HEAVY WATER AT ASWAN

Production of heavy water, which is used as moderator in certain types of nuclear reactors, is under way or being planned in several countries. One of the methods is to recover heavy hydrogen (deuterium) from industrial hydrogen and then to use the deuterium gas for the production of heavy water (D_2O). And an important source of industrial hydrogen is a nitrate fertilizer plant.

A fertilizer factory is being built by Egyptian Chemical Industries (Kima) at Aswan on the upper Nile; it will produce a mixture of ammonium nitrate and calcium carbonate adjusted to contain 20.5% nitrogen. It is also proposed to construct a heavy water plant to be located at and integrated with the fertilizer factory.

At the request of the Government of the United Arab Republic, the International Atomic Energy Agency sent Dr. Victor Thayer to carry out an expert investigation of the technical, economic and other related aspects of the proposed production of heavy water. As a member of the Atomic Energy Division of the Du Pont Company, Dr. Thayer has worked on methods of heavy water production and design and construction of heavy water plants.

Dr. Thayer has submitted a report to the IAEA Director General. His main conclusions can be summarized as follows: (1) Production of heavy water as a by-product of fertilizer manufacture at Aswan is technically feasible. Separation of deuterium from industrial hydrogen for this purpose could be done either by catalytic exchange or by liquefaction and distillation; the choice should depend on economic considerations. (2) The heavy water produced at Aswan should be competitive in cost with that produced elsewhere; this, however, would depend on whether firm contracts are obtained for the delivery of equipment at guaranteed prices and with guaranteed performance, and whether such prices are in reasonable agreement with preliminary estimates. (3) The future market for heavy water is difficult to predict. For one thing, there is a very large production capacity in the USA, most of which is idle due to lack of demand. Secondly, there is a relatively small production outside the USA that is sold at prices higher than that charged by the US Government. The future of the market is necessarily contingent upon the possibility of future free sale by the US Government.

At the end of his report, Dr. Thayer has also given his comments on possible further assistance to the project by IAEA. He notes that Egyptian Chemical Industries expect to contract for the heavy water plant on the basis of firm contract prices for the delivery of equipment and firm performance guarantees as to the quantity of hydrogen processed, the quantity of power used, and the quantity of heavy water produced by that equipment. He states that if, however, the suppliers who have made preliminary offers for such equipment should later find that they are not in a position to offer firm contracts at acceptable prices, the Egyptian Atomic Energy Authority and Egyptian Chemical Industries might wish to have assistance in re-evaluating the whole question of heavy water production in the UAR.

The following is a summary of Dr. Thayer's detailed observations on the project.

Technical feasibility

Recovery of deuterium from industrial hydrogen and particularly from electrolytic hydrogen (the method of production of hydrogen at Aswan) has been demonstrated to be feasible. Heavy water is now being produced by this method in Norway and Canada. Several processes for recovery are available, including catalytic exchange with water in the vapour phase, distillation of liquid hydrogen and catalytic exchange with water in liquid phase.

Economics of the Proposed Plant

Cost of heavy water (including capital charges) derived from electrolytic hydrogen should be in the range of $20 to $30 per pound, depending principally upon the capital cost of the plant and the rate of capital written off. Firm capital costs are not yet available, although preliminary estimates have been obtained. Operating costs, excluding capital charges, appear to be in the range of $7 to $13 per pound.

In view of the technical progress that has been made in recovering heavy water directly from natural water, there does not appear to be any inherent economic advantage in producing heavy water as a by-product of industrial hydrogen. Over the long term, direct production might very well turn out to be cheaper. For the present it can be said that costs for both the direct and by-product methods are in the same range.

Market Outlook

(1) Existing Capacity

The United States has an installed capacity of about 1 000 short tons (900 metric tons) per year, but due to lack of demand less than one half is in operation. The process used is H_2S - H_2O exchange for direct recovery of heavy water from natural water.

