THE ROLES PLAYED BY THE CANADIAN GENERAL ELECTRIC COMPANY'S ATOMIC POWER DEPARTMENT IN CANADA'S NUCLEAR POWER PROGRAM: WORK, ORGANIZATION AND SUCCESS IN APD, 1955 - 1995

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ABSTRACT

The Roles Played by the Canadian General Electric Company's Atomic Power Department in Canada's Nuclear Power Program: Work, Organization and Success in APD, 1955 -1995

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This thesis explores the roles played by the Canadian General Electric Company's Atomic Power Department (APD) in Canada's distinctive nuclear power program. From the establishment of APD in 1955 until the completion of the KANUPP project in Pakistan in 1972, the company's strategy encompassed the design, manufacture, and commissioning of entire nuclear power projects in Canada and abroad. APD then developed a specialized role in the design and supply of complete nuclear fuel handling systems, nuclear fuel bundles, and service work, that sustained a thriving workplace.

Five key factors are identified as the reasons behind the long and successful history of the department:

-- Strong, capable and efficient management from the start,

-- Flexible organizational structure,

-- Extremely competent design group,

-- Excellent manufacturing, test, commissioning and service capabilities,

-- Correctly identifying, at the right time, the best fields in which to specialize.

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Peter Wylie

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To all of the CGE Nuclear staff, current and retired, the author expresses thanks for your contributions, not only to this thesis, but more importantly to the advancement of Canada's nuclear industry. It was always an honour for me to be part of the team.

ABBREVIATIONS

AECB:	Atomic Energy Control Board
AECL:	Atomic Energy of Canada Limited
APD:	Atomic Power Department (CGE)
ASME:	American Society of Mechanical Engineers
BLW:	Boiling Light-Water (Reactor)
CANDU:	Canadian Deuterium Uranium (Reactor)
CAPD:	Civilian Atomic Power Department (CGE)
CGE:	Canadian General Electric Company
CRNL:	Chalk River Nuclear Laboratories
F/H	Fuel Handling
GE:	General Electric Company
KANUPP:	Karachi Nuclear Power Plant (Pakistan)
NPD:	Nuclear Power Demonstration
NPG:	Nuclear Power Group
NPPD:	Nuclear Power Plant Division
NRC:	National Research Council of Canada
NRU:	National Research Universal (Reactor)
NRX:	National Research Experimental (Reactor)
OCDRE:	Organic-Cooled Deuterium-Moderated Reactor -- Experimental
OCR:	Organic-Cooled Reactor
OH:	Ontario Hydro
OTR:	Organic Test Reactor
PEng:	Professional Engineer
PHW:	Pressurized Heavy-Water (Reactor)
PRG:	Power Reactor Group
PWR:	Pressurized Light-Water Reactor
RAPP:	Rajasthan Power Projects
WNRE:	Whiteshell Nuclear Research Establishment
WR-1:	Whiteshell Reactor No. 1
ZEEP:	Zero Energy Experimental Pile

NOTE: The principal participants in Canada's nuclear power program have undergone numerous organizational and corporate name changes since the program's beginnings in 1955. Their most familiar names in the time period covered in this thesis were: AECL, Ontario Hydro, and CGE, and these for the most part are the names used here.

In 1955, CGE's nuclear department was called the "Civilian Atomic Power Department" (CAPD) but in 1965 the name changed to "Atomic Power Department" (APD) and for simplicity that is the title generally used throughout this thesis.

In the late 1980s, "Canadian General Electric Company" changed its name to "GE Canada" and the Peterborough plant's name became "GE Peterborough." All three of these names appear in this thesis. The American parent company's name remained unchanged: "General Electric Company" or "GE Company."

CHRONOLOGICAL CHART SHOWING APD STAFFING ACTIVITIES & LEVELS

1955: Department formed with small core (approx. 30) mix of former AECL staff, CGE employees, and attached Ontario Hydro personnel to start design of the NPD station.

1957: Design restarted (NPD 2).

1958: Staffing levels over 100, mostly design personnel.

