Canadian Nuclear Industry Study

Prepared by the Department of Industry, Trade and Commerce in association with Atomic Energy of Canada Limited and the Department of Energy, Mines and Resources.

March 1975

Industry, Trade and Commerce
Industrie et Commerce

CANADIAN NUCLEAR INDUSTRY STUDY

An analysis of Canadian manufacturing & engineering industry capability to meet projected requirements of the CANDU program for the domestic and export markets to 1983.

Prepared by the Department of Industry, Trade & Commerce in association with Atomic Energy of Canada Limited and the Department of Energy, Mines and Resources.

March 1975.

NOTE:

NO ATTEMPT HAS BEEN MADE IN THIS STUDY TO FORECAST THE RATE OF PRICE ESCALATION IN RESPECT OF GOODS AND SERVICES INVOLVED IN THE CONSTRUCTION OF NUCLEAR POWER PLANTS. DOLLAR AMOUNTS USED THROUGHOUT THE STUDY ARE IN TERMS OF 1974 DOLLARS.

TABLE OF CONTENTS

I. EXECUTIVE SUMMARY

1. The projected domestic program for CANDU power stations during the period 1974 to 1983 involves the construction of 43 nuclear reactors. Six reactors are presently under construction in Canada, and construction is expected to start at an average of four units per year from 1975 to 1983, reaching a peak of six units in 1983.

2. This program could result in $5 billion of new business for Canadian industry, of which - $2 billion for nuclear equipment; $2 billion for related conventional power equipment; and $1 billion for engineering services.

Forecasted export sales could represent an additional $1 billion for Canadian equipment and services.

3. The principal firms involved in the production of nuclear equipment constitute a wide ranging group, from large heavy engineering equipment manufacturers to small precision machining firms. For these firms, the production of nuclear plant equipment must compete for space and facilities with the manufacture of conventional products.

To date, the principal suppliers of nuclear products have produced over $500 million worth of components for the nuclear program, of which about 60% has consisted of equipment for the Nuclear Steam Supply System (NSSS) portion of nuclear power stations. It is estimated that the industry has achieved an average level of 75% Canadian content on this production.

The major items for the nuclear system which have not been available from Canadian production have been special alloy tubing and sheet, stainless steel or carbon steel plates, large forgings, components for fuelling machines and special instrumentation and controls.

4. The Canadian manufacturing and engineering industry has the technical know-how to cope with the unique requirements of the CANDU program in terms of quality, reliability and ability to meet exacting dimensional and material standards. These unique requirements apply mainly to the NSSS portion of nuclear power plants.

.../2

5. At present, Canadian industry has the overall capacity to supply NSSS components for two to three nuclear reactors per year. To meet the requirements of the projected nuclear program, capacity will need to be expanded to six reactors per year.

6. Capacity to supply equipment for the conventional power generation system (PGS), from both domestic sources and offshore, is considered adequate to meet the needs of the nuclear program. However, the level of Canadian content for turbo-generator sets is low - ranging from 20% to 50%. To attain a significantly higher content would require expansion in plant capacity.

7. Large capital expanditures will be required over the next four years in order to expand plant capacity to meet the total equipment requirements of the nuclear power program (both NSSS & PGS). Nearly $100 million of capital investment is either already committed or projected by several of the major manufacturers. Additional investments, however, will likely be needed to meet the requirements of the nuclear power program. Decisions by the industry to undertake such additional capital expenditures will be influenced by such factors as import competition and the high capital costs, often not recoverable on conventional products, involved in meeting nuclear quality control standards and in increasing capability and/or capacity for nuclear production. In the final analysis, the basis for increased involvement in the nuclear area will be the individual firm's expectations as to the amount of future business it is likely to obtain in order to realize a reasonable return on investments.

8. Projected CANDU exports will not have an appreciable impact on Canadian industry's ability to meet domestic requirements. In most cases, while the export of CANDU to a particular country could result in <u>initial</u> large orders for Canadian equipment, subsequent exports would likely involve a decreasing level of Canadian equipment content as the purchasing country would add more components either from its own production or from third countries.

9. In conjunction with the nuclear power station construction program there will be a requirement for heavy water plants. A total of ten 400-ton units are under construction or projected within the next ten years at an estimated cost of $800 million for equipment and engineering services. There is adequate capacity in Canada to meet this requirement.

.../3

II. SCOPE & COVERAGE

The scope and coverage of this study is based on:

A. A forecast of domestic plans for the construction of nuclear power stations in Canada and for export sales over the next ten years.

The forecast takes into account provincial utilities' anticipated generation requirements, availability of hydro and fossil-fuelled generating resources and financial implications of nuclear power construction programs. Estimates of probable export sales reflect recent expressions of confidence and acceptance of the CANDU concept in a number of countries, which have been further encouraged by recent Canadian sales to Argentina and Korea. The forecast also includes consideration of projected heavy water plant construction programs to meet requirements of nuclear power stations.

B. A survey of over 60 Canadian companies that have been most directly involved in or that have particular capabilities for the supply of equipment and services for nuclear power stations on a continuing basis.

The companies were requested to provide detailed information on a number of points including: special production capability for nuclear work; ability to cope with expected continuing improvements in nuclear technology; experience in producing equipment or providing services for nuclear power projects; supply implications of varying future demand levels in terms of existing capacity, expansion of existing capacity, and willingness and ability to undertake expansion programs to meet increased demands; impact of nuclear business on ability to meet requirements of traditional industrial markets; availability of materials and components; profitability of nuclear production and extent of continuing interest in this area.

C. A general assessment of the capability of the Canadian resource industries to meet the special requirements of the nuclear energy program for basic materials.

Because of the unique and particular requirements of nuclear energy, the study concentrates primarily on Canadian manufacturing capabilities as they relate to the design and construction of the Nuclear Steam Supply System (NSSS) of a nuclear power station.

.../4

The study also includes views and conclusions of public and private organizations that have been involved in the examination of various aspects of the supply and demand implications of recent developments in energy and resource related areas.

III. BASIC ELEMENTS OF A NUCLEAR POWER STATION

A Nuclear Power Station (NPS) consists of two major sections - the Nuclear Steam Supply System (NSSS) and the Power Generation System (PGS).

The NSSS is the unique element of a nuclear power station which distinguishes it from the conventional power stations using coal, oil or natural gas to produce steam. In a NSSS, steam is produced by "burning" uranium (nuclear fission). The NSSS is the part of a CANDU power system which embodies the unique Canadian technology.

The steam produced in the NSSS is piped into the PGS where it drives the turbine-generators. Except for technical differences, particularly in terms of equipment sizes and speeds, the PGS in a nuclear power station is similar to a conventional station, incorporating a steam turbine, electrical generator and ancillary equipment.

In addition to elaborate equipment, the NPS requires extensive engineering and civil works. The Canadian nuclear power program also includes the construction of heavy water plants.

All of these elements are considered in detail in this study.

.../6

IV. NUCLEAR POWER CONSTRUCTION PROGRAM

Estimates of the growth of nuclear generating capacity in Canada and export sales possibilities have been made by the Department of Energy, Mines & Resources, Atomic Energy of Canada Limited, the Canadian Nuclear Association and others. The projections that are presented in graphic form in Appendix A reflect the latest information as to developments likely to take place within the next decade. Table I below summarizes these projections. Forecasts of the nuclear construction program contained in this study are intended to provide a time frame or point of reference against which to measure the demands that will be imposed on the engineering and manufacturing industry in Canada and assess the capability of the industry to meet these requirements.

