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ATOMIC ENERGY OF CANADA LIMITED

L'ÉNERGIE ATOMIQUE DU CANADA LIMITÉE

THE CANADIAN HEAVY WATER SUPPLY PROGRAM

by

A. DAHLINGER and P.J. McNALLY

Paper presented at the Session on Heavy-Water Reactors,
Canadian Nuclear Association 16th Annual Meeting,
Toronto, Ontario, 13-16 June 1976

Heavy Water Projects
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Programme canadien d'approvisionnement en eau lourde*

par

A. Dahlinger et P.J. McNally

*Rapport présenté à la Session des réacteurs à eau lourde de l'Association nucléaire canadienne au 16ème Congrès annuel tenu à Toronto, Ontario du 13 au 16 juin 1976.

Résumé

Le but de ce rapport est de passer en revue l'expérience canadienne en ce qui concerne la production de l'eau lourde jusqu'au projet actuel de fourniture à long terme et de mettre en corrélation ce projet et la demande d'électricité prévue à long terme.

On y décrit en détails la performance actuelle des usines d'eau lourde canadiennes ainsi que les projets de construction d'autres usines.

Ces données, mises en corrélation avec la demande à long terme en électricité indiquent que les approvisionnements en eau lourde et cette demande sont raisonnablement équilibrées et que le programme CANDU ne sera pas entravé par suite d'une pénurie d'eau lourde.

L'Energie Atomique du Canada, Limitée
Groupe de l'eau lourde
Ottawa, Canada

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ABSTRACT

The purpose of the paper is to present a review of the Canadian experience in the production of heavy water, to present a long-term supply projection, and to relate this projection to the anticipated long-term electrical energy demand.

To accomplish this the performance to date of individual Canadian heavy water plants is described in detail as are the current plant construction plans.

These data, when related to the long-term electricity demand indicate that heavy water supply and demand are in reasonable balance and that the CANDU program will not be inhibited because of shortages of the commodity.

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INTRODUCTION

The following paper explains the current level of development of the Canadian heavy water industry as well as the roles and contributions of the two current producers. In addition, it sets out the forecasts of how heavy water supply and demand will develop between to-day and the year 2000.

The forecasts developed herein are designed to portray an overall picture of the industry and are not intended for use in actual planning exercises.

Heavy water is a vital component of the CANDU* and SGHWR* reactor systems. The success of these systems is dependent on our success in producing heavy water when required, and at an acceptable cost. We will indicate to-day that we have confidence that we will meet these criteria.

In outline, we will briefly describe the existing structure of the Canadian heavy water supply program. We will then consider our Supply projections and Demand projections, after which we will combine the two to present a picture of our overall future situation. We will then consider the Price of heavy water in relation to overall station costs. Finally, we will bring the Conference up to date on our past year's operating experience.

Before getting into the review, it might be well to briefly define the terms employed.

Heavy Water - a liquid having an isotopic content of D_2O of greater than 99.750 mass %.

Design Capacity - The Heavy Water output from a plant as designed if all systems work perfectly 100% of the time over a seven-day period. The unit is kilograms per hour (kg/h).

Production - refers to the quantity of Heavy Water actually (or estimated to be) produced. The unit of measurement is the megagram (Mg), or metric tonne.

Production Level - is the percent of Design Capacity that was actually produced or that is planned to be produced in a specified time interval (usually measured over a year). Therefore, Production Level multiplied by time at Design Capacity is the Production during the time period.

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*CANDU - Canada Deuterium Uranium
SGHWR - Steam Generating Heavy Water Reactor

Supply/Demand - have the normal connotations, Supply being the number of Mg available, and Demand the number of Mg required to service the reactor industry. We express both of these in cumulative (i.e. total to date) terms.

The Canadian heavy water supply program involves -

- Ontario Hydro which is responsible for the construction and operation of heavy water plants with a capacity sufficient to satisfy the demands of all CANDU reactors employed and forecasted for the Ontario energy generation program, and,

- Atomic Energy of Canada Limited (AECL) which is responsible for the purchase and the construction and operation of heavy water plants with a capacity sufficient to satisfy the demands of CANDUs which will be employed in the energy programs of all other Canadian provinces as well as foreign countries.