1961: NPD design work nearly finished, main activities manufacturing and supply, construction and commissioning. Douglas Point fuel and fuelling machine manufacture in progress. Design staff busy on proposal work, organically-cooled reactors (OCRs), and design/development studies.

1962: NPD in service. Design starts on Whiteshell reactor (WR-1). Staff continue proposal work and design studies, especially the development of improved fuelling machines featuring electric motors and ballscrew drives to replace existing hydraulic drives. Success of development work eventually leads to incorporation of improved drives, etc. into replacement fuelling machines for NPD, and later, KANUPP.

1965: Start design of KANUPP station; work continues on WR-1, proposals, and development of components for larger fuelling machines based on KANUPP design.

1970: Join forces with AECL's fuel handling group and start design of Bruce A fuel handling system plus 600 MW fuel handling work packages.

1976: Start design of Bruce B; work continuing on Bruce A design and supply plus 600MW equipment.

1978: Start design of Darlington fuel handling system; work on the Bruce and 600MW continues. Start of build-up to maximum workload in department's history.
Number of employees exceeds 400.

1980s: As the Darlington work nears completion, staff levels drop during the late 1980s.

1990s: Most new F/H work is service work (rather than fuel handling systems) requiring a small number of staff in design, supply and test.
Fuel manufacturing continues but automated facilities reduce shop floor manpower to a minimum while maintaining technical support and quality control staff. Total number of APD employees: less than 200.

INTRODUCTION

Peterborough, Ontario, is located roughly 110 kilometres north-east of Toronto on the Trent-Severn Waterway in the Kawartha Lakes tourist area. Incorporated as a city in 1905, its population in 1955 was approximately 40,000[1], and by 1995, over 60,000. Home of Trent University, and Sir Sandford Fleming College, it also contains several large manufacturing companies, such as GE Canada Incorporated, The Quaker Oats Company of Canada Limited, and Fisher Gauge Limited.

Since 1955, GE Canada's plant in the city has played a major part in Canada's nuclear program. The employees of its Atomic Power Department[2] have made significant and major contributions, arguably unique, to the design, manufacturing, testing and commissioning of nuclear power system equipment for reactors operating in Canada -- primarily in Ontario, but also in Manitoba, Quebec, New Brunswick -- and in other countries, e.g. Argentina, South Korea, and Pakistan.

Many of the individuals who came together in Peterborough to form the original design group, and those who followed later in the manufacturing/ testing/commissioning units, stayed together as a closely-knit team until they reached retirement. Their labours in building Canada's nuclear power industry have never been fully acknowledged, their story never told. One aim of this thesis is to redress these omissions and illustrate the importance of their

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[1] 1951 census: 38,272; 1986 census: 61, 049.

[2] See Glossary for the Department's various name changes.

contributions.

The story of GE Canada's role in Canada's nuclear power program parallels and is often interwoven with that of Atomic Energy of Canada (AECL) the crown agency established by the federal government in 1952. In fact, some founding members of the core group in Peterborough came to the city from AECL's Chalk River facility, and a number of GE people have, over the years, joined the staff of AECL.

During the late 1980s, AECL management recognized the need for the writing of the history of that company before too much time had elapsed and while the individuals involved were still available for consultation. To accomplish this, they enlisted the services of noted Canadian historian Professor Robert Bothwell of the University of Toronto. The result is an excellent book, Nucleus: The History of Atomic Energy of Canada Limited. Writing in the foreword to this book, James Donnelly, then President of AECL, notes:

> Nothing is as perishable, or as forgotten, as the recent past. This phenomenon is as true of companies as it is of individuals. As I discovered when I became president, . . . the usable memory bank of a large company may go back five years, or ten, but in the nature of things it is confined to the recollections of the employees who have had the opportunity, and the time,to dwell on the past and its meaning. As retirements and death took their toll, AECL's corporate memory was dwindling and our company faced the prospect of losing its history. In my view it is important that this should not happen.[3]

These remarks sparked my interest -- as a former member of the CGE nuclear department -- in enlisting the assistance of former colleagues in

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[3]James Donnelly, "Foreword," Robert Bothwell. Nucleus: The History of Atomic Energy of Canada Limited. (Toronto: University of Toronto Press, 1988) xii

researching, documenting, and preserving, its (and their) story.

