The Generation of Pure Hydrogen for Industrial Applications

ON-SITE PRODUCTION USES SILVER-PALLADIUM MEMBRANES

The development of a robust mobile hydrogen generator for meteorological purposes has been described in a previous article in this Journal (1). Using the same basic technology, commercial generators have been built and are now used in a growing variety of industries.

These industrial generators are built on a modular principle, and each module can produce up to 10 cubic metres an hour of hydrogen at atmospheric pressure and ambient temperature. Thus to provide an output of 40 cubic metres an hour four modules are linked together by a common manifold. As each module is independent, one may be turned off, inspected, repaired or replaced without shutting down the remainder of the plant.

Industrial Uses of Hydrogen

Hydrogen is used in a wide variety of industrial applications as a protective atmosphere, as a fuel and as a cooling fluid. During the annealing of stainless steel components a pure hydrogen reducing atmosphere may be employed to prevent oxidation of the steel while avoiding any possibility of nitriding, which may occur if hydrogen nitrogen mixtures are used for this purpose.

The semiconductor manufacturing industry has a requirement for ultra-pure hydrogen which both prevents oxidation and serves as a carrier gas in the doping of silicon wafers, and diffusion units made by Johnson Matthey Metals Limited have been used for many years for purifying this gas. However, the quality of hydrogen produced by Johnson Matthey Metals modular generators, which is better than 99.9999 per cent with a dew point less than −70°C, is the same as from a diffusion unit, and one major semiconductor manufacturer is now making hydrogen with such a generator.

The inert gas argon is extracted from the air by a liquefaction process, and hydrogen is used during the removal of the oxygen content.

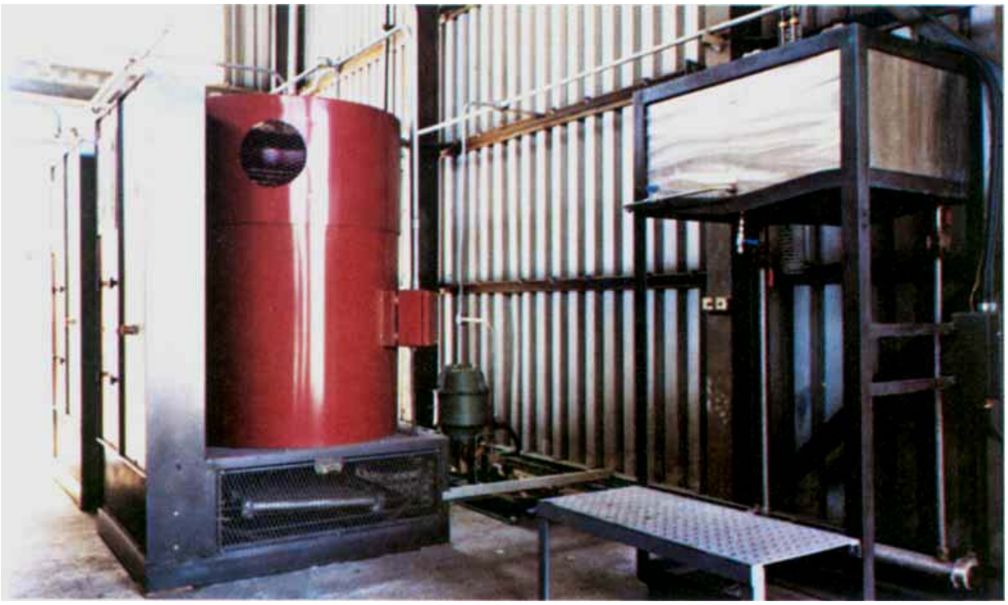
Benefits of On-Site Production

In general the consumers of hydrogen must either produce it on-site or buy it in cylinders, a popular standard size holding 7 cubic metres. For processes where very large amounts of the gas are required, such as for the manufacture of edible oils, both logistic and economic considerations favour on-site production and the electrolytic generators traditionally used for this purpose have outputs measured in hundreds of cubic metres an hour. However such generators are difficult to scale down to produce smaller amounts economically, and users requiring such amounts have had to rely on the delivery of hydrogen in cylinders.

Johnson Matthey Metals generators can now satisfy the user requiring outputs of between 10 and 100 cubic metres of pure hydrogen an hour, and this gas is produced generally for less than half the price of gas delivered in cylinders. An added advantage is, of course, the continuity of supply that is available to a manufacturer who maintains a store of methanol on-site. A 10,000 gallon tank holds 36 tonnes of methanol, sufficient fuel to make 56,000 cubic metres of hydrogen. When the contents of such a tank have been reduced to about 16 tonnes a road tanker would normally be expected to deliver another load of 20 tonnes, however the remaining 16 tonnes provides a considerable on-site reserve—being equivalent to 25,000 cubic metres of hydrogen, the capacity of 3,400 standard gas cylinders.

Principle of Operation

A fuel mixture of 64 per cent by weight of methanol and 36 per cent demineralised water has been found to give the greatest hydrogen



This Johnson Matthey Metals G20 hydrogen generator, consisting of two modular units and with an output of 20 cubic metres an hour, is in use at the Central Electricity Generating Board power station at West Thurrock, where the hydrogen is used for cooling the alternators. The generator and the diffusion unit of one module is contained within the red cylinder, on the left of which are the two separate control panels. The mixture feed tank, on the right, is automatically filled from the bulk storage tanks and the fuel mixture is fed by accurate metering pumps into the two modules

yield, the output from a module being controlled by the amount of mixed fuel piped into the system through an accurate metering pump. The fuel flows through a heat exchanger where it is preheated by waste gases before passing into the reaction chamber, which is controlled at a temperature of 350°C. After vaporisation, the methanol and steam mixture flows over a catalyst where hydrogen is produced in a two stage reaction:

Methanol cracking

$$CH_3OH \longrightarrow CO + 2H_2$$

Carbon monoxide shift

$$CO + H_2O \longrightarrow CO_2 + H_2$$

The complete reaction being

$$CH_3OH + H_2O \longrightarrow CO_2 + 3H_2$$

Vaporisation of the fuel, and the effective doubling of the gas volume as it passes over the catalyst, causes a pressure increase within the system, and this is controlled at 300 psig with appropriate valves. The diffusion of ultra-pure hydrogen through silver-palladium membranes has been reported previously in this Journal (1 and 2) and this phenomenon is utilised to separate the hydrogen from the carbon dioxide in the gas mixture that is produced. The hydrogen may then be used immediately, or stored in low pressure tanks at up to 200 psig, 13 bars, without the use of a compressor. The waste gases are discharged safely to the atmosphere, once the excess heat has been recovered.

Conclusion

The production of hydrogen from Johnson Matthey Metals Limited generators is now well established both in the European Economic Community and elsewhere. The robust construction and simple operation of the modular units have ensured their ready acceptance by operators and maintenance engineers throughout the world.

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References

1 J. E. Philpott, *Platinum Metals Rev.*, 1976, **20**, (4), 110

2 P. M. Roberts and D. A. Stiles, *Platinum Metals Rev.*, 1969, **13**, (4), 141, and references therein