TABLE I

Projected Construction Starts - No. of CANDU Reactors

	Domestic				Export
	500 MW	600 MW(i)	750 MW(ii)	TOTAL	600 MW
----			3	3 (iii)	-
1974	1	1	1	3	-
1975	1	1	1	3	1
1976	1	2	2	5	2
1977	1		2	3	2
1978			4	4	2
1979			3	3	1
1980			4	4	1
1981			4	4	1
1982			5	5	1
1983			6	6	1
				43	12

Notes:

(i) Where reference is made to 600 MW reactors in this study the comments are generally applicable to 500 MW reactors as well.

(ii) In those instances where definite sizes have not been indicated in the planning forecasts of utilities, 750 MW units have been assumed.

(iii) Three units on which construction started before 1974.

Canada now has approximately 2,500 MW of installed nuclear power capacity, consisting primarily of a 4 x 500 MW commercial station at Pickering, Ontario and smaller units at Gentilly and Douglas Point. It is estimated that by 1984 nuclear power capacity will have increased to a level of approximately 19,000 MW. Projections to the year 2000 indicate that Canada will have approximately 100,000 MW to 130,000 MW installed nuclear power capacity, although the rate of growth in nuclear power installations is expected to moderate after 1984. Approximately 50% of the projected nuclear capacity will be for the energy requirements of the Province of Ontario, with the balance distributed generally as follows: Quebec 30%; Western Canada 15%; and 5% for the Maritime Provinces.

The projected domestic program for CANDU power stations during the period 1974 to 1983 involves the construction of 43 nuclear reactors. Six reactors are presently under construction of which three are 1974 starts, and construction is expected to start at an average of four units per year from 1975 to 1983 reaching a peak of six units in 1983. In addition to the domestic construction program, it is considered that Canadian industry could be called upon to supply for export, equipment and services equivalent to at least one unit per year during the same period.

Assuming for practical purposes an average cost per unit of $340 million for a 750 MW reactor and $300 million for a 600 MW reactor, based on 1974 estimated cost levels, the domestic program implies construction costs totalling upwards of $13 billion in terms of construction starts over the next decade. Fifteen percent or approximately $2.0 billion represents the cost of nuclear equipment, another $2.0 billion will be required for conventional power equipment and $1.0 billion for engineering and consulting services. This implies a contribution of $5.0 billion by the Canadian engineering and manufacturing industry to the domestic nuclear power program in the next decade. The balance of approximately $8.0 billion represents the cost of civil works, contingencies, carrying charges, etc. To the above may be added projected export sales of $1.3 billion of Canadian content, mainly for equipment and services on foreign projects of about $3 billion.

The foregoing indicates total potential business accruing to Canadian industry, over the next decade, in the order of $6 to $7 billion which is seven to ten times the value of the nuclear business Canadian industry has had in the previous decade.

.../8

In addition, the provision of equipment and services for heavy water plants under construction or projected will involve an expenditure in the order of $800 million over the next ten years (for the equivalent of 10 x 400 ton units).

.../9

V. STRUCTURE OF THE INDUSTRY

Approximately 60 Canadian companies can be considered suppliers of major components and services for the CANDU power program. These firms have become increasingly involved in and committed to the nuclear power program and have established special capabilities to meet requirements on a continuing basis. These firms, in turn, rely on a number of sub-suppliers for machining capacity, special components, heavy castings and forgings and certain high-alloy or exotic materials.

These companies constitute a diversified and fragmented group ranging from large heavy engineering equipment manufacturers to small highly skilled machine shops and precision machining firms. With the exception of a few plants which produce nuclear products exclusively, the production of nuclear plant equipment must compete for space and facilities with the production of conventional products.

The product range of these firms extends to such areas as: general purpose industrial machinery such as pumps, valves, compressors; power conversion equipment including heat exchangers, boilers, pressure vessels, turbines, engines, electric motors and generators; special industry machinery such as rolling mills, metalworking equipment, oil and gas process equipment, pulp & paper machinery, mining, drilling and ore processing equipment; construction and materials handling equipment; and such items as instrumentation, data acquisition and control equipment.

Other than an awareness that they are all involved in an exacting area of work, the firms have no separate organizational framework for concerted activity in terms of a nuclear equipment industry. However, an avenue for collective action is provided through the participation of the industry in the Canadian Nuclear Association which groups together suppliers of materials and equipment, consultants, utilities and other groups with a particular interest in the nuclear power program.

These establishments have a combined annual production, for all their products, of approximately $1 billion, employ about 25,000 people and occupy some 11 million sq. ft. of plant space in which they have collectively invested over $400 million in buildings and equipment. Ten percent of the firms have annual shipments in excess of $50 million and over 1,000 employees each. Small companies, with less than $5 million of annual shipments and approximately 100 employees each, represent about 30% of the total.

.../10

Many of the firms are located in Ontario (67% of the establishments). Establishments located in Quebec represent 30% of the total, but, because they include some of the larger equipment plants, account for a proportionately larger share of total shipments (40% of the total). A few important suppliers are located in the Western Provinces.

A number of Canadian consulting firms have also developed considerable experience and expertise in the nuclear power field, particularly in such areas as feasibility studies, the design of conventional systems, integration of the power generating system with the NSSS, the design and supply of research reactors. Their role has been particularly significant in the design, engineering procurement and construction of heavy water plants.

However, in agreement with the provincial utilities, the engineering of the non-conventional design aspects of the NSSS is performed by the federal government through Atomic Energy of Canada Limited because of the need for integrated research, development and engineering and for powerful technical and financial resources. The participation of Canadian consultants in this area has therefore been mainly in support of the major part played by AECL. In addition, their involvement has been limited because the major domestic projects are those of electric utilities, principally Ontario-Hydro to date, who have traditionally provided their own engineering on major phases of projects.

VI. CHARACTERISTICS & SPECIAL REQUIREMENTS OF NUCLEAR PRODUCTION

One of the advantages of the CANDU concept is that it involves technology which is within the range of capabilities and competence of Canadian industry. Nevertheless, it still remains that Canadian equipment suppliers face certain technical problems due to the peculiar and unique characteristics of nuclear energy. This applies principally to the design and construction of the NSSS portion of nuclear plants.

These problems relate to such factors as:

(i) special nuclear requirements such as shielding against radiation and containment of heavy water which impose on manufacturers of equipment very stringent standards in terms of close dimensional tolerances, high performance requirements and use of exotic or difficult to work materials.

(ii) new and changing technology which is uniquely Canadian but to a large extent is outside of the manufacturing industry's traditional range of experience and technical know-how.

(iii) increasingly severe requirements of utilities for standards of nuclear plant construction which will achieve high plant availability ratios, high system and component reliability and reduced incidence of maintenance.

(iv) high cost and exacting nature of quality assurance which involves levels of inspection, testing, and control well above normal requirements of other industrial applications to date.

Canadian manufacturers have developed or installed highly advanced and sophisticated facilities to meet the unique requirements of nuclear work. These include: special production methods for nuclear work; separate facilities and specially trained personnel for quality control and inspection; clean rooms for production of nuclear components; elaborate array of sophisticated equipment for inspection, testing, fabrication and assembly operations; development of new and expanded capabilities to work special alloys and exotic materials, to achieve very high standards in materials or components, and to manufacture unusually large components to exact tolerances; highly developed welding capabilities, etc.