Currently Ontario Hydro owns and operates the Bruce Heavy Water Plant A (BHWP A) and is constructing the BHWP B and D plants. All three plants are located on Lake Huron on the same site as the 206 MWe* Douglas Point Nuclear Generating Station and the 2984 MWe Bruce Nuclear Generating Station.

Atomic Energy of Canada Limited owns and operates the former Canadian General Electric Heavy Water Plant at Port Hawkesbury, Nova Scotia (PHHWP), is in the process of commissioning a plant at Glace Bay, Nova Scotia (GBHWP) and is constructing the La Prade Heavy Water Plant (LHWP) at Gentilly, Quebec.

Until the end of 1977, Ontario Hydro and AECL are allocating the total supply of heavy water according to the terms of their existing Pooling Agreement. From 1978 each party will have as its own primary responsibility the services mentioned above. We expect continued close cooperation on heavy water supply in this period.

1. SUPPLY

Significant changes have occurred in the Canadian heavy water industry's planning for future supply since last June. Ontario Hydro announced during February of 1976 that the Bruce Heavy Water Plant C was cancelled and that there will be a two-year delay in the construction and commissioning of Bruce Heavy Water Plant D. Both of these changes resulted from a reduced rate of installation of nuclear generating stations.

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*e = electrical

As a result of a cutback in the annual funding available for the construction and commissioning of the La Prade Heavy Water Plant, AECL was forced to extend its schedule by three years.

The overall affect of these cutbacks and extensions is illustrated in Table 1. Total planned Canadian capacity has been reduced by 96.6 kg/h, and, in addition, as the bottom part of the Table illustrates, there has been a significant stretching out of the capacity build-up.

TABLE 1

Canadian Heavy Water Plant Capacities

	Previous Forecast		Current Forecast	
	Design Capacity (kg/h)	Start Date	Design Capacity (kg/h)	Start Date
PHHWP - AECL	48.3	In-Service	48.3	In-Service
BHWP A - O.H.*	96.6	In-Service	96.6	In-Service
GBHWP - AECL	54.4	1975	54.4	1976
BHWP B - O.H.	96.6	1978	96.6	1978
LHWP - AECL	94.6	1979	94.6	1982
BHWP D - O.H.	96.6	1979	96.6	1981
BHWP C - O.H.	96.6	1980	Cancelled	

Canadian Heavy Water Design Capacity (kg/h)

	1976	1977	1978	1979	1980	1981	1982
Previous Forecast	199.3	199.3	295.9	487.1	583.7	583.7	583.7
Current Forecast	199.3	199.3	295.9	295.9	295.9	392.5	487.1

*Ontario Hydro

The effect of these changes on the forecasted heavy water supply over the next twenty years is illustrated in Figures 1, 2 and 3 which compare the probable cumulative supply as presented in last year's Canadian Nuclear Association Conference to that currently being projected.

The figures illustrate the changes in both the Ontario Hydro and AECL programs plus the combination of each in the total Canadian program. In all cases a Production Level of 70% has been employed in forecasting the probable supply. The term "probable" means there is a 50% chance that this supply will be exceeded. It must be emphasized that a 70% Production Level is not used for supply planning. Since alternative supplies of heavy water to Canada are very limited, supply planning must tend toward conservatism.

2. DEMAND

During the past twelve months there has been a significant increase in the total effort devoted to improving the forecasts of the future Demand for heavy water. To date, that effort has involved the two heavy water producers and several federal government Departments (Energy, Mines and Resources; Industry, Trade and Commerce; Finance; Treasury Board). The forecasts will be significantly improved with more input from other provincial utilities.

Whereas last June we were forecasting for a ten-year period (to 1985), we have now extended these forecasts to the year 2000. The domestic demand is based on the projected nuclear electric generation demand as developed by the Department of Energy, Mines and Resources and is illustrated in Figure 4 broken into 3 categories: Ontario, Quebec and all other provinces.

It should be noted that these data do not represent the total electricity demand, but only that portion which is forecast to be met by nuclear electric generation. In 1990, for instance, the total demand is something more than five times the nuclear portion.

