The On-Site Production of Hydrogen

A MOBILE GENERATOR FOR METEOROLOGICAL AND INDUSTRIAL PURPOSES

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The established commercial techniques for producing pure hydrogen are not always practicable when relatively small quantities of the gas are required at remote locations. This paper describes the development of a robust mobile generator, required for meteorological purposes by the military, which can readily be adapted for commercial use and which can operate in extreme climatic conditions.

The production of ultra-pure hydrogen by the diffusion of hydrogen through palladium-silver alloys has already been described in this Journal (1, 2, 3, 4 and 5) and commercial diffusion units capable of handling hydrogen flows of more than 100 cubic metres per hour, are now available. The hydrogen feedstock for such application is generally obtained from high-pressure hydrogen cylinders, from cracked ammonia or, occasionally, from hydrogen-rich process gases produced on-site. For most industrial applications the choice of feedstock is determined by existing facilities. Generally hydrogen is available from high-pressure gas cylinders and can be piped directly to the diffusion unit via a pressure regulating valve. Where an ammonia cracker is already installed the output gas mixture of nitrogen and hydrogen can be fed to the diffusion unit after a compressor has raised the pressure to 20 bar (300 psig). Similarly, hydrogen-rich process gases can be piped to the diffusion unit at a pressure of 20 bar, provided that those components which might damage the diffusion membranes have been scrubbed out.

There are, however, some applications where the conventional sources of hydrogen are difficult to employ because of problems in transporting and storing the gas, for example at weather stations in remote areas. These difficulties can now be overcome by the use of the mobile hydrogen generator, developed for military applications, which is described here.

Military Meteorology

Among the factors influencing the accuracy of artillery fire are the local meteorological conditions, and if these can be measured the information allows precise calculation of projectile trajectories. Atmospheric weather conditions are monitored by radio-sonde devices carried aloft by weather balloons inflated with pure, dry hydrogen. The British Army has recently introduced a new Artillery Meteorological System which requires meteorological soundings to be made every hour instead of every four hours as was previously the case; and consequently the amount of hydrogen required has quadrupled. At present the hydrogen for filling meteorological balloons is obtained from high-pressure hydrogen cylinders carried on five-ton trailers which are towed by ten-ton vehicles. The supply of gas carried on each trailer will only last for between 50 to 70 hours of operation which is barely sufficient as the empty cylinders have to be exchanged and recharged at a base which may be more than a day's journey away. To avoid this hazardous journey and the considerable possibility of an

A hydrogen generator undergoing field trials with the British Army. The balloon which is about to lift the radiosonde equipment into the atmosphere, has just been inflated with pure, dry hydrogen produced on-site. As the generation of hydrogen proceeds the gas is used to fill the hydrogen storage cylinders in readiness for the next launch

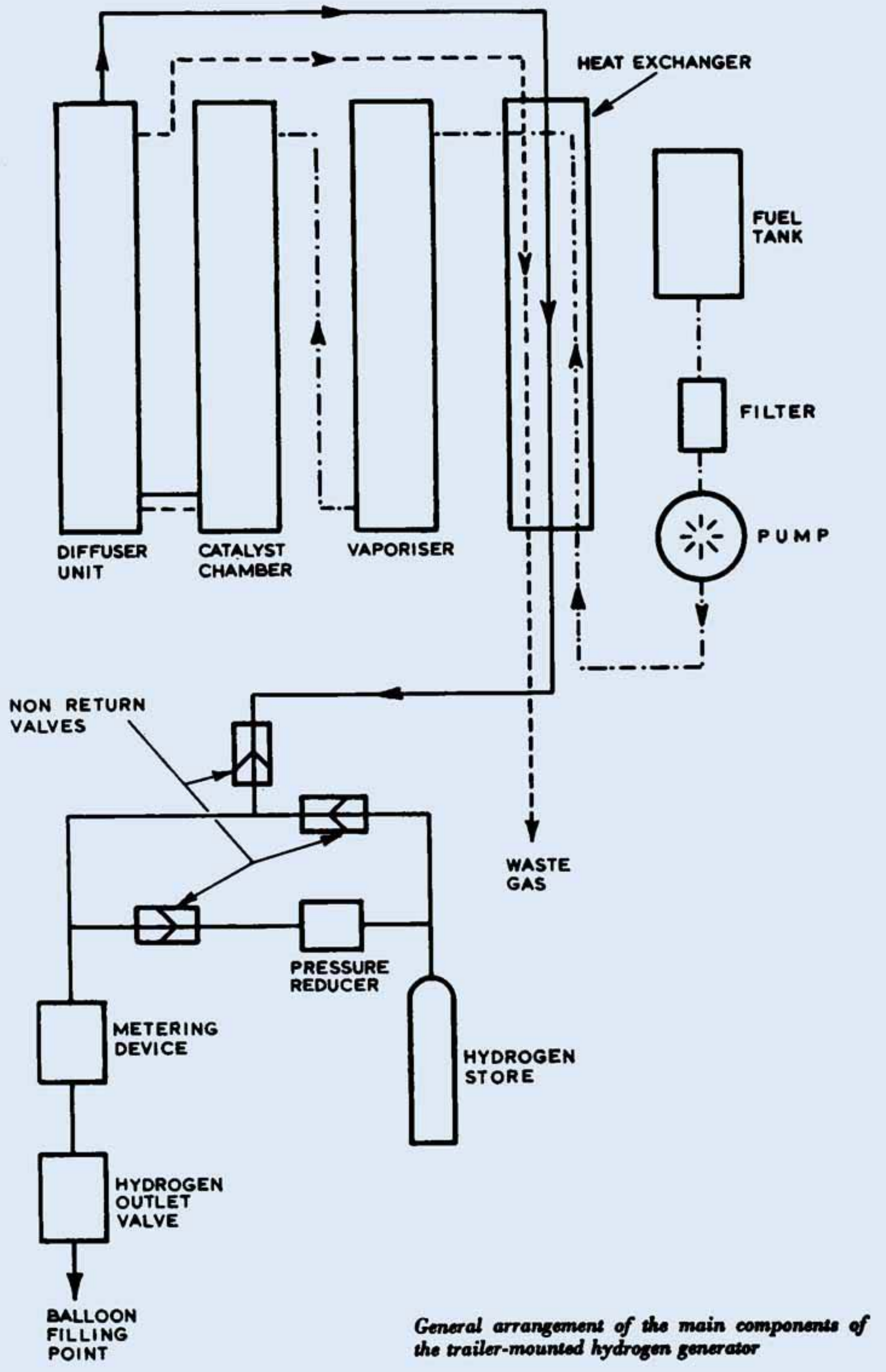
interruption in the availability of hydrogen, it was decided to generate the daily requirements in the field.