The principal aims of this thesis are twofold. First, to document the history of the operations of the Nuclear Department of GE Canada over the forty-year period, 1955-1995, and second, to use this historical background as the context in which to describe and assess the importance and significance of the roles played by the Department and its people in Canada's nuclear power program.

These various roles can be summarized here as follows:

The department was:

-- Selected as the prime contractor for the first nuclear power demonstration (NPD) plant in Canada, in 1955.

-- The major private enterprise in the Canadian nuclear power program, continuously for over forty years, starting from its inception.

-- The only company in Canada with proven capability to design, manufacture, test, install and commission complete fuel handling systems.

-- An active partner with Atomic Energy of Canada Ltd and Ontario Hydro in nuclear power system design and commissioning.

-- Able to manufacture and test fuelling machines and associated equipment designed by AECL, in addition to those of its own design.

-- Recognized by AECL and Ontario Hydro for its expertise in nuclear matters and technical competence as borne out by its continuing selection by those companies for design and manufacturing contracts.

-- The only Canadian company to handle a turnkey contract for an overseas nuclear power plant, KANUPP in Karachi, Pakistan.

To acquire and retain these roles, the Department constantly evolved, adapted, and changed, developing the organizational structure, technological capabilities and expertise it needed to ensure its survival. Starting from the Department's formation in the mid-fifties when the new technology was popular with the general public -- through to the mid-nineties when nuclear power had fallen out of public favour -- this was a major accomplishment. [4]

Operating as a component of a privately-owned company, the department's survival depended at all times on its success in obtaining work for its staff, often in direct competition with their counterparts at AECL and Ontario Hydro, agencies of the federal and provincial governments, with their much greater financial and technical resources. As a result, and as might be expected, the department's operating history has not been an unbroken stream of successes; on the contrary, it has enjoyed many high points and endured its share of low points over the years. As this thesis will demonstrate, the department successfully overcame its setbacks by continually adapting to its changing role in Canada's nuclear power industry, resulting in its survival as an important and unique participant in that industry.

The Department, although a subsidiary of the General Electric Company (GE) of the United States, maintained its Canadian identity in its nuclear operations throughout the forty-year period, performing completely separately from its parent company by adopting and pursuing the CANDU system design

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[4] Bernard L. Cohen, Before It's Too Late: A Scientist's Case for Nuclear Energy, (New York: Plenum Press, 1983) 256.

rather than the U.S. light-water reactor designs. [5]

The history of APD's operations can be examined and assessed from several aspects. Those selected are later described in detail by this thesis, and summarized here as follows:

a) Organizational theory -- i.e. how CGE management established, organized, and staffed an entirely new department in order to enter the nuclear business.

b) Business strategy -- i.e. how it operated.

c) Workplace culture -- i.e. what was special and different about APD's culture.

d) Technological innovation -- i.e. APD's involvement, influence and contribution to the technological aspects of the CANDU program.

e) Impact on Peterborough -- i.e. how the city was affected by the arrival of the new department and its accompanying workforce.

<u>A Note Re Sources Cited</u>:

Due to the very limited archival material and historical literature available concerning the detailed operations of APD during the years 1955 - 1995, considerable use is made of interviews and discussions with those people personally involved at APD during that period -- supported by their personal files -- plus technical reports, journals, in-house newsletters and newspaper articles of that time, supplemented by secondary material dealing with associated

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[5] This is an interesting example of independent technological expertise surviving, and flourishing, in the frequently complex relationships between Canadian subsidiaries and their parent American-owned companies as discussed in Graham Taylor's "Charles F. Sise, Bell Canada, and the Americans: A Study of Managerial Autonomy, 1880-1905," Canadian Historical Association, <u>Historical Papers</u>, (1982), 11-30.

aspects of the nuclear industry.

