HEAVY WATER AT ASWAN

by Dr. Victor Thayer

In response to a request from the Government of the United Arab Republic, two experts were sent by IAEA, at the beginning of November, to Egypt, Mr. B.V. Nevsky (USSR) and Dr. Thayer (USA). Mr. Nevsky examined the possibilities and economics of extracting uranium from ores rich in phosphates, which are plentiful in Egypt. His report was not available when the Bulletin went to press.

Dr. Thayer has reported to the Director General on the possibilities and the economic interest of producing heavy water by the electrolytic method as a by-product of an ammonium nitrate fertilizer factory now being constructed at Aswan. Dr. Thayer is a member of the Atomic Energy Division of the Du Pont Company and is working as a heavy water expert at the American Atomic Energy Commission's Savannah River project. We publish below excerpts from Dr. Thayer's report.

SUMMARY

1. The proposed production of heavy water as a by-product of fertilizer (nitrate) manufacture at Aswan on the upper Nile is technically feasible.

The separation of heavy hydrogen (deuterium) for subsequent conversion to heavy water could be done either by catalytic exchange or by liquefaction and distillation. The choice of process should be made on an economic basis.

2. Provided that firm contracts are obtained for delivery of equipment at guaranteed prices and with guaranteed performance, and provided that such prices are in reasonable agreement with preliminary estimates, the heavy water produced at Aswan should be competitive in cost with that produced elsewhere.

3. The future market for heavy water is difficult to predict. It is important to note first, that there is a very large production capacity in the USA, most of which is idle due to lack of demand, and second, that there is a relatively small production outside of the USA that is sold at prices higher than that at which the U.S. Government sells heavy water. The future of the market is necessarily contingent upon the possibility of future free sale by the U.S. Government.

4. Comments as to further IAEA participation in the project are given in section (j) of this report.

(a) GENERAL DESCRIPTION, EXTENT AND PURPOSE OF PROJECT

The purpose of the project is to recover deuterium gas (heavy hydrogen) from industrial hydrogen. The deuterium gas will then be converted to heavy water. The industrial hydrogen to be thus used as raw material will be available at the fertilizer plant now being built by Egyptian Chemical Industries (Kima) at Aswan. In effect, the proposed heavy water production would be a by-product of the fertilizer plant. Construction of the fertilizer plant is well advanced and start-up is scheduled for early in 1960.

As a matter of interest, it may be noted that the fertilizer to be produced at Aswan is a mixture of ammonium nitrate and calcium carbonate adjusted to contain 20.5% nitrogen. It may be noted also that power for the fertilizer plant is to be supplied by a hydroelectric plant now under construction at the present Aswan dam. Construction of this power plant is well advanced and completion is scheduled for late in 1959.

(b) THE SCIENTIFIC AND TECHNICAL FEASIBILITY OF THE PROJECT

Recovery of deuterium from industrial hydrogen and particularly from electrolytic hydrogen (the type to be produced at Aswan) has been demonstrated to be feasible. Heavy water is now being produced from such hydrogen in Norway (Rjukan) and Canada (Trail). Several processes for recovery are available including catalytic exchange with water in the vapour phase (Trail process), distillation of liquid hydrogen (plant recently started by Farbwerke Hoechst), catalytic exchange with water in liquid phase (pilot plant being operated in West Germany by Prof. Becker with the support of Uhde, a subsidiary of Farbwerke Hoechst). Catalytic exchange between ammonia and hydrogen has also been suggested, but experimental data in support of this process is not adequate to justify including it in the list of available processes.

(c) ECONOMICS OF THE PROPOSED PLANT, INCLUDING COST ESTIMATE FOR THE HEAVY WATER PRODUCED

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.

It is important to note here that, 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. Pintsch Bamag (Fed. Rep. of Germany) are known to be working on the direct $H_2S - H_2O$ process.

Although the Savannah River technology on this process is for the time being not available as public information, the future publication of this information must be considered a possibility.

(d) THE OUTLOOK OF THE HEAVY WATER MARKET AND THE POSSIBILITIES OF EXPORT TO THE EXTENT INFORMATION IS AVAILABLE

Pertinent comments on the heavy water market are summarized in the following paragraphs:

1. Existing Capacity

U.S.A. Installed capacity is about 1000 short tons (900 metric tons) per year. Less than one half is operating due to lack of demand. Process used is H_2S - H_2O exchange for direct recovery of heavy water from natural water.

Canada. Trail plant makes about 8 short tons per year. Marginal (out-of-pocket) cost is probably less than U.S. 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 U.S.A.

Norway. 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.

Fed. Rep. of Germany. Farbwerke Hoechst reported at Geneva that they put into operation in June 1958 a plant for liquefaction of distillation of ammonia synthesis gas (mixed gas, 75% H_2, 25% N_2). Design capacity 6 tons per year of heavy water. If this plant is successful, Farbwerke Hoechst would presumably build a larger plant.

Soviet Union. The technology of distilling industrial hydrogen to produce heavy water was discussed by Russian 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 of heavy water are produced there.

2. Projected Capacity

India has a developed proposal for 14 T/year plant, at the Bhakra Nangle project on the Sutlej River, based on distillation of hydrogen produced at a fertilizer plant. As far as is known, contracts have not yet been placed.

A study team from OEEC (Organization for European Economic Cooperation) 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 geothermal (underground) steam in Iceland.

Pintsch Bamag (Fed. Rep. 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 U.S.A. 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. 1000).

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 U.S. 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 for Heavy Water for Use in Reactors

Britain's large power program is based on natural uranium and graphite. They are pushing this hard and presumably can get along without heavy water.

Canada has announced an experimental or "pilot" power reactor based on heavy water and natural uranium. Canada's requirements for heavy water, beyond that produced at Trail, are obtained from the U.S.A.

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.

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