Solar Hydrogen Project at Neunburg vorm Wald, Germany

SWB
A member of the Bayernwerk Group

Field of Solar Hydrogen
Solar Hydrogen Plant No. 24

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Objectives and prime results of SWB's Solar Hydrogen Project at Neunburg vorm Wald, Germany

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Project objectives

- Construction and testing of major technical systems for a potential (solar) hydrogen energy scheme with consideration to initial aspects of phased transition from contemporary energy supply based primarily on fossil fuels.
- Studying individual behavior of separate plant subsystems, largely commercial-scale prototypes or new developments. Comparing different technologies, notably in solar generators and associate converters, water electrolyzers, hydrogen storage systems, gas-fired heaters, fuel cell plants, liquid hydrogen filling couplings and vehicle fuel tanks.
- Checking out interaction of plant subsystems under long-term operating conditions aligned to commercial application. Investigating various technical and energy supply hook-up concepts for existing plant subsystems.
- Creating reliable data for updated assessment of the prospects and challenges of energy supply based on (solar) hydrogen as an energy medium.
- Acquiring know-how for planning, constructing and operating similar projects and related economic issues.
- Realistic public relations work, national and international, applying first-hand expertise and information. Relaying comprehensive practical - and meanwhile widely implemented - recommendations to manufacturers/suppliers, specialists, operators/users and visitors.

Prime results achieved by SWB

Technical plant systems

- From 1990 on, successful long-term operation of eight different solar generator technologies.

- Improvements to production processes employed by manufacturer of polycrystalline solar modules as a result of SWB findings concerning internal electrical defects (incipient aluminum stress fracture of cell connectors causing break in cell interconnection after four years of trouble-free operation) .

- Improvements to converter control circuit boards for individual solar generators following aging due to thermal stress.

- Development of solar system fault monitor usable with all types of solar generator and associate converter.

- Successful long-term field testing of different solar generator support designs (including steel guyropes as alternative to conventional tables).

- Various recommendations to improve installation of solar generators.

- Direct coupling of solar generator to water electrolyzer.

- From 1991, successful long-term operation of new design of alkaline low-pressure electrolyzer incorporating advanced technology (111 kW_{el}, zero-gap geometry, polysulfone diaphragms, activated nickel electrodes, increased current density).

- Promoting significant improvements to alkaline pressure-type electrolyzer (100 kW_{el},). Manufacturer's newest third version of cell stack (polysulfone-bonded ceramic diaphragm, non-activated nickel electrodes, new seal design) currently performing far better than both predecessors, which could not support practical operation loads.

- Practical testing of three hydrogen storage systems employing different technologies (5,000 m^3, 30 bar compressed gas; 3,000 l liquid hydrogen; 26 m^3 metal hydride).

- Extensively positive operating experience, including improvement of efficiency and reduction of emissions, with air-oxidized 20 kW_{th} gas-fired heating boiler, 10 kW_{th} catalytic heater (both calorific-value units), and also with 79 kW_{el}/42 kW_{th} phosphoric acid fuel cell plant after promoting significant design improvements. Highly promising results with these three plant subsystems also as regards initial technical steps for transition from present-day, primarily fossil-fuel-based energy supply to potential energy supply using hydrogen generated without carbon dioxide emissions as energy medium. Additionally, operation of these units with natural gas, with hydrogen and with mixtures of these two fuel gases.

- Successful test operation of catalytically hydrogen-fueled 17 kW_{th} absorption-type refrigeration unit (modified conventional air conditioning refrigeration unit fired with natural gas).

- Test operation of three fuel cell plants incorporating different technologies.
  - Use of 6.5 kW_{el} alkaline fuel cell (AFC) plant to generate electricity and coupled with hybrid system to simulate electric vehicle operating cycles. AFC proved it to be too susceptible due to its complexity and high purity demands on feed gases (hydrogen, oxygen). Manufacturer relinquished design in favor of membrane technology (PEMFC).
  - Combined-cycle heat and power cogeneration operation of phosphoric acid fuel cell (PAFC) plant optimized for electric output, alternately using natural gas and hydrogen. Efficiency additionally to be improved by enriching cathode air with oxygen as high as 50 vol% (normally 21 vol% oxygen). Heat decoupling at approx. 165°C. Valuable

longterm operating experience, notably in intermittent working (over 500 start-stops).
- First demonstration application of air-oxidized 10 kW_{el} PEMFC plant (proton-exchange membrane) in standard production model of electric forklift truck for mobile and stationary tests. Repeat use of hybrid system employed with AFC to simulate run cycles. Hydrogen fuel filled in the form of pressurized gas and stored in metal hydride. Forklift employed on actual material handling duties at the Neunburg vorm Wald facility as well as for tests.