As can be seen in the bibliography there are many books covering just about every aspect of global nuclear energy, but relatively few dealing in detail with the Canadian aspects. The three most relevant books covering Canada's nuclear history are:

Nucleus: The History of Atomic Energy of Canada Limited., R. Bothwell;

Canada Enters the Nuclear Age: A Technical History of AECL, D. Hurst et al.;

Nuclear Pursuits: The Scientific Biography of Wilfrid Bennett Lewis, R. Fawcett.

Accordingly, extensive reference is made to these sources.

2.0 ORIGINS OF CANADA'S NUCLEAR POWER PROGRAM

Canada's involvement in the science of nuclear energy dates back to the pioneering work of Ernest Rutherford, at McGill University, in the early 1900s, but its first significant involvement in the application of that science occurred during the years of the Second World War as an adjunct of the British and American nuclear weapons programs. In 1941, the United States negotiated long-term purchases of Canadian uranium and heavy water, and in 1942 Canada acceded to requests from the British government for assistance in the continuation of its heavy water/uranium research. Canada agreed to house the British team of scientists and supply laboratory facilities plus scientific support through its own scientific arm, the National Research Council (NRC). Dr. C.J. Mackenzie, at that time the president of NRC, welcomed this move, foreseeing the potential advantages for Canada, namely, a head start in a field with major peacetime applications including a new source of energy, and Canada becoming a supplier of uranium.[6]

In 1944, the Canadian government established nuclear research laboratories at Chalk River, Ontario, and it was there, in 1945, that the first reactor outside the United States, "ZEEP" (Zero Energy Experimental Pile), became operational. ZEEP was followed by the much larger research reactors NRX (1947) and NRU (1957). Each of these reactors used natural uranium as fuel and heavy water for its moderator,[7] the design concept -- later to be called CANDU (CANada,

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[6]D.G. Hurst. "Introduction." Canada Enters the Nuclear Age: A Technical History of Atomic Energy of Canada Limited. (Montreal: McGill-Queen's University Press, 1997) 4.

Deuterium - Uranium) -- on which Canada had developed considerable expertise due to continuous research and development dating back to NRC's first involvement in 1942.

By the early 1950s, as the Chalk River staff were becoming increasingly involved in the emerging nuclear power program, the Canadian government decided it needed to establish a new agency more suited to handling this type of work and to replace the purely research-oriented NRC.[8] In 1952, it formed Atomic Energy of Canada Limited (AECL), a crown corporation. Its mandate was to research, and in conjunction with the power utilities and private industry, explore the peacetime applications of atomic energy. The success of the Canadian research reactors, using the relatively simple CANDU concept, indicated that this type of system would be a logical choice for Canada's power reactors. However, as Wilfrid Eggleston observes, a number of other systems were explored and if any one of them had promised better results under Canadian conditions it would have been chosen. Power reactor feasibility

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[7]In a nuclear reactor, atomic energy is obtained from the fission process, i.e. the splitting of uranium atoms. Fission occurs when an atomic particle (called a neutron) collides with a uranium atom, producing more neutrons and large amounts of heat energy. The collision of these neutrons with other atoms produces still more neutrons, eventually leading to a self-sustaining chain reaction. However, the high speeds at which the neutrons travel greatly reduces the probability of fission occurring, so their speeds must be reduced, or moderated, by means of a material called the moderator. There are a number of materials which can be used as the moderator, e.g. graphite, light water, and heavy water (Deuterium Oxide). A moderator of high efficiency, such as graphite or heavy water, is essential for use with natural uranium fuel in the fission process.

[8]Hurst, 6

studies at Chalk River involving AECL and power utilities' representatives started in 1953. After very thorough debate it was decided that the CANDU design concept appeared superior to all the others for the Canadian nuclear program, and early in 1954 a Nuclear Power Branch was established to set the guidelines for Canada's first power reactor, a demonstration prototype.[9]

At that time, the power utilities, especially Ontario Hydro, facing challenging post-war power demand growth were very interested in the potential of nuclear power for the generation of electricity, especially if its cost was competitive with coal-powered stations, one of the benchmarks for the nuclear designers. [10] Until 1960, approximately 90% of Canada's electrical generating capacity was provided by water power. At first, sites such as the Niagara Gorge, near the load centres such as Toronto, were developed. But as demand continued to rise, and as transmission technology advanced, more remote sites were used. However, by the early 1950s it became clear that when all economically feasible water power sites had been developed, they would not meet the predicted demand.[11] Thermally-based generation would be needed to supplement water power. This led to the serious consideration of nuclear energy as a means of producing the required electrical power.