.../12

The average expenditure of the firms engaged in the production of nuclear components on quality control has represented approximately 20% of total manufacturing cost of these products. This compares to an average of less than 5% for conventional products. The added quality control costs are accounted for by: (a) the purchase and use of precise and sophisticated testing and inspection equipment; (b) special training for engineers and technicians assigned to nuclear quality control operations; (c) extensive training to develop highly skilled and capable welders, industrial radiographers, etc.; (d) the development and upgrading of quality control manuals and procedures to meet changing specifications; (e) close control and monitoring of work done by sub-suppliers; (f) participation in Standards Committees of the Canadian Nuclear Association, Canadian Standards Association, or American Society of Mechanical Engineers, and close working liaison with AECL and the utilities in the establishment of/and conformance to quality control standards; (g) on-going requirements for engineering improvements and technical modifications; and (h) the large amount of rework which is required to maintain nuclear standards.

Whereas the bulk of R & D activity related to the nuclear area has traditionally been done by Atomic Energy of Canada Limited, several manufacturers and consultants participate in this activity either under contract from AECL for specific components or on their own account in order to resolve certain technical problems in the adaptation of their proprietary products to nuclear standards. In some cases there is adequate in-house capability to undertake the required R & D activities while in some instances the R & D resources of parent companies are utilized. To date, however, R & D activities related to nuclear work have not been significant for most of the firms involved in nuclear work with the exception of certain large producers, who have developed products and techniques which are unique to NSSS. The companies surveyed have reported total expenditures of approximately $15 million on R & D activities over the last five years either on their own account or funded by AECL in areas related to nuclear products.

In summary, it is considered that Canadian industry has the technical capabilities to cope with existing and foreseeable requirements of Canada's nuclear energy program in terms of standards of quality, reliability and ability to meet the exacting dimensional and material requirements of AECL and

.../13

electric utilities. This presupposes continuing and in some cases improved technology transfer arrangements between AECL, electric utilities and the industrial sector, particularly with regard to suppliers who may not presently be involved in the nuclear area but who may have to become active participants as the demand for nuclear energy increases.

VII. INDUSTRY COMMITMENT TO NUCLEAR PROGRAM

The principal suppliers of nuclear products have to date produced over $500 million worth of components for the nuclear program, of which about 60% has consisted of equipment for the NSSS portion of nuclear power stations.

It is estimated that the industry has achieved an average level of 75% Canadian content on this production. The major items which have not been available from Canadian production have been special alloy tubing and sheet, certain sizes of stainless steel or carbon steel plate and piping, large forgings, special components for fuelling machines, rotating components and highly-engineered parts for turbo-generator sets, and various instrumentation and control items.

Current involvement of the industry in the nuclear area is at an unprecedented high level but generally not yet to the extent that operating capacity is strained given the flexibility provided by the possible addition of more shifts, greater resort to sub-contracting, possible changes in product mix and a level of availability of manpower and materials which, to date, has been generally adequate. However, the industry is generally well aware of accelerated new requirements for nuclear energy and realizes that additional manufacturing resources on a large scale will have to be committed to the nuclear programme within a short time.

The more significant and specialized suppliers have generally identified the type and extent of capability expansion required in order to be in a position to undertake a targeted portion of the nuclear business, and they are prepared to commit substantial new financial and technical resources for this purpose. At present, well over $100 million of capital investment is either committed or projected by the major firms in this area. A number of firms have also identified other nuclear products which would fit their capability and experience and have indicated a willingness to upgrade or expand capacity in order to become accepted as suppliers in these new areas. However, there are several companies that have expressed a certain hesitation in committing substantial new resources to the nuclear program. This hesitancy is due to a number of factors such as: (a) sustained heavy demand for traditional products of a less exacting nature; (b) relatively low level of profitability in the past on nuclear production due to high cost of quality control and discontinuity of orders; (c) uncertainties re future opportunities which will be available to them to supply nuclear components; (d) lack of financial resources to expand to the levels indicated by the anticipated needs of the nuclear energy program, or uncertainties re their share of this business, which make it difficult to allocate necessary funds for capital expansion.

.../15

VIII. ANALYSIS OF CURRENT & PROJECTED MANUFACTURING & ENGINEERING CAPACITY

The analysis of current and projected production capability in the nuclear industry reflects the participating companies' views regarding the volume of business they expect to be able to undertake on the basis of existing capacity and projected plans for expansion. The basic approach has been to examine the capacity to produce each of the major components, or groups of components constituting a manufacturing package, in order to identify the particular products that could constitute bottlenecks when comparing current and projected output against probable annual levels of demand. Particular attention has been given to those components that enter into the manufacture of the NSSS portion of nuclear stations because of the unique characteristics of these components and the particular problems involved in their manufacture.

Certain basic assumptions have had to be made in arriving at a measure of the balance between capacity and demand that can be expected over the next decade - i.e.:

(i) No major design changes will be introduced which would significantly affect Canadian industry's ability to cope with technical requirements of nuclear plants.

(ii) The level of demand for nuclear equipment during the next decade will remain within the following limits:

- average construction starts of four units (reactors) per year for domestic requirements and one unit per year for export;
- peak annual demand of six domestic units plus one export, possibly occurring in 1983.

(iii) Canadian producers will be able to proceed with projected expansion plans within their presently foreseen financial, technical, and physical resources and there will be no insurmountable problems caused by significantly aggravated material shortages, non-availability of manpower, offshore supply difficulties, etc.

It is also assumed, for practical purposes, that if Canadian industry can expand its production capacity to supply, on a continuing basis, up to six reactors per year, all essential requirements (including exports) during the next ten years will be met.

.../16

The analysis of current and projected capacity covers four distinct areas - major components of NSSS, major components of PGS, heavy water plants, engineering and consulting services - each of which is treated separately.

A. Major Components of N.S.S.S.

The major components of the NSSS are: calandrias with end shields and tubes; shield plugs, closure plugs and end fitting assemblies; nuclear steam generators; reactor headers, feeder pipes and pressure tubes; nuclear heat exchangers; fuelling machines and fuel handling equipment; reactivity mechanisms; pumps; valves; nuclear fuel fabrication; induction motors for heat transport pumps; and instrumentation and control systems. The total value of NSSS components ranges from $40 to $45 million per reactor.

1. Calandrias, End Shields and Tubes

The calandria, together with its end shields and tubes, constitutes the core of the nuclear reactor. In the case of nuclear reactors in the 500 to 600 MW range (Pickering and Gentilly II), these three elements form a $4 million manufacturing package which can be fabricated and assembled in one plant. These designs involve the use of a concrete shield which is constructed on site. For the 750 MW design of reactor (Bruce), the in-plant manufacturing package includes a carbon steel shielding enclosure which, together with the added size of the reactor, adds another million dollars to the cost of the package and presents certain challenges with regard to assembly in the manufacturer's plant and shipment to the nuclear station site. Normal lead times are 3½ years.

Estimated Canadian requirements for nuclear reactors through 1983 call for the supply of at least four reactors per year with a peak demand of six units occurring in 1983. Possible export sales imply an additional demand for at least one reactor package per year.

On the basis of projected expansion programs, it is expected that there will be sufficient capacity to supply up to six reactors per year which should be adequate to meet the essential requirements of the anticipated nuclear construction program. This represents a significant increase over present capacity which can only accommodate four reactors of the 600 MW design or, alternatively, two units of the 600 MW size and two units of the 750 MW design.