As was pointed out in the Introduction, AECL carries the responsibility for the development of an off-shore CANDU market. The forecast of heavy water demand generated by this market has been developed by AECL based on potentials and probabilities, and the Department of Industry, Trade and Commerce's estimates of Canada's industrial capability to supply reactor components. Currently AECL has two committed off-shore systems underway which are scheduled for completion in the next five years, is forecasting three to four further CANDU generating systems prior to 1986/87, and projects an off-shore market averaging one reactor per year thereafter.

The above nuclear electric generation demand has been translated into a demand for heavy water using reactor dependent factors which average about 0.85 Mg/MWe. To complete the demand forecast an annual

allowance of approximately 1% of the initial reactor load has been built in along with additional amounts representing an "operating reserve" for contingencies.

The resultant forecast is illustrated in Figure 5, which identifies both the values associated with the total program and the components of the program.

3. SUPPLY VERSUS DEMAND

Figures 6, 7, 8 compare the Supply and Demand forecasts that have been developed. In the late 1960's Canada was faced with a serious heavy water shortage. We were forced to play "catch-up" and install plants quickly. A temporary excess supply in the early 1980's, diminishing gradually to a period of undersupply in the early 1990's is the result.

Two points should be noted from these figures (6, 7, 8); first that the heavy water supply is not a limiting factor in the decision to opt for a CANDU nuclear electric generating system in the near future; and second, that the cross-over point of Supply and Demand is far enough out in the future to provide the time to react to longer-term heavy water demands.

Our planning studies indicate that an operating reserve of heavy water is a vital necessity at all times -

(a) to deal with acute situations in operating reactors, caused by major leaks or major downgrading, which result in the loss or loss of use of significant quantities of heavy water.

(b) to deal with acute situations in operating heavy water plants which could result in these plants being out of service for extended periods of time. A reserve is required unless reactor schedules are to be delayed.

A total allowance of 800 Mg (both parties) has been allotted in the cumulative demand curves for these purposes, i.e. the assurance that reactors may be filled and started up on time, and that they may continue to operate after acute events affecting their heavy water inventory.

The Demand curves given in the Figures represent smoothed average data over the Projection horizon, while it is known that actual Demands will in fact occur as large amounts of heavy water to be delivered in a relatively short time span. Supply planning must accommodate this stepping "fine structure" of Demand. In the smoothed data used for illustration, this accommodation is achieved by having an excess of Supply over Demand beyond the operating reserve allowed for in the Demand curves.

Finally, an inventory is unavoidable at certain specific times because of the difficulties of matching Supply and Demand.

(a) In the late 1960's Canada was faced with a serious heavy water shortage. As previously stated we were forced to 'play catch-up" and install plants quickly. A temporary excess supply of water in the 1980's is the result.

(b) The nature of the plants themselves introduces a problem. Each plant since the commitment of GBHWP and PHWP produces approximately 600 Mg per annum and therefore the introduction of one plant has a significant impact on the total supply situation. The lead time from decision to build the plant to its In-Service date is seven to eight years, and thus, it is difficult to accurately match supply to forecasted demand. Although the construction period may be extended if the demand forecast weakens and if the resultant price can be justified, once a plant is commissioned it is extremely difficult to mothball it - to temporarily take it out of service.

(c) We must also consider the comparative youth of the total nuclear industry. Being a young industry, and especially, being a young industry with a characteristically long lead time, it is extremely difficult to forecast the number of nuclear steam supply systems which will exist ten years hence, and which must be planned for now.

The fundamental issue concerning an inventory of heavy water, however, concerns the raison d'être of the heavy water industry and, indeed, of the nuclear industry as a whole.

The provision of an adequate electrical energy supply is considered to be of paramount importance, and since the supply of heavy water is critical to a part of this provision, the build-up of a heavy water inventory during this period of youthful uncertainty is the only way to ensure that some flexibility exists in the nuclear part of electrical energy planning. In the unlikely event that in, say, 1986 we should find that the supply and demand curves presented here were absolutely correct, we have still experienced an overall gain in that the inventory inevitably postpones the need to commit new productive capacity.

4. PRICES

In this paper we will consider the topic of Price in the context of the nuclear electric generating system.