Ontario became the first province to use the CANDU reactor for electrical power generation. It sought a power source which would be secure far into the

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[9]Wilfrid Eggleston. Canada's Nuclear Story. (Toronto: Clarke, Irwin, 1965) 311-15.
[10]Ruth Fawcett. Nuclear Pursuits: The Scientific Biography of Wilfrid Bennett Lewis . (Montreal: McGill-Queen's University Press, 1994) 89.
[11]Eggleston, 309.

future because all of its fossil fuels had to be imported, either from the United States (for most of the coal) or from western Canada (for most of the oil, natural gas, and some coal). The absence of indigenous fossil fuels, together with the presence in Ontario of economically-mineable uranium, completed a set of circumstances favorable to the development of nuclear power.[12] When it appeared that nuclear power offered the only foreseeable long term prospect for secure and economical power production, Ontario Hydro cautiously embarked on its program of nuclear power station construction in southern Ontario.

Before starting on the design and construction of its first commercial nuclear power station, Ontario Hydro joined with AECL in the decision to build two smaller prototype stations to demonstrate the feasibility, practicality, and safety of the CANDU design. The first of these stations -- "Nuclear Power Demonstration" or NPD for short -- would be handled by a tripartite organization. AECL would be responsible for the strictly "nuclear" design segment; Ontario Hydro would be the operator. The role of prime contractor, responsible for the design, supply, installation and start-up of the station, would be awarded to private industry. Bothwell explains that this arrangement was in accordance with the views of C.D. Howe, the minister responsible.

> In Howe's view, AECL's real purpose was research and development. Granted, it was research and development towards an appointed end, nuclear power. But nuclear power, once achieved, should be turned over to private industry for manufacture, and to the utilities that would be expected to buy it. [13]

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[12] Rea, <u>The Prosperous Years: The Economic History of Ontario 1939-1975</u>. (Toronto: University of Toronto Press, 1985) 39, 169 - 172.
[13] Bothwell, <u>Nucleus</u> , xiv.

In December 1953, AECL's board approved funding for a joint feasibility study with Ontario Hydro. The resulting team -- the Power Reactor Group (PRG) -- contained scientists and engineers from AECL, Ontario Hydro, and the Montreal Engineering Company. One year later, invitations to bid for the role of prime contractor were issued, and by the beginning of March 1955 replies had been received from several major companies, including Canadian Vickers, Dominion Bridge, John Inglis, Orenda, Canadair, and Canadian General Electric. Their proposals were judged on their capability to handle the work -- which quickly eliminated several companies -- and the contribution each company would make towards the project. On this second point, the outstanding bid was from the Canadian General Electric Company. In addition to its proven engineering and manufacturing capabilities, it offered to contribute $2 million in design and development services towards the estimated total cost of $13 million for the project. AECL's board approved CGE's bid, and recommended its acceptance to C.D. Howe. At a meeting on March 23, 1955, Howe submitted his proposal for the establishment of Canada's nuclear program -- a joint AECL-Ontario Hydro-CGE arrangement -- to the federal cabinet. His submission was approved without modification. [14]

Canadian General Electric at that time was one of Canada's largest manufacturing companies with plants and sales offices all across the country. Its Peterborough plant, dating back to 1891, was built to design and manufacture a wide variety of products, ranging from small electrical products, to large

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[14]Bothwell, Nucleus, 206-10.

equipment such as streetcars and massive waterwheel generators. Through the years, the plant had continually expanded and diversified its product range mostly for industrial and commercial applications, but also for many years consumer products including refrigerators.