.../17

2. Shield Plugs, Closure Plugs and End Fitting Assemblies

These components provide a means of access to fuel bundles in the reactor, seal the fuel channels, provide shielding against radioactivity and form the connections between fuel channels and the feeder pipes. A reactor in the 600 MW range requires (including spares) about 800 of each of these components and a 750 MW reactor requires about 950. The value ranges from $2 to $3 million per reactor depending on the design used. Normal lead times for the production of these units is one to two years.

The demand for these items over the next ten years could range from an average of 4450 sets (for five reactors) to a maximum of 6500 sets (seven reactors). Present annual capacity is estimated at 5850 shield plugs, 4200 closure plugs and 2400 end fitting assemblies. Projected expansion plans of the firms involved is expected to increase the capacity for shield plugs and closure plugs to 6975 and 5700 respectively but there are as yet no firm plans for increasing the production of end fitting assemblies beyond the present level of 2400 per year.

In summary, it would appear that the supply of two of these components (shield plugs & closure plugs) should be adequate to meet at least a targeted capability of six reactors per year (5700 plugs) on the basis of plant expansions currently under consideration. However, in view of the presently limited capacity for the production of end fittings, and the lack of any firm expansion plans in this area, the overall Canadian capability might be sufficient to accommodate requirements for only three reactors per year. This potential bottleneck may be overcome if industry feels assured of a continuity of orders sufficient to justify expansion of existing facilities and/or the establishment of new production facilities.

The firms currently involved in this area have relatively small production plants and limited resources, and they are particularly vulnerable to material shortages and price escalations. They have suggested that common purchasing of raw materials by a central agency would provide definite advantages in terms of lower prices and improved delivery for large quantity purchases as well as reducing the amount of capital the firms themselves would have to tie up for inventories.

.../18

3. Nuclear Steam Generators

These generators are in fact large heat exchangers whose function is to transfer heat from the reactor cooling fluid (heavy water) and generate steam (from ordinary water) to drive the turbine.

The Bruce "A" reactors (750 MW) employed eight generators, field welded in groups of four to common steam headers. The reactors for all subsequent designs will employ four independent generators each. Future reactors will each require four steam generators at a total cost of approximately $6 million for a 750 MW reactor and $4 million for a 600 MW reactor.

Present manufacturing capacity is estimated at eight steam generators (two reactors) per year and projected plant expansions would boost capacity to a peak of 34 generators per year, which should be adequate to meet the foreseen requirements during the next ten years. Maximum expected demand is estimated at seven reactors for any one year which implies a peak requirement for 28 generators per year.

4. Reactor Headers, Feeder Pipes and Pressure Tubes

The function of these components is to form the connecting link between the steam generators and the calandria. The heavy water coolant from the generator enters a header or manifold which connects through a number of feeder pipes with the individual pressure tubes in the calandria.

The "package" for a 750 MW reactor (Bruce type), consisting of eight headers, 900 feeder pipes and 450 pressure tubes is valued at approximately $4 million. A similar package for a 600 MW reactor would cost about $3.5 million.

The assembly of header and feeder pipes tends to be handled by one group of manufacturers and pressure tubes by another.

(a) Headers & Feeder Pipes

No problems are foreseen regarding the assembly of feeders and headers as this requires only standard bending, welding and assembly operations and there are several companies

.../19

with recognized competence and adequate capacity. Except for the customary stringent requirements of nuclear work in terms of testing, inspection and quality assurance standards, the type of work involved is consistent with the production of such items as pressure vessels and power boilers for which Canada has internationally recognized capability. Normally a leading supplier would have prime responsibility for shop assembly and on-site installation from components which could be fabricated in other plants.

The manufacture of the headers themselves has been a source of difficulty in the past with the result that some requirements have been met from offshore supply. However, new Canadian capability in this area is being established and it should be possible to meet future requirements from domestic supply.

(b) Pressure Tubes

Present Canadian capacity for the production of finished pressure tubes is sufficient to meet requirements for only one 750 MW reactor per year. However, projected expansion plans, if carried through, should result in sufficient capacity being established to meet future requirements of the nuclear program.

While there is no Canadian source at present for the zirconium alloy tubing which makes up the bulk of the cost of the pressure tubes, new production facilities are being established to produce this material in Canada.

5. Nuclear Heat Exchangers

In normal operation a nuclear power plant requires cooling of the reactor moderator, reactor shields, fuelling machines and miscellaneous other components. In addition,

.../20

there are special cooling functions which must be carried out during routine or emergency shutdown procedures. These cooling operations are generally carried out by means of shell and tube heat exchangers which are of moderate sizes and pressure ratings. The combined value of the various heat exchangers required for a large CANDU reactor (750 MW) is approximately $1 million.

While the quality requirements of these exchangers are more exacting than in most other industrial applications, the shop work is well within the existing capability of several Canadian companies. There is sufficient capacity in place to meet the anticipated requirements of the nuclear construction program. Competitive bidding is expected to continue and orders for the CANDU program should be filled without undue delays.

The supply of tubing for these heat exchangers remains a problem and the practice of pre-ordering and stocking this material which has been adopted by Ontario-Hydro may have to be continued and perhaps extended to other major utilities.

6. Fuelling Machines & Fuel Handling Equipment

Fuelling machines for CANDU reactors are sophisticated units designed to change fuel bundles while the reactor is operating. This means that the closure and shield plugs must be removed and fuel bundles removed and replaced by remotely controlled machines while the tubes and fittings contain heated heavy water under pressure.

The 600 MW range of reactors (Pickering & Gentilly II) need two fuelling machines per reactor plus a number of spares depending on the number of reactors in a station. The 750 MW (Bruce type) reactors use six fuelling machines for four reactors as the machines can be moved from one reactor to another within the same station. The cost of fuelling machines and related fuel handling equipment is approximately $3 million per reactor for the 750 MW type and $2.5 million for the 600 MW range. Normal lead times are two to three years.

To reach a capacity level equivalent to six reactors per year, which is generally considered adequate to meet all essential requirements of the nuclear program, Canadian industry would have to be able to supply a total of approximately 11

.../21

machines per year. Assuming a probable mix of 2 x 600 MW reactor units and 4 x 750 MW reactor units per year average, this means a demand of around five machines for 600 MW reactors and six machines for 750 MW reactors. With projected capacity of 9 x 600 MW machines and 6 x 750 MW machines, on the basis of proposed expansion programs, the needs of the nuclear power program should be met with relative ease on an overall basis. There may, however, be a shortfall in capacity to meet two peak demand periods which are likely to occur in 1976 for 600 MW type reactors (12 fuelling machines) and in 1983 for 750 MW reactors (9 machines). This may require concerted action by AECL, the utilities and the producers involved in taking appropriate pre-ordering or pre-inventorying measures in anticipation of peak loads.

Some of the components for fuelling machines have to be imported - e.g. recirculating ball lead screws, and it is not expected that they will become available in Canada in the near future.

7. <u>Reactivity Mechanisms</u>

These mechanisms consist basically of guide tubes with drives whose function is to move reactivity elements in or out of the reactor core. They may be called booster rods, shut-off rods, absorbers or adjusters depending on their particular functions in the process.

Current designs call for the use of about 50 reactivity tubes and drives per reactor at a cost of approximately $1 million. The system also requires a number of mounting platforms. Future changes in control methods could add to the number and cost of mechanisms required for each reactor.

The demand for these items during the next ten years could range from an average of 250 sets per year for five reactors, to a maximum in any one year of 350 sets (seven reactors). Present capacity is estimated at 425 tubes, 100 drives and mounting platforms for four reactors per year. Projected expansion plans are expected to increase annual capacity to 500 tubes, 300 drives and platforms sufficient for six reactors.