Both major producers of heavy water, i.e. the Nuclear Generation Division in Ontario Hydro and Heavy Water Projects AECL, must recover as

revenue all costs associated with the production of heavy water. These costs include operating and maintenance expenditures, the cost of energy consumed in production, and the payback of capital investment in the plants, plus the additional and necessary expenditures for administration and on-going development work on the production process. The escalation rates we experience in these costs are the same as everyone experiences. Since the total cost of heavy water contains a significant factor related to capital payback, it therefore seems reasonable that, for in-service plants, the overall escalation in the unit cost of heavy water will be less than the overall escalation rate. During a period in which a new plant is being brought into production the escalation rate in heavy water costs will increase to reflect the new plant construction costs, but when the plant is in a mature operating state the escalation rate should again fall off.

The payback of capital investment has been cited above as a significant factor in the price of heavy water. Putting this in the context of the nuclear industry we find that the capital investment in heavy water plants represents only 5% of the nuclear plant investment it will service.

Relating the cost of heavy water to the cost of a CANDU generating station, current estimates indicate that the cost of heavy water has remained in the area of its historical proportion of total station costs, i.e. at about 15-20% of the total investment. As has been suggested we are anticipating no significant changes in this ratio.

5. REVIEW OF YEAR'S PERFORMANCE

1975 was a year of mixed achievements in the Canadian heavy water industry. Individually, the experience with the three heavy water plants in existence was as follows:

(a) Bruce Heavy Water Plant A

Experience through the year has been better than expected. In early 1975, capacity was about 5% under the design 96.6 kg/h. Capacity has been increased to three to five percent greater than design through increased knowledge of how to operate and the results of the AECL and Ontario Hydro development program directed to plant operation.

The Production Level in 1975 was 71.5%, which is above the probable Production Level for this type and age of plant. Plant performance is largely determined by operation of the hydrogen sulphide containing enrichers which extract heavy water from the feed. The major extraction losses were:

(i) Planned outages whose critical path was tray cleaning and line thinning.

(ii) Tray fouling.

(iii) Various forced outages of which the effluent line fracture was the largest.

Production of Heavy Water for the calendar year amounted to 605 Mg. Of this, 31.3 Mg was produced as 20% product and upgraded elsewhere.

(b) Port Hawkesbury Heavy Water Plant

On May 16, 1975 the plant was purchased by AECL from Canadian General Electric Company. Most plant operation personnel joined AECL, ensuring continuity of staffing.

The Production Level in 1975 was 41.3%. The major production losses were:

(i) Planned outage for major overhaul commencing May 16. Unplanned maintenance requirements extended the outage to August 1, 1975.

(ii) An incident involving the rupture of a tank caused by overpressure following a loss of steam resulted in an outage from September 21, 1975 to November 16, 1975.

(iii) 1st stage problems in a blower and piping kept one of the three first-stage towers out of service for about four months.

Production of Heavy Water for the year amounted to 175 Mg.

(c) Glace Bay Heavy Water Plant

Major construction was substantially completed in 1975 and most systems of one of the two enrichers (the North Enricher) and the finisher were completed. The North Enricher was charged with H_2S and in March 1976 produced intermediate product. The enricher operating parameters are being adjusted to optimize in steps toward the design conditions. As at mid-May the North Enricher was extracting heavy water at 50% Design Capacity.

The finisher has been processing Ontario Hydro 20% product to Heavy Water since the end of 1975.