The greatest expansion of the plant occurred during the 1940s and 1950s due to the war effort and the post-war boom. New buildings were constructed for the production of military equipment, almost doubling the plant size, and the workforce tripled in size during this decade to a maximum of approximately 5000. In 1948 it opened its giant Building 10, one of the largest and best-equipped machine and assembly shops in Canada. [15]

As a long-established and dynamic company, CGE has always explored ways to expand, searching for favourable new markets and striving for leadership in its various fields. In 1955, it recognized the potential opportunities offered by entering, at the start, the nuclear power program in Canada. The company had the necessary resources, financial, technical, and manufacturing, to embark on a completely new, for it, enterprise which appeared to have a most promising and profitable future. It made a bold bid for partnership with AECL and Ontario Hydro, and was successful.

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[15]McLaren, Standards of the Highest, 24-28.

3.0 THE HISTORY OF CGE'S NUCLEAR DEPARTMENT

3.1 SYNOPSIS [16]

The Civilian Atomic Power Department of Canadian General Electric was formed in 1955 to participate in the development, design, and construction of the 20 MWe Nuclear Power Demonstration Generating Station (NPD) in conjunction with the Research Division of AECL and the Thermal Division of Ontario Hydro.

The company foresaw the NPD project as the entry into a promising new high technology field which fitted well with its existing business scope in the energy field and matched its strategic plan for continued growth. It was the company's understanding at the time that CGE would be in an enviable "first-in" position and free to pursue domestic and foreign nuclear power station business. For these reasons the Company committed resources of its technical manpower and facilities to the project. Although these employees were highly skilled, most lacked experience in nuclear work. To help remedy this shortcoming, AECL permitted CGE to hire a small number of its experienced Chalk River staff to act as key members of CAPD's nucleus design-development staff. In addition, intensive in-plant, university-level training courses were implemented to quickly instruct all of the design staff on the details of the CANDU system, and the special requirements of nuclear work in general. These included basic nuclear science, reactor and fuel design, radiation safeguards, the effects of radiation on

[16]Compiled from CGE internal documents recording CGE's history in the Nuclear Business -- edited to remove areas and and items of a confidential nature -- augmented and corroborated by interviews with former senior managers of the Department including P.D. Scholfield, K.G. Zimmermann, A.C. Hoyle, and R.L. Beck. Access to this confidential material was granted the author by CGE.

materials, shielding requirements, special instrumentation, fail-safe and back-up systems, special quality control measures, etc.

Starting virtually from scratch, CGE's nuclear fuel design and manufacturing business was created during this NPD design and development period. Techniques for welding the critical zirconium alloy fuel sheathing were developed in Peterborough while, in parallel, the development of the UO_2 fuel pellets was carried out at CGE's Carboloy tool plant in Toronto.[17] AECL provided technical assistance using the metallurgical and chemical expertise gained from its research reactors at Chalk River.

The NPD station was completed and commissioned in 1962.[18] By all standards of the then-existing technology it was successful. Most importantly for the entire CANDU program's future, the CGE-designed fuelling machines and fuel handling system demonstrated that O/H engineer Harold Smith's daring concept of "bi-directional on power refuelling" of a nuclear reactor operating at electric power steam generating conditions was both practicable and economical.[19] NPD continued to operate and serve as a major operator training facility, fuel-testing facility and a reliable producer of electric power for many years, operating until 1985 and finally taken out of service in 1989.[20]

In 1958, concerned about the future commercial aspects of falling behind the American and British nuclear programs, AECL and Ontario Hydro decided to

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[17] P. D. Scholfield. Personal Interview, February 6, 2001. (For title see p. 161)
[18] Original and unrealistic timetable date :1959. See Bothwell, Nucleus, 231.
[19] Fawcett, 101
[20] H. K. Rae. "Candu Development," Canada Enters the Nuclear Age, (Montreal: McGill - Queen's University Press, 1997) 197.

accelerate the Canadian nuclear power construction program by proceeding with the design and construction of a 200 MWe nuclear generating station at Douglas Point, on the shores of Lake Huron. To plan it, in conjunction with Ontario Hydro, AECL established the Nuclear Power Projects Division (NPPD) in Toronto and offered industries and other utilities the opportunity to lend engineers to the division to gain nuclear experience -- in direct competition with CGE.