- Successful testing and improvement of liquid hydrogen filling station for passenger cars. Manual coupling of filling line to vehicle, program-controlled fuel tank filling. Optimization of refueling resulting in loss-free automatic filling of about 100 liters LH_2 in 3 minutes, sufficient for about 300 kilometers travel (BMW 7 Series). Capability of refueling cars in immediate succession. Technology employed in robotic filling station at Munich Airport.

- Extensive acquisition of test data as basis for verifiable evaluation and documentation of versatile test programs. Investigations extending beyond customary scope of interfaces between different plant systems to include structures and actions within separate equipment.

- No fundamentally new safety-related risks requiring attention in safety concept as implemented for Neunburg vorm Wald facility. Existing regulations for safe working with hydrogen, already used in industry for decades (and also for other fluids at the facility, such as natural gas, oxygen, carbon monoxide, nitrogen or potassium hydroxide) proved adequate despite widespread breaking of new ground. Temporary unattended operation of hydrogen-containing systems agreed with licensing authorities (for maximum periods of 24 hours). Safety engineering principles combined with experience of staff employed at facility ensuring several years of safe, trouble-free operation to date, including work with prototypes and new developments.

Budget, public relations

- Expenditure less than authorized budget regardless of three-year extension of test operation.
- Visitors to Neunburg vorm Wald solar hydrogen plant and information center numbering about 130,000 from over 100 countries to date, 35 percent of them professionals and other specialists.

Practical knowledge of a general nature

- Centralized hydrogen generation, storage and subsequent utilization for energy purposes preferable, because advantageous for cost reduction, safety engineering systems and optimum management.
- Hydrogen systems for energy conversion generally available only as prototypes or new developments.
- Process engineering and electrochemical nature of hydrogen systems employed is closer to field of process plant engineering and construction than that of renewable energy.
- Scope and complexity of plant peripherals widely underestimated. Large-capacity plants preferable with view to variety of necessary utility and ancillary systems.
- Outdoor installation recommended for large gas production and utilization systems.
- Many systems initially unsatisfactory as supplied. Solutions found to problems occurring at start-up and during test operation both on individual subsystems and their interaction. Numerous significant improvements developed, mainly in collaboration with manufacturers/suppliers.
- Contribution to promoting many innovations in plant subsystems: certain crystalline solar cell technologies (AS hybrid, HE and BSF), alkaline low-pressure electrolyzer, gas-fired heating boiler, catalytic heater, absorption refrigeration unit with catalytically heated desorber, operation of an alkaline pressure-type electrolyzer, air-oxidized

PEMFC in standard-model electric forklift truck, clean-break coupling systems and vehicle fuel tank system without cryovalves for refueling LH_2 test vehicles.

Energy scheme assessment, perspectives

- Multi-faceted advancement of (solar) hydrogen scenario as a result of work at Neunburg vorm Wald project.
- Long-term operation of plant oriented to commercial conditions and acquired knowledge base supported by verifiable data recorded in miscellaneous series of tests since 1990 demonstrate technical feasibility of energy scheme with (solar) hydrogen as energy medium.
- Introduction of energy scheme based on hydrogen as energy medium at earliest meaningful after extensive development of electric power generation from renewable resources.
- As of present time, hydrogen-based long-term energy storage medium not a pressing issue. Balanced energy mix may be expected to remain appropriate for some time to come. Prospects for hydrogen increasingly good long term.
- Use of hydrogen as energy medium contributes to environmental protection, provided production is in the main supported by renewable energy sources.
- Spread of technology beyond limited specialized applications unrealistic in foreseeable future.
- Possible exception under contemporary aspect is road transport in densely populated areas, i.e., use of motor vehicles fueled with environmentally friendly, readily storable hydrogen to reduce source emissions.
- At least indirect application of hydrogen attending possible change or switch in energy supply: Intensive efforts worldwide to initially make natural gas-fired cogeneration plants based on commercial phosphoric acid and molten carbonate fuel cells competitive with gas engines. Also extensive work on small-scale stationary application of natural gas in membrane and solid oxide fuel cell plants.
- Appropriateness/necessity of continuing technology-oriented industrial-scale demonstration and pilot projects for practical testing of prototypes and associated peripherals concurrent with basic research and development projects. Further support for commercial introduction by such uses of hydrogen as energy medium meaningful with increasing attention to economy in operational use.
- Subsidization of Neunburg vorm Wald project confirmed by Bavarian State Ministry of Economics as having laid foundation for entry into technology of hydrogen as energy medium. Findings gained from SWB project also basis for several subsequent schemes (including WIBA, Munich Airport Hydrogen Project, fuel cell drive in municipal vehicles, 1 MW photovoltaic plant at Munich exhibition center) .
- Further implementation of wide-ranging know-how acquired by SWB during 13 project years in design/construction of other (solar) hydrogen facilities. Successful reintegration of SWB staff at shareholder companies.
- Many technologies investigated at Neunburg vorm Wald meanwhile established fields of activity at SWB shareholder companies with varying focus.