SUMMARY

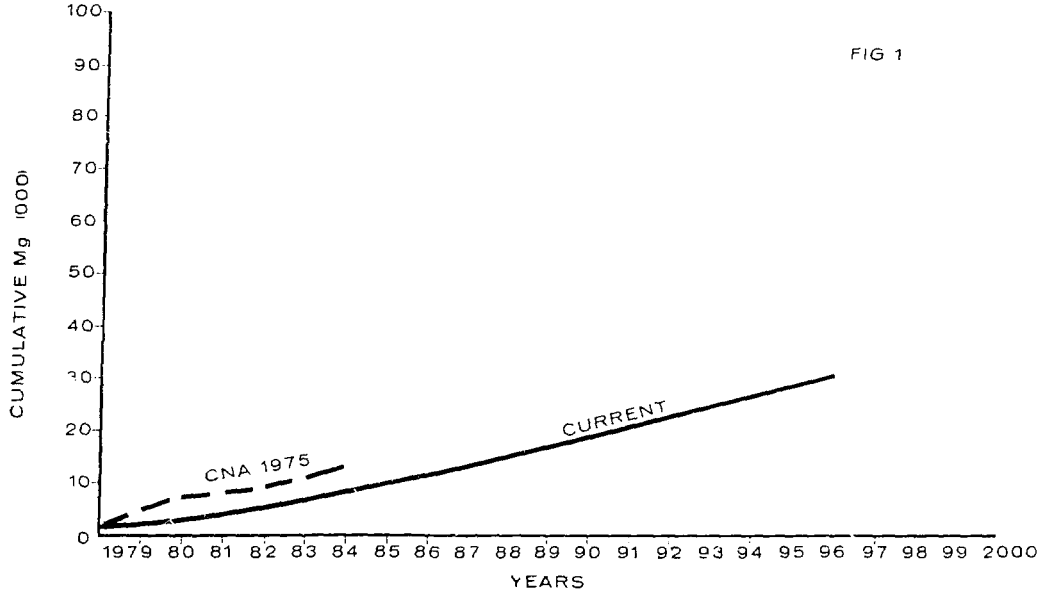
The aim of this paper was to bring the Association up to date on the current situation in the Canadian heavy water program and to present our projections of what the future looks like.

During the past year there have been some major changes in the supply program, but, even with these changes, we are looking towards a future where Heavy Water will be available in the required quantities and on the required schedule. Further, even with an increase in demand, sufficient lead time is available to bring on new production capacity to match it.

The price of Heavy Water is seen as rising steadily in the future for as long as all other prices are seen as rising, but, at an overall rate somewhat below that generally experienced. In any event, we anticipate the cost of Heavy Water to hold at a relatively constant proportion of total CANDU station costs.

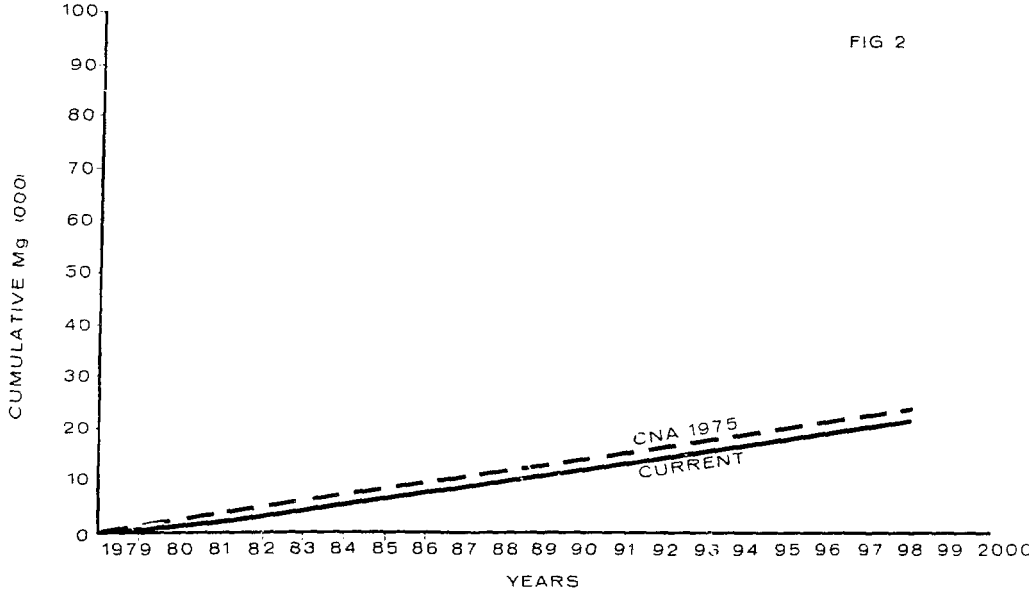
ONTARIO HYDRO HEAVY WATER SUPPLY FORECAST (70% PRODUCTION LEVEL)