CGE was not given the opportunity to design Douglas Point partly because its staff was heavily engaged in the design and construction of NPD, but mainly due to this major shift in the nuclear program's organizational structure following the 1957 defeat of the federal Liberal government, the exodus of Howe and his nuclear policies.[21] After NPD, there would be no further tripartite arrangements between AECL, Ontario Hydro and private industry. For future Ontario Hydro projects, the role of industry would be secondary only, in support of the provincial utility and AECL. Since AECL had to create and develop a design staff for the Douglas Point project, as opposed to an expansion of the already established and now moderately experienced APD organization, the move must be interpreted as a change in policy by Ontario Hydro to greatly reduce the role of CGE and to minimize the company's very real potential for dominating the Canadian nuclear industry.

In a way, NPD was an aberration; Ontario Hydro's preferred way of designing and building its power stations was by using its own staff for the design, and then negotiating and supervising contracts with equipment suppliers. It had

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[21]Bothwell, Nucleus, 239-40.

established teams to do this for its hydraulic and coal-powered stations, and in conjunction with AECL was repeating the process for future nuclear stations by setting up NPPD.[22] By returning to its former practices, Ontario Hydro had also ensured that it would not be too dependent on a sole supplier.

From 1960 onwards, as the NPD design load at CGE progressively decreased, it became an urgent matter for the Company to find other projects on which to employ its nuclear design team effectively. An "organically cooled" reactor project appeared to be a logical contender as a follow-up to NPD. The NPD work had shown that substantial cost and complexity were associated with containing the high temperature-high pressure heavy water used as the reactor coolant and heat transfer medium. Because of their low vapour pressure at high temperature, organic liquids appeared to offer an attractive alternative as a reactor coolant while still retaining cool heavy water as the moderator and natural uranium as the fuel.

CGE undertook a number of reactor design studies incorporating such coolants. The results showed sufficient promise that AECL decided in 1962 to construct a heavy water-moderated, organic-cooled experimental/research reactor. The site selected was WNRE, AECL's new research centre at Whiteshell, in Manitoba. CGE undertook the project on a firm price basis. The sales-billed value of this project, including the fuel supplied was approximately $14 million.[23]

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[22]Gordon H.E. Sims. "The Evolution of AECL." M.A. Thesis, (Carleton University, 1979) 113.
[23]CGE internal documents, located in the APD Archives, GE Peterborough.

The Whiteshell reactor was completed by CGE within the budgeted price and very close to the schedule. The reactor first went critical in 1965 and within a short period was at full power. This reactor system more than fulfilled its designers' hopes. In addition to eliminating the concerns and costs associated with leakage of heat transport system heavy water, the reactor demonstrated that higher coolant temperatures and therefore a more efficient turbine steam cycle were possible.

In 1964, prior to successful operation of Douglas Point (1968), Ontario Hydro indicated its intentions of building a larger multi-unit station. CGE pressed for an opportunity to participate in the design and presented to senior Ontario Hydro staff a preliminary proposal for design and construction of a four unit, 2000 MWe station to be built in stages. Estimates for the first two units were tabled and the Company offered to submit a firm price proposal for the complete design, supply and construction of the units. However, after substantial provincial and federal government funding was made available (28 and 32 percent cost sharing of the project respectively) for the first two units, Ontario Hydro committed itself to constructing the Pickering station on the northeast boundary of the Toronto metropolitan area [24] AECL Power Projects Division was given the engineering responsibility for the nuclear steam supply system portion of the station and Ontario Hydro undertook responsibility for the balance of the plant. CGE bid on the manufacture of many of the components, but without a broader base of business on which to liquidate its large engineering and support staff it was

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[24]H.K.Rae. "CANDU and Its Evolution." Canada Enters the Nuclear Age. 200.

generally not competitive against straight manufacturing companies. Fuel bundle manufacture was an exception.