In Canada, the Trail plant produces about 8 short tons per year. Marginal (out-of-pocket) cost is probably less than the US price of $28 per pound, although the full cost, including capital charges, is probably

more than $28 per pound. Canada buys heavy water from the USA.

Heavy water was produced at Rjukan in Norway as far back as 1940. Current Norwegian production is reported to be of the order of 10 to 12 tons per year.

Farbwerke Hoechst of the Federal Republic of Germany reported at Geneva that they put into operation in June 1958 a plant for liquefaction and distillation of ammonia synthesis gas (mixed gas, 75% H_2, 25% N_2). The design capacity is 6 tons per year of heavy water.

The technology of distilling industrial hydrogen to produce heavy water was discussed by Soviet authors at the Second Geneva Conference. Although no definite information is available as to the amount of heavy water actually being produced in the Soviet Union, the reported development of heavy water-moderated reactors in the eastern European trading area leads to the inference that significant quantities are produced.

(2) Projected Capacity

India has a developed proposal for 14 t/year plant, at the Bhakra Nangal project on the Sutlej River, based on distillation of hydrogen produced at a fertilizer plant.

A team from OEEC (Organization for European Economic Co-operation) is making an extensive study of all processes to determine the desirability of building a plant in the area encompassed by the 14 nations participating in OEEC. Iceland has been mentioned as a possible location because of the availability of underground steam there.

Pintsch Bamag (Federal Republic of Germany) has published a process design for the H_2S - H_2O process: "Chemie-Ingenieur-Technik, 30, No. 5 (1958)" by Prof. G. Weirs. It is quite possible that Pintsch Bamag may soon be in a position to build a plant using this process. Costs in the Fed. Rep. of Germany should be lower than in the USA due principally to lower wage rates both in construction and operation. West German research on a liquid phase catalytic hydrogen-water exchange process was reported at Geneva by Prof. Becker (Paper No. 1 000).

L'Air Liquide (France) reported at Geneva about their pilot plant studies on hydrogen liquefaction and distillation. France is reported to be working intensively on this and other methods for producing heavy water.

In general, it may be said that technical interest in heavy water production is at a high level in many areas. In addition to the countries mentioned, others including Sweden, Switzerland and Japan are reported to be doing research on this subject.

(3) Prices

The US price of $28 per pound reflects operating cost (including full overhead) of about $14 and capital charges of about $10 based on about a 16 2/3 year write-off. The reported West German purchase offer of 800 DM/kg (about $87 per pound) is apparently a "free market" price that does not involve negotiating with a government. This price would very probably come down if the Fed. Rep. of Germany builds a large scale plant, for instance by the H_2S - H_2O process.

(4) Prospective Needs

Britain's large programme for the generation of nuclear power is based on natural uranium using graphite, and not heavy water, as moderator. Canada, however, has announced an experimental or "pilot" power reactor based on heavy water and natural uranium.

It is probably too early to say how the heavy water moderated power reactor will compare, in the long run, with other types. It should be noted, however, that Canada's emphasis on the heavy water-moderated reactor is based on the availability of heavy water at $28 per pound. If the price were $87 per pound, it is possible that the emphasis might be different.

In selling heavy water, the US A. E. C. imposes certain restrictions. In view of these restrictions and because of the current interest in reactors moderated by heavy water, there is a considerable "free market" sale of heavy water at a price that is much higher than $28 per pound charged by the US A. E. C. There is also intensive research on heavy water production. In the long-term future, however, the world price for heavy water is likely to be at or near that set by the US Government, which owns productive capacity adequate to support a large power expansion based on heavy water-moderated reactors.

Plans for the Aswan Project

The fertilizer plant at Aswan is scheduled for completion late in 1959. It will supply all raw materials and services needed for the heavy water plant. About two years would be required for construction of the heavy water plant after the placing of contracts.

Technical Personnel

Technical personnel for the fertilizer plant have been assembled and are located either at the site or in training with European firms supplying the equipment. This training programme appears adequate. Since the heavy water plant will be, in effect, part of the fertilizer plant, only a minor extension of the present personnel programme would be needed for the heavy water plant.