FIG 1

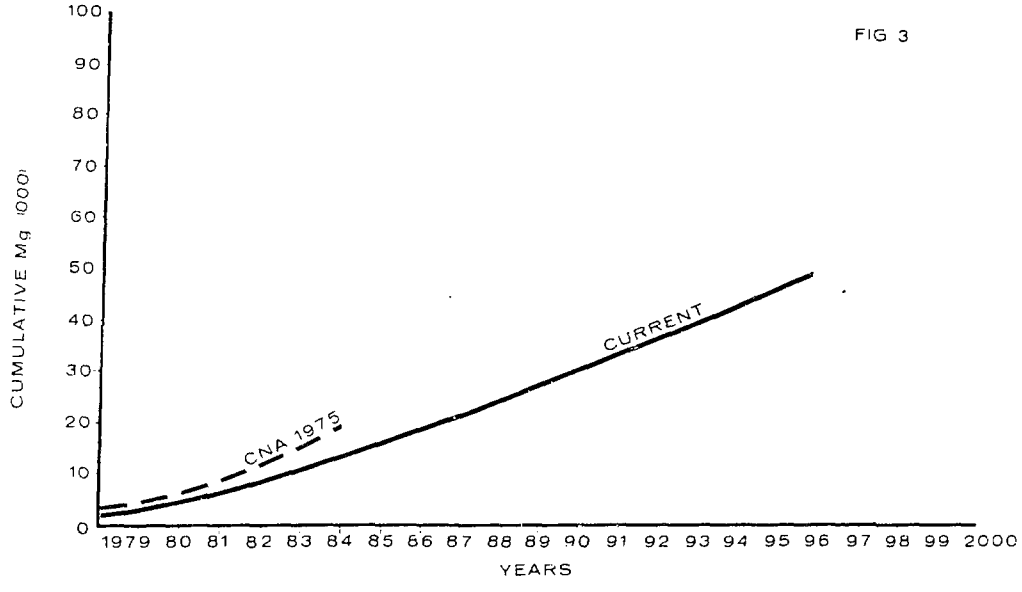


AECL HEAVY WATER SUPPLY FORECAST (70% PRODUCTION LEVEL)

