priority Areas of the Russian Scientific and Technological Complex Development for 2007-2012". Rep. on results. 2008. FASI 2008 (in Russ).