It is therefore expected, on the basis of proposed plant expansions, that Canadian capacity will be sufficient to accommodate a demand of at least six reactors per year

.../22

with enough margin to satisfy higher peak demand levels if required. Temporary supply difficulties could be experienced due to dependence on foreign sources for zirconium alloy tube material and special gearing. However, the zirconium alloy tube material is expected to be available from Canada by the end of 1975.

8. Pumps

The current standardized design of a 600 MW CANDU unit requires a total of 16 pumps at an approximate total cost of $4 million. The major requirement is for 4 - 9000 HP heat transport pumps whose function is to drive heavy water through the reactor core, absorb heat generated in the reactor and transfer it to heat exchangers where the heat is then released to a light water system to generate steam for the turbines. Two 1000-HP pumps are required for the moderator circulating system which acts as a secondary system to control the rate of heat generation in the reactor and dispose of excess heat. A number of smaller pumps (ten) ranging in size from 10 to 250 HP are required for various auxiliary functions.

The heat transport pumps for 750 MW reactors are larger (11,000 HP). Otherwise, an arrangement similar to the 600 MW reactors prevails with more or less significant modifications due to design variations.

In terms of Canadian production capacity, only the large heat transport pumps could present a difficulty. The projected average annual demand for these heat transport pumps, over the next ten years, is estimated at 8 x 9000 HP pumps for 2 x 600 MW reactors and 12 x 11000 HP pumps for 3 x 750 MW reactors. However, it is anticipated that there may be two peak demand periods, occurring around 1976 and 1983 which could require the supply in one year of up to 20 x 9000 HP pumps in the one case and 24 x 11000 HP pumps in the other case. Present capacity of the Canadian producers with experience in the manufacture of large heat transport pumps is considered adequate to meet requirements for four reactors per year in pump sizes up to 11000 HP. With projected expansion plans, Canadian capacity would be increased to seven reactors per year, which could accommodate whatever mix of 600 MW and 750 MW reactors is required.

.../23

The industry's assumptions re future capability are predicated on sustained availability of the large nuclear grade castings for the pump bodies, which represent approximately 25% of the value of finished pumps. In periods when the few Canadian foundries capable of supplying castings of the required size and quality are operating at full capacity, the pump manufacturers must resort to offshore sourcing to meet commitments.

There are several established pump producers in Canada with sufficient overall capacity and experience to satisfy all foreseen requirements for the other pumps used in nuclear reactors.

9. Valves

A 750 MW reactor requires approximately $1.3 million worth of various types and sizes of valves.

The capability to meet the quality standards required for the NSSS in the valve industry is selective. Nevertheless, the industry considers that it now has the technical and physical capabilities, and a capacity (provided that nuclear quality castings are available), sufficient to meet all the foreseen requirements for NSSS in the future. This should provide an opportunity to increase the Canadian valve industry participation in the nuclear program significantly. Canadian procurement of these items in the past has amounted to approximately 50% of total NSSS requirements.

10. Fuel Fabrication

The fuel charges for CANDU reactors consist of bundles of zirconium metal tubes containing refined UO_2 pellets. They are presently produced by two fuel fabricators in Canada using UO_2 powder from a Canadian refinery. The zircaloy tubing and strip is presently supplied by foreign producers.

The finished fuel costs are high. The cost of the first charge of fuel for the Bruce station is approximately $28 million and the cost of the first charge for Pickering was $19 million. The refined UO_2 used by the fuel fabricators represents about ½ of this cost.

.../24

The UO_2 is produced at the refinery from uranium ore. The fabricators press and sinter the pellets and grind the sintered pellets to uniform circumference. The pellets are then placed in tubes and the tubes are assembled into bundles. These production operations require many exacting operations such as brazing of spacers, welding of end caps and end plates as well as degreasing, pickling and rinsing of metal components. Many inspections are required to assure acceptable quality.

It is considered that there will be adequate production capacity in Canada to meet all foreseen requirements for nuclear fuel. Current dependence on foreign suppliers for zirconium material could present temporary difficulties but new Canadian sources for this material may be established.

It is expected that existing refining facilities will be expanded sufficiently to provide adequate quantities of UO_2 to meet demand during the next ten years. In addition, refined UO_2 may become available from uranium mining companies starting around 1980.

11. Induction Motors For Heat Transport Pumps and Boiler Feed Pumps

The heat transport pumps for a 750 MW reactor require 11,000 HP motors. On the basis of projected domestic and export market demand the maximum requirement for any one year would not exceed 24 - 11,000 HP motors, plus spares.

Currently, only one Canadian company has complete capability in this area including design competence, production facilities and experience in building them for nuclear power stations. To meet all future requirements from domestic production, additional Canadian facilities will have to be established. There are indications that new investments in this area are being considered.

12. Instrumentation and Control Systems

A nuclear power plant requires extensive and sophisticated instrumentation and control systems due to exacting control requirements resulting from the fact that human operators cannot reach many parts of the plant when it is in operation. The instrumentation is basically made up of radiation, temperature

.../25

and pressure sensors which detect operating conditions in plant equipment and convert them into electrical signals. Computers analyze the signals and provide output signals to alarm and control equipment.

Total cost of instrumentation and control hardware is approximately $5 million per reactor. Much of this equipment will continue to be imported as domestic capability is limited and there are few opportunities to establish new production facilities.

Some radiation sensing equipment is presently produced in Canada. However, thermal and pressure sensors are generally imported. A fairly wide range of auxiliary equipment for computers is also produced in Canada. However, the main computers will not likely be produced in this country for some years to come. While capability exists to build computers in a number of firms, current designs are not suitable for nuclear power plant application. The main computers, however, are a small part of the total computer installation.

13. Other Equipment

No particular supply problem is expected for the other components included in the NSSS. For most of these items competitive bidding is expected to continue and orders for NSSS should be filled without undue delay.

14. Summary of Supply Outlook for NSSS

In summary, it would seem that Canadian industry will be able to cope with all essential NSSS requirements of a nuclear construction program involving up to six reactors per year, provided the needed plant expansions are carried through within required time limits. Possible shortfalls should be overcome if certain reservations regarding future business opportunities are removed so that existing producers become persuaded to expand capacity beyond proposed levels and/or the participation of other firms who could develop the required expertise is obtained. The industrial expansion implied in the projected nuclear program represents as much as a threefold increase over existing capacity in certain areas.

.../26

B. Major Components of the Power Generation System (PGS)

The PGS equipment is grouped in a separate power house adjacent to the reactor (NSSS) building. The steam supply system is isolated from the reactor by means of the heat exchanger built into the steam generator. This degree of isolation from the nuclear reaction permits the use of conventional equipment in the PGS and the acceptance of more conventional quality standards for most of the machinery involved.

The major components of the PGS include: the turbine-generator; condensers; feed water heaters and miscellaneous heat exchangers; pumps; valves; and various electrical apparatus such as transformers, switchgear, small motors, process control equipment, etc. The total value of PGS components is approximately $40 to $45 million per unit.

1. Turbine-Generators (T-G Sets)

The relatively low pressure of the steam produced in the nuclear reactor calls for very large turbines. These turbines are too large for shop assembly or transportation by conventional means. As a result, they are designed to be made in several distinct sections which can be shop assembled on an individual basis, dismantled for shipment and reassembled in the field. On the other hand, the main generator must be completely assembled and tested in the shop. Once the stator has been assembled, it cannot be broken down for shipment as its size and weight demands special carriers and special handling gear for shipment. It is expected that all stators required within the next ten years will be designed for shipment over land. Subsequent designs, however, may have to be built in plants located adjacent to waterways for barge shipment.