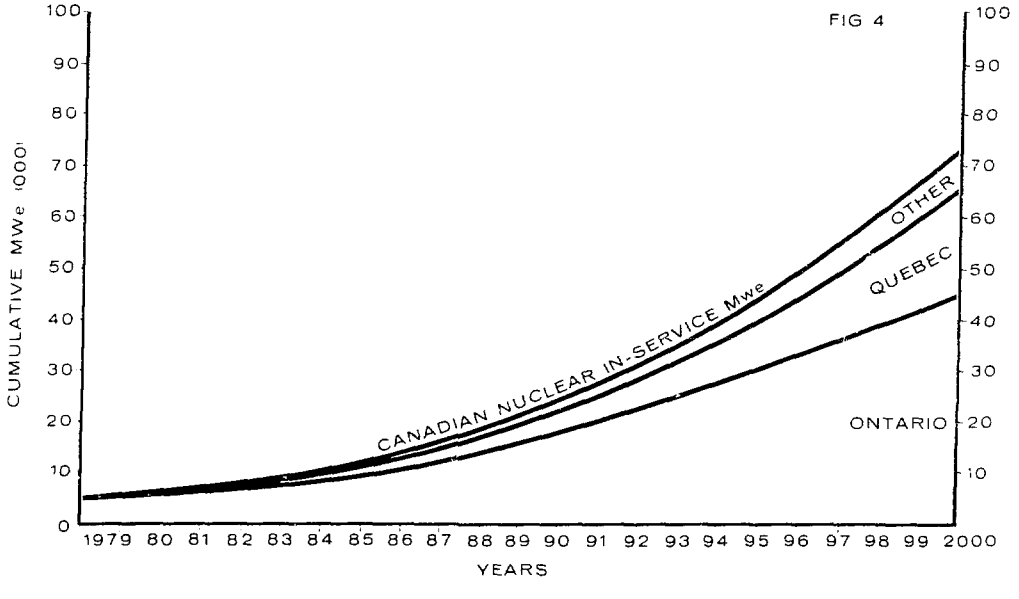
FIG 2



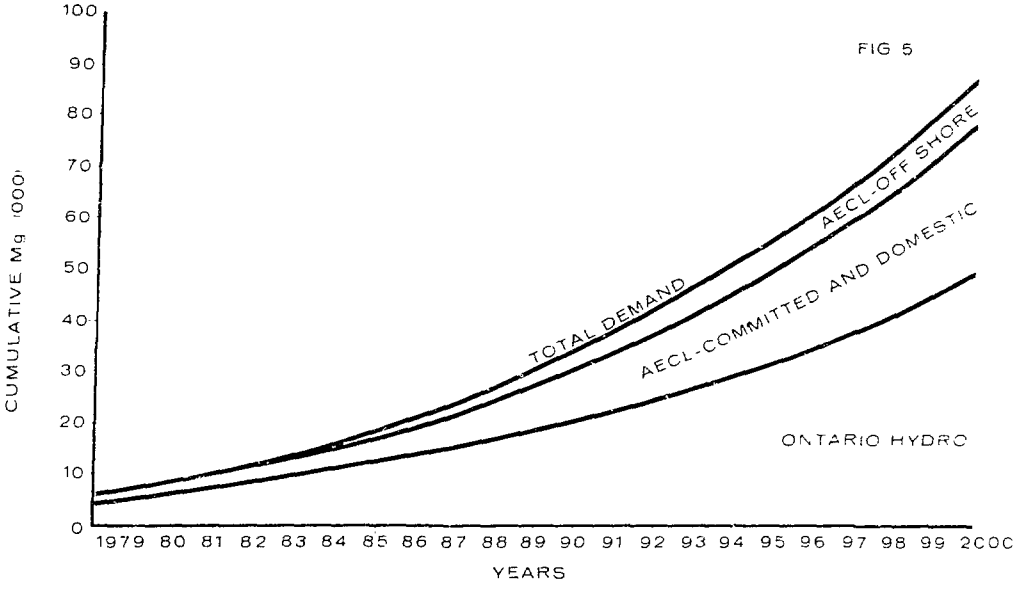
CANADIAN HEAVY WATER SUPPLY FORECAST



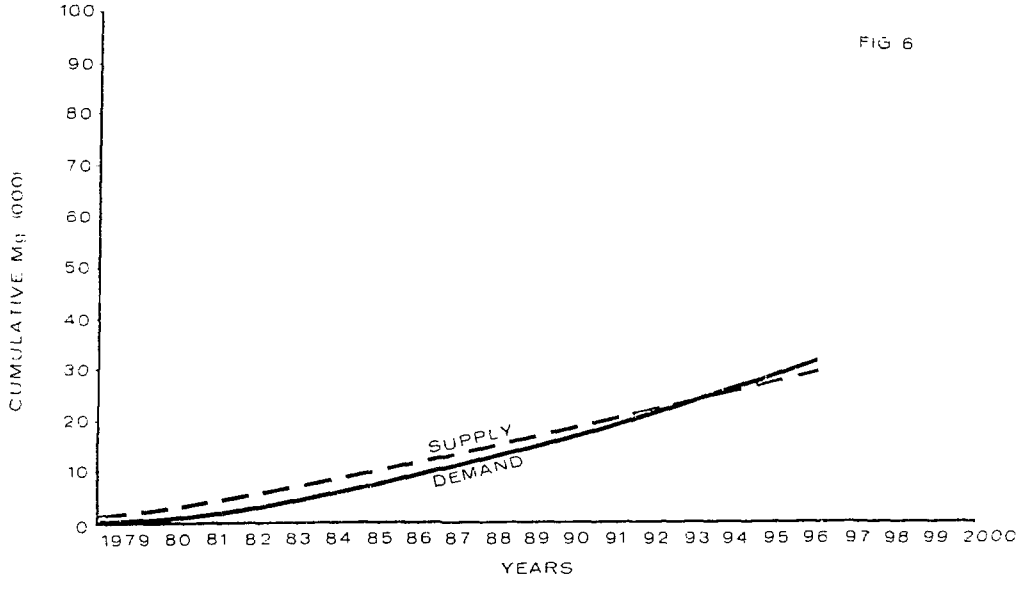
DOMESTIC NUCLEAR POWER



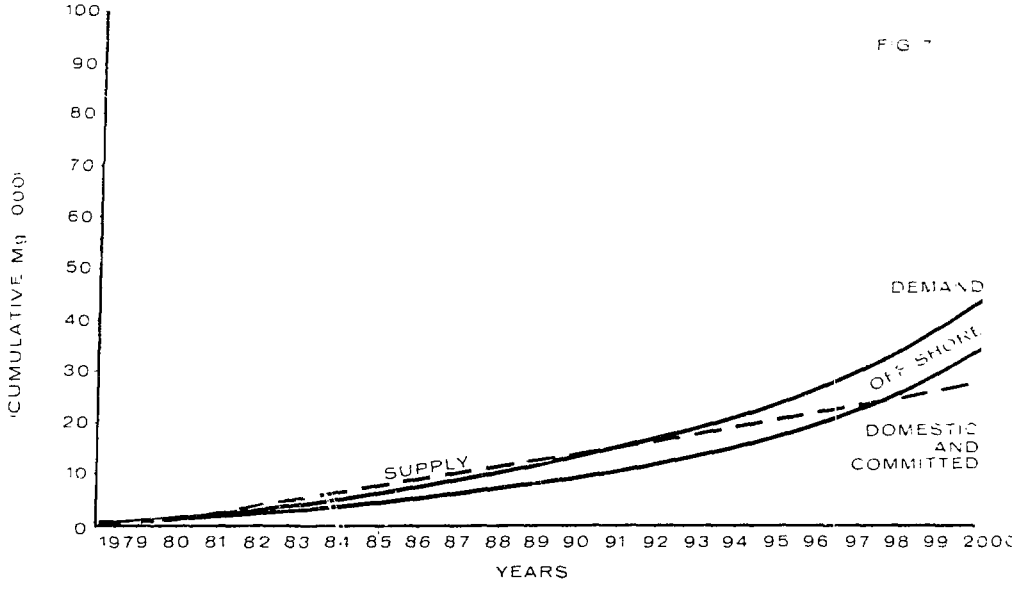
DEMAND FORECAST FOR HEAVY WATER (FROM DOMESTIC NUCLEAR POWER FORECAST)