Hydrogen Production

Several possible methods of producing hydrogen in a mobile plant were considered including electrolysis, simple chemical reactions and cracking processes. The high electrical power requirements and the heavy equipment involved were disadvantages which ruled out the use of electrolytic processes. Simple chemical processes were discounted because they need bulky supplies of expensive and corrosive chemicals, considerable operator attention is required, and the gas produced is delivered hot, wet and at low pressure.

Of the several cracking processes that were possible the low-temperature steam-methanol reaction, coupled with the use of a diffusion membrane to separate pure hydrogen from the gas mixture produced, appeared to have the most advantages. Methanol/water mixtures are already present in military logistic systems while other possible chemical compounds such as ammonia, naphtha, hydrazine, etc., are not. In addition the methanol/water mixture is easily carried in light, thin-walled containers such as jerry cans whereas ammonia needs to be transported in heavy iron cylinders, and hydrazine, though transportable in steel drums, is a corrosive chemical with a toxic and explosive vapour. Economically the methanol/water feedstock is the cheapest of the possible starting materials and it is available internationally at an acceptable standard of purity. The use of naphtha as an alternative feedstock was considered but the possible variations in its chemical composition, and the high cost of the cracking catalyst, made it unacceptable.

The hydrogen generator being developed for the British Army is mounted on a standard one-ton general-service trailer and produces hydrogen at a rate of 4.2 cubic metres per hour (150 cu ft/h) at standard temperature and pressure. This output consumes fuel at a rate of just over a gallon per hour.



General arrangement of the main components of the trailer-mounted hydrogen generator

During production the fuel, a 1 : 1 molar methanol/water mixture, is pumped through a heat exchanger then into a vaporiser, as shown in the Figure opposite, before entering the catalyst chamber where the methanol is cracked into hydrogen and carbon monoxide. Subsequently steam reacts with the carbon monoxide to produce carbon dioxide and more hydrogen all of which passes into the diffusion module.

Diffusion Module

The module consists of a large number of small diameter thin walled tubes of palladium-silver alloy closely packed in a stainless steel case. The tubes provide a large surface area through which diffusion can take place. The high density packing provides mechanical strength and ensures that the hydrogen in the input gas has every opportunity to diffuse through the membrane, rather than being vented with the unwanted impure gases through a bleed valve to the atmosphere. Furthermore, the arrangement of the tubes is such that the formation of a layer of stagnant impure gas on the surface of the diffusion tubes, which would considerably retard diffusion, is prevented.

The hydrogen which diffuses through the palladium-silver membrane is a cool, pure, dry gas with maximum lifting power. This pure hydrogen can be fed either directly to a balloon filling nozzle or to hydrogen storage containers mounted on the trailer.

A metering device incorporated in the equipment automatically measures the amount of hydrogen necessary to life the balloon and its load to the required height, 20,000 metres, at a specified rate of six metres per second. In addition the device indicates both the volume and the rate of flow of the hydrogen.

Field Trials

The generator described has already successfully completed most of the extensive trials considered necessary before entering service with the British Army. These have established that the equipment can perform satisfactorily in arctic and tropical conditions, in driving rain and in dust storms. Furthermore it has been shown that towing the equipment over rough roads or through flooded open country does not significantly affect the output performance, in fact the generator is sufficiently rugged to withstand and operate in a military environment regardless of weather conditions. Compatibility trials have established that the function of the equipment will not affect, nor be affected by, the operation of other military equipment in the vicinity.

It is now expected that the generator will be in service with the British Army towards the end of this year. A considerable interest has been shown in this generator by six of the NATO countries and at the last meeting of the NATO Meteorological Panel it was agreed that the hydrogen generator would be accepted by NATO for standardisation.

Civilian Applications

The generator has been built on a modular principle and both larger and smaller models are being designed to cover a range of outputs of 1 to 17 cubic metres per hour (35 to 6,000 cu ft/h). Civil applications for small hydrogen generators exist in meteorological stations for weather soundings and also in industry for such purposes as semiconductor manufacture, the heat treatment of metals, in brazing, and for many laboratory applications. The robust construction of the military generator will enable it to form the basis of the design of commercial equipment capable of operating in the open, exposed to all weather conditions, as has now been shown by the performance of the first commercial hydrogen generator supplied which is now operating satisfactorily at Halley Bay Base, Antarctica.

References

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