The manufacture of T-G sets involves unique requirements for large forgings, castings, and fabrications made of materials to special standards and with a predominance of heat resisting alloys. The turbine and generator are usually supplied by the same company as a set. The total price for a set in the Pickering and Gentilly II size range is $28 million, while the large Bruce type units cost approximately $33 million.

Canadian production of these units to date has been highly dependent on foreign technology and on imports of rotating components and other highly engineered parts. The existing domestic capacity exceeds possible requirements for

.../27

up to six reactors per year. However, Canadian content on this production is low, ranging from 20% to 50%. To attain a significantly higher Canadian content would require expansions which would likely be undertaken only with appropriate assurances of future business opportunities. Reliance on foreign sources may not be a suitable alternative as the recent heavy demand, worldwide for T-G sets for nuclear plants is straining the capacity of the major international suppliers.

2. Main Condensers

Each steam turbine is equipped with a condenser at a cost of approximately $2 million.

The existing condenser suppliers are able to meet all of the projected requirements. However, the tubing which accounts for a large portion of the material in a condenser is not available from Canadian production. In addition, this material is in short supply internationally and utilities are currently pre-ordering and stocking this item for issue to manufacturers.

3. Feed Water Heaters and Miscellaneous Heat Exchangers

The PGS contains a variety of heaters and coolers. The main feed heating train contains twelve large heaters valued at approximately $1 million.

There are several established suppliers of these units whose combined capacity exceeds anticipated requirements.

4. Pumps

These pumps are made to less exacting standards than those used in the NSSS portion of nuclear stations. They include pumps for condensate extraction, process water, boiler feed, low pressure service water, condenser cooling water and auxiliary boiler feed. For a station of 4 - 750 MW units, the approximate value of the pumps is $5 million.

In anticipation of a large increase in requirements for pumps for nuclear power stations and heavy water plants in the near future, several manufacturers have recently expanded their production facilities. As a result there is adequate plant capacity to produce the conventional pumps for all the projected nuclear stations for the next ten years.

.../28

5. Valves

The Canadian valve industry has adequate capacity to produce all the various types and sizes of valves required for the PGS portion of nuclear power stations projected in the future. This industry has been experiencing severe competition from foreign suppliers and is generally operating at less than full capacity.

6. Electrical Apparatus

Most electrical items in the PGS portion of nuclear power plants are standard products currently produced by several manufacturers. These items, such as transformers, switchgear, small motors, motor control centers and process control components are similar to those used in conventional power plants. No particular supply problem is expected in this area.

7. Other PGS Equipment

Most other items of equipment in the PGS portion of nuclear power plants are standard products currently produced by several manufacturers. No particular supply problem is expected in this area.

8. Summary of Supply Outlook for PGS

The production of equipment for the PGS does not present the same problems to industry as the NSSS which involves sophisticated new technology and extremely exacting standards of manufacture and quality assurance. In the case of the PGS, the degree of isolation from the nuclear reaction permits the use of conventional equipment and the acceptance of conventional quality standards for most of the machinery involved. No major capacity problems are expected in this area as existing facilities are generally considered adequate to meet the needs of the projected nuclear power construction program.

However, it is possible that there will continue to be heavy reliance on foreign sources for major components of turbo-generators and this could cause certain problems as the recent heavy demand, worldwide, for T-G sets for nuclear plants is straining the capacity of the major international suppliers. A significantly higher Canadian content on T-G sets than the 20 to 50% level achieved to date would imply major expansion decisions which would be influenced in large measure by the companies' expectations as to the opportunities that would be available to them to supply future nuclear requirements.

.../29

C. Heavy Water Plants

The construction of a 400-ton capacity heavy water production unit represents a cost of approximately $200 million (in 1974 dollars) of which approximately $30 million is required for engineering services and $80 million consists of various kinds of equipment. A total of ten such 400-ton units are under construction or projected within the next ten years, at a total estimated cost of $2 billion, to meet anticipated domestic and export needs.

Major equipment components for a 400-ton unit (Bruce) include:

- six enriching towers in heights up to 275', 28'6" diameter and up to 3½" wall thickness;
- four finishing unit towers in heights to 172' diameter up to 10'6" and wall thickness of 9/16";
- one 475' flare tower;
- 230 pumps in sizes up to 5000 HP;
- five compressors up to 6900 HP;
- 45,000 valves;
- 250 heat exchangers;
- 175 tanks and vessels;
- 1000 tons of structural steel;
- 600,000 feet of pipe, from 3/8" to 52" diameter.

The combined capability of the Canadian engineering firms with experience in the design and construction of heavy water plants is considered adequate to meet project engineering requirements of the construction program noted above, as well as any additional demand that could arise.

It is also considered that there is adequate capacity in Canada to supply the bulk of the machinery and equipment that will be needed for the heavy water production program. Certain basic materials will continue to be imported but it is not expected that world shortages in these areas will be such as to significantly affect the program.

.../30

D. Engineering & Consulting Services

Participation by Canadian consulting firms in the CANDU program has been complementary to the major part played by AECL in the engineering design aspects of the NSSS portion of nuclear plants. Their role has also been limited to a certain extent because the major domestic projects have been those of electric utilities, principally Ontario-Hydro to date, who have traditionally done their own engineering. Nevertheless, Canadian consultants have developed considerable experience and expertise in feasibility studies, the design of conventional systems, integration of the power generating system with the NSSS, the design and supply of research reactors and component design. Their role has been particularly significant in the engineering, procurement, and construction of heavy water plants.

Of the $60 million worth of engineering services that go into a single 600 MW station, approximately $28 million represents the contribution of private firms for engineering, design and project management. Of this total, about $8 million would represent the cost of linking the NSSS engineered by AECL and the PGS engineered by the consulting firm or the power utility.

There is a considerable body of engineering expertise in the private sector to complement the activities of AECL and the utilities in the design, engineering development and construction of CANDU power stations and heavy water plants. The accumulated experience of those firms who have worked on nuclear projects in the past, together with the extensive capabilities of other major consulting firms, could support a significantly expanded involvement of the Canadian engineering and consulting industry in the nuclear area in the future, particularly with regard to possible CANDU sales abroad.

.../31

IX. GENERAL CONSTRAINTS & PROBLEM AREAS

The recent domestic and international environment has been characterized by persistent shortages and constraints affecting a number of industrial areas. While there has been a considerable easing in certain commodity shortages lately, these conditions still affect the resource and energy-related sectors. Consideration of these factors is therefore required, in order to provide some perspective regarding their possible impact on the Canadian nuclear industry.

A. Manpower Limitations

The question of labour supply to meet the requirements of the nuclear program does not fall within the scope of this study. Nevertheless, other studies indicate that the lack of suitably trained manpower may become a constraint.

The technical qualifications of labour utilized for nuclear work has to be of a higher level than in most other industrial sectors because of very demanding safety requirements due to radiation hazards, stringent quality assurance requirements for manufacturing and the extremely high technological competence required in general. As this is a new technology there is no large pool of trained and experienced personnel from which to draw.