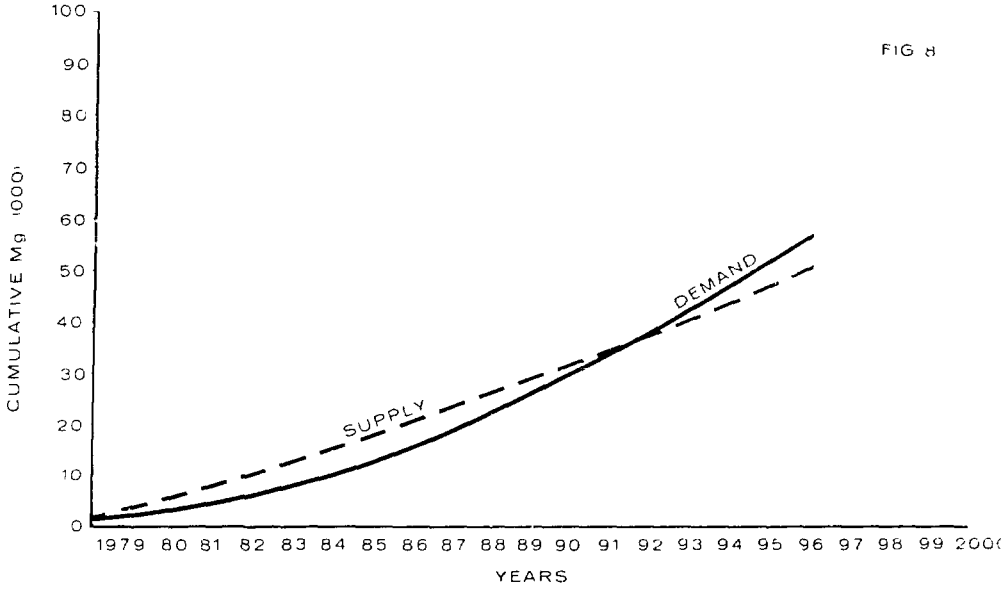
ONTARIO HYDRO SUPPLY/DEMAND FORECAST (1978 ON)



AECL SUPPLY/DEMAND FORECAST (1978 ON)



TOTAL CANADIAN SUPPLY/DEMAND FOR HEAVY WATER (1978 ON)



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