There are about 1500 engineering and technical personnel involved in the engineering of nuclear power stations in addition to significant technical and engineering groups employed in manufacturing plants. This engineering staff will have to be increased about 40% over the next two years to meet the expanding program. With the high level of demand for engineering talent prevailing in other Canadian resource sectors such as tar sands development, mining, etc. and the acknowledged shortage of trained technical staff in the U.S. and Europe where engineering talent would otherwise be sought, it will be necessary to seek means of achieving significant economies of engineering effort through such measures as standardization of designs, etc.

To date about 3,500 people have been involved in manufacturing for the nuclear power program. It is estimated that by 1979 the nuclear power program will require a manufacturing labour force of close to 15,000. Many of these people will be highly skilled welders, machinists, electricians, quality assurance personnel and technicians working with the exotic materials and extremely close tolerances demanded by nuclear operating and safety

.../32

standards. Many of the manufacturing facilities that will utilize this labour force still remain to be expanded or built. This implies that if manufacturers proceed with the required expansion programmes there will be a marked acceleration in the demand for these kinds of skills.

The manpower constraints that will be felt in the civil works involved in nuclear plant construction and in the operation of nuclear power stations are not of direct relevance to the equipment manufacturing and engineering sectors, except that this is another area of heavy demand which will further reduce the available skilled labour pool from which the manufacturing sector will have to draw for its requirements.

B. Material Shortages

What sets the nuclear equipment industry apart as a major user of primary materials and non-fabricated components is not so much the quantities required (which are large by any standard) but the unusual requirements for large size items - e.g. castings & forgings, close dimensional tolerances, special alloy or exotic materials and extremely fine quality in terms of purity of material composition. Many of these items are available in Canada but there is also a fairly widespread reliance on foreign supply, particularly for certain high-alloy components or for certain sizes of steel plate and tube for which the overall demand in Canada has not been sufficient to justify economic production.

In the foregoing description of Canadian capacity for the supply of major nuclear components, reference has been made to particular material supply problems experienced by the manufacturers involved. In addition to those specific procurement difficulties, the nuclear equipment industry as a whole, will continue to be affected by fluctuations in world supply of steel and other materials. On the whole, however, present indications are that the nuclear equipment industry will likely be able to obtain adequate supplies of basic materials or components. Nevertheless, depending on the nature and extent of possible shortfalls of essential materials, remedial or precautionary measures may be required to ensure: (a) the pre-stocking of materials by a common purchasing agency (as is done in some areas already); (b) an expanded Canadian capability to produce castings and forgings to meet the exacting requirements of the nuclear industry; and, (c) the establishment of new production facilities for certain materials or components, which otherwise could not be produced in Canada on an economic basis, in the event of interruptions of deliveries from offshore sources.

.../33

The following are examples of some material procurement areas that present certain problems:

(i) Primary Steel

There has been a recent worldwide shortage of steel due to heavy demand and insufficient plant capacity. However, the steel industry has been expanding capacity as rapidly as possible and should be able to meet the long term demand.

(ii) Castings (Stainless Steel and/or Carbon Steel)

Each 600 MW reactor requires 680 valves with cast bodies of stainless steel and/or carbon steel, of which approximately 420, weighing 94 tons are of "nuclear" quality. Nuclear grade castings are also required for 12 pumps in the reactor building. Four of these pumps have cast carbon steel bodies weighing 20,000 lbs. - six weighing 5,000 lbs. and two require stainless steel castings weighing 8,000 lbs. Although there are a number of Canadian foundries with the capability to manufacture nuclear grade castings, the serious deterioriation in deliveries last year has forced Canadian valve and pump manufacturers to look for suppliers offshore. As these castings are the basic materials for valves and pumps, this shortage could become a serious bottleneck if it persists or reoccurs. This is one area where Canada may have to upgrade and expand existing facilities.

(iii) Forgings

The four steam generators required for a 600 MW reactor each contain a tube sheet made from a forging 9 ft. in diameter, 17 to 18 inches thick, weighing 35 tons. Recent purchases have been placed offshore as adequate pouring capacity and pressing equipment is not available in Canada. The supply problem in this area could probably be alleviated through the acquisition of a sufficiently large press and auxiliary equipment to undertake work of this size.

(iv) Stainless Steel Plate

Approximately 160 tons of stainless steel plate is required for the calandria for a 600 MW unit, ranging in thickness

.../34

from 3/4" to 3". Because of limitations in the maximum thickness and size of overall sheet available in Canada, some of the demand to date has been supplied from the USA and Sweden. The demand is not likely to be such as to justify investment in additional production capacity in Canada. However, in case of difficulties with offshore supplies, it may be advisable to stockpile this material for issue to manufacturers as required.

(v) Carbon Steel Plate for Heavy Water Plant Towers

A 400-ton capacity heavy water plant requires some 14,000 tons of this plate up to $3\frac{1}{2}$ inches thick, weighing approximately 8 metric tons each. Plate of this size is not available in Canada in required widths and has been obtained principally from France, Germany and Japan. It would appear that this material should be pre-ordered to ensure adequate supplies when needed.

Zirconium alloy sheet and tubing are essential components for the cores of CANDU reactors. They are needed in relatively large quantities in three generic classes for three distinct functions. Canadian capability in this area is limited at present but new plants are being built in Arnprior, Ontario to manufacture zirconium alloy products including specialized alloy tubing, zirconium alloy fuel-sheathing tubes, zirconium alloy pressure tubing and high-nickel alloy heat exchanger tubing, to be available by the end of 1975. This will remove the present dependence on imports of this material in finished form.

C. Import Competition

The CANDU power program to date has generally made use of Canadian production facilities wherever possible, and imports have consisted mainly of items not available in Canada. The high proportion of Canadian content is due in large measure to the fact that the CANDU system is uniquely Canadian and both AECL and the utilities have had to develop close working relationships with the private sector on design and development aspects and the establishment of appropriate specifications and standards. Now that the major design parameters have been established and with increased standardization of components it will become progressively easier for foreign suppliers to compete in Canada.

The foregoing analysis of Canadian manufacturing capacity makes it clear that large scale investments by the private sector

.../35

will be required in the near future to make it possible for Canadian industry to meet future requirements of the nuclear power program. In the main, these investments will be for new specialized facilities which could not be effectively used for other than nuclear work. It is also evident that many of the proposed investments will not be carried through unless the manufacturers are sufficiently confident regarding future procurement orders to justify the costs of the expansions involved. Canadian producers are not overly concerned with domestic competition. However, the prospects of having to contend with severe price competition from offshore suppliers could discourage some firms from undertaking the required investments. Granted that Canadian industry has some technical lead in CANDU technology, many international producers have the technological resources to easily acquire this competence. In addition, they have the advantages of larger plants and greater financial resources.

CANDU is a new area of sophistication and high technology which can raise the technological competence of Canadian industry to unprecedented levels. If this technology is widely disseminated throughout industry through optimum participation in the nuclear construction program, it will provide added benefits in terms of international competitiveness in other product areas as well. On the other hand, reliance on the foreign supply of components for the CANDU program implies the gradual and damaging transfer abroad of unique Canadian competence. It should also be noted that the projected CANDU construction program in Canada is, by itself, large enough to provide the basis for a large and strong manufacturing industry.

D. Technological Factors

The Canadian manufacturing industry has shown a remarkable ability to upgrade its technological competence to meet the high standards of the CANDU system in terms of close tolerances, quality of materials, dimensional requirements, quality assurance, etc.

The major problem for the individual company is the high cost of gearing up to nuclear standards which can only be recovered through several repeat orders over a number of years. These upgrading expenditures in many cases have not been supported by a sufficient continuity of new orders, with the result that profit margins for nuclear work have been generally low. Those firms that are highly committed to the nuclear program are confident of

.../36

a reasonable eventual payoff. However, there appear to be several producers who have been hesitant to commit additional new resources to expand their technological capability in this area due to uncertainties regarding opportunities that will be available to them to obtain contracts in the future. This attitude has also fostered in some instances by the recent heavy demands for the companies' conventional products. This is the case, notably for certain sub-contractors, such as suppliers of large castings or forgings, who have been faced with full order books for conventional items that are less exacting. Further discussions between governments, utilities and the industry should serve to dispel reservations that have existed in this regard.

X. EXPORT IMPLICATIONS

Approximately two-thirds of the cost of a nuclear power station is for on-site construction and civil works. Accordingly, export opportunities related to the sale of CANDU abroad will be mainly for engineering services and specialized equipment. Nevertheless, a significant participation by Canadian industry in the CANDU export program could provide important benefits in helping individual companies to amortize the costs of plant expansions and upgrading of capabilities to meet nuclear standards as well as filling gaps in orders for the domestic program. It could also bring about indirect benefits in terms of enhancement of the international reputation of Canadian industry as a supplier of high technology equipment which would indirectly assist the export marketing of other equipment.

The major export opportunities will be in the supply of specialized NSSS components for which Canadian industry has a technological lead at the moment. There will be comparatively fewer opportunities for the sale of the conventional PGS equipment in view of the widespread international capability in this area. Export marketing should provide an opportunity for an expanded role on the part of Canadian engineering and consulting firms, working in conjunction with AECL, as foreign utilities have not yet acquired the specific experience or expertise that some Canadian utilities have in the design and construction of CANDU reactors.

To a large extent, Canadian industry participation in the CANDU export program will depend on the financial and technological resources of the purchasing country. Sales of equipment and services to developing countries without financial resources of their own will be governed by the amount of export financing provided by Canada. Other developing countries, with substantial financial resources, could pursue a much more independent policy with regard to the purchase of conventional equipment and some of the NSSS components from third countries. There may also be opportunities for CANDU sales to certain industrialized countries not yet committed to a nuclear power technology of their own. Such countries could be in a position to provide the bulk of equipment required from their own capabilities or from traditional suppliers, and would therefore be more interested in license agreements providing for the supply from Canada of only the essential technology and perhaps certain highly specialized items of equipment. Thus in most cases, while the export of CANDU to a particular country could result in <u>initial</u> large orders for Canadian

.../38

equipment and services, subsequent exports would involve a decreasing level of Canadian content as the purchasing country would gradually add more and more components from its production or from third countries.

The overriding factor which will have a direct bearing on the level of Canadian engineering and equipment exports for CANDU sales abroad is the availability of export financing. Given the heavy domestic capital requirements, combined with the large capital cost for nuclear stations (approximately $300 million each), it seems doubtful that export financing on a large scale could be made available without diverting financial resources from other domestic and export needs.

In view of the foregoing considerations, a level of Canadian nuclear exports equivalent to one reactor per year for the next ten years appears to be a reasonable estimate. An export program of this size will not significantly affect Canadian industry's ability to meet domestic requirements.

.../39

APPENDIX A

ESTIMATED REQUIREMENTS FOR CANDU REACTORS

1974 - 83

DOMESTIC POWER STATIONS

Construction Time and Start-Up Dates

	74	75	76	77	78	79	80	81	82	83
Bruce A										
1 x 750 MW	...	...	x							
1 x 750 MW	...	...	...	x						
1 x 750 MW	...	...	...	...	x					
1 x 750 MW	x	...	...	...	...	x				
Pickering B										
1 x 500 MW	x	...	...	...	...	...	x			
1 x 500 MW		x	...	...	...	...	...	x		
1 x 500 MW			x	...	...	...	...	...	x	
1 x 500 MW				x	...	...	...	...	...	x
Bruce B										
1 x 750 MW		x	...	...	...	...	...	x		
1 x 750 MW			x	...	...	...	...	...	x	
1 x 750 MW				x	...	...	...	...	...	x
1 x 750 MW					x	...	...	...	...	...
Darlington										
1 x 750 MW			x	...	...	...	...	...	x	
1 x 750 MW				x	...	...	...	...	...	x
1 x 750 MW					x	...	...	...	...	...
1 x 750 MW						x	...	...	...	...
Gentilly										
1 x 600 MW (II)	x	...	...	...	...	x				
1 x 600 MW (III)			x	...	...	...	...	x		
New Brunswick										
1 x 600 MW		x	...	...	...	...	x			
1 x 600 MW			x	...	...	...	...	x		

.../40

APPENDIX A

ESTIMATED REQUIREMENTS FOR CANDU REACTORS

1974 - 83

DOMESTIC POWER STATIONS

Construction Time and Start-Up Dates

Future Domestic	74	75	76	77	78	79	80	81	82	83
1 x 750 MW					x......................x					
1 x 750 MW					x......................x					
1 x 750 MW						x......................				
1 x 750 MW						x......................				
1 x 750 MW							x.................			
1 x 750 MW							x.................			
1 x 750 MW							x.................			
1 x 750 MW							x.................			
1 x 750 MW								x.............		
1 x 750 MW								x.............		
1 x 750 MW								x.............		
1 x 750 MW								x.............		
1 x 750 MW									x.........	
1 x 750 MW									x.........	
1 x 750 MW									x.........	
1 x 750 MW									x.........	
1 x 750 MW									x.........	
1 x 750 MW										x....
1 x 750 MW										x....
1 x 750 MW										x....
1 x 750 MW										x....
1 x 750 MW										x....
1 x 750 MW										x....

.../41

APPENDIX A

ESTIMATED REQUIREMENTS FOR CANDU REACTORS
1974 - 83
EXPORT MARKET

Construction Time and Start-Up Dates

	74	75	76	77	78	79	80	81	82	83
Argentina										
1 x 600 MW		x....	....	....	....	....	x			
1 x 600 MW (Proposed)				x....	....	....	....	....	x	
Korea										
1 x 600 MW			x....	....	....	....	....	x		
1 x 600 MW (Proposed)					x....	....	....	....	....	x
Future Export										
1 x 600 MW			x....	....	....	....	....	x		
1 x 600 MW				x....	....	....	....	....	x	
1 x 600 MW					x....	....	....	....	....	x
1 x 600 MW						x....	....	....	....	....
1 x 600 MW							x....	....	....	....
1 x 600 MW								x....	....	....
1 x 600 MW									x....	....
1 x 600 MW										x....
1 x 600 MW										

.../42

APPENDIX A

ESTIMATED REQUIREMENTS FOR CANDU REACTORS

1974 - 83

HEAVY WATER PLANTS

	Construction Time and Start-Up Dates									
Gentilly	74	75	76	77	78	79	80	81	82	83
1 x 400 Ton	x	....	....	....	x					
1 x 400 Ton		x	....	....	....	x				
OHEPC										
1 x 400 Ton	x	....	....	....	x					
1 x 400 Ton	x	....	....	....	x					
1 x 400 Ton		x	....	....	....	x				
1 x 400 Ton		x	....	....	....	x				
1 x 400 Ton		x	....	....	....	x				
1 x 400 Ton		x	....	....	....	x				
Other Future (AECL)										
1 x 400 Ton					x	....	....	....	x	
1 x 400 Ton						x	....	....	....	x