In 1965, the federal government, the government of Quebec, and Hydro-Quebec reached an agreement on financing a 250 MWe prototype reactor to be built at Gentilly, Quebec.[25] CGE had argued strongly that this should be of the organic-cooled type which was performing so well at Whiteshell and which offered such attractive cost and performance benefits. However, AECL studies indicated their candidate, a boiling light water cooled, heavy water moderated reactor (CANDU-BLW) would be equally or marginally more attractive. Although unproven as a concept, the boiling light water reactor was selected and the Power Projects Division was given the responsibility for this project also, in addition to the Pickering work.

In 1966, the Power Projects Division moved from its temporary quarters to the new offices and laboratories at Sheridan Park, in Mississauga. Initially, AECL officials claimed that the vast laboratory facilities would be available to industry on a rental basis. This did not come to pass, and the Division grew rapidly in quite a monopolistic fashion. Indeed, it can be said that what AECL set out to prevent in the manufacturing sense, they created in the design and and development sense within its own engineering division.

It had already become obvious to CGE that it could not play a designer/ supplier role for the domestic market, so it then mounted a major export sales

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[25]R.G. Hart. "Boiling-light-Water and Organic-liquid-cooled CANDU Reactors." Canada Enters the Nuclear Age . 323.

campaign. Its first success was a 137 MWe reactor for Pakistan, known as KANUPP, in 1965, following close to two years of preliminary design and negotiations. This was a firm price, turnkey project, and it was carried out within the contract price despite the Indo - Pakistani war, civil insurrection within Pakistan, and major unforeseen inflation.[26] Completion of the station was delayed by the above factors until 1972. The station, manned entirely by Pakistanis with key personnel trained in Canada, has proved to be a reliable power producer for the Karachi grid. During its many years of operating, the CGE-designed reactor did not have the tubing problems experienced by the AECL-designed reactors at the Pickering and Bruce stations.[27]

From 1965 to 1968, substantial effort was directed at improving the product CGE was offering, and reducing its cost. In particular, CGE invited an international team of twenty engineers and scientists to work in Peterborough on the design and costing of a large, vertical, heavy water cooled reactor (VHWR). In international bidding, this reactor proved to be competitive with the British and American offerings. Two major opportunities subsequently developed, Finland and Argentina, but both failed to materialize for reasons other than price or confidence in the product.[28]

A number of factors help explain why CGE was successful in obtaining the KANUPP contract but unsuccessful with the bids for projects in Finland and Argentina. First, Pakistan, acutely aware that India had purchased two

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[26]A. C. Hoyle. Personal Interview, February 14, 1997. (For title see p.160)
[27]P. D. Scholfield. Personal Interview, February 6, 2001. (For title see p.161)
[28]R. L. Beck. Personal Interview, February 13, 2001. (For title see p.160)

Canadian-designed reactors (RAPP I & I I) from AECL in 1963, wanted to enter the nuclear power field itself, and quickly. It sought from Canada a firm price, tightly-scheduled package deal for a small reactor station to be completed in 52 months. These requirements, necessitating an experienced and capable supplier, could be met by CGE, and at that time its nuclear department needed the work to keep its workforce busy. Another important factor was that a very busy AECL was quite willing to let CGE handle the work with AECL acting in a subsidiary role.[29] By contrast with Pakistan, Finland and Argentina were not as eager or willing to commit their countries to a quick-contract settlement with CGE or any other bidder. Furthermore, AECL was interested in acquiring the Argentina project itself. This experience confirmed to CGE that political, international trade, and financing factors overruled technical excellence, and that heavy Canadian government involvement in these areas would be required to conclude a successful foreign sale.

The Company also recognized that the very high marketing expenses, hundreds of thousands of dollars annually, could not be supported without a solid domestic base. Since the solid base had been pre-empted by AECL, and since the necessary government involvement was presumably more readily available to a federal agency such as AECL, the Company was forced to the difficult decision of withdrawing from the export market and from the design and supply of complete nuclear steam systems.

In July 1968, the Canadian government, through AECL and after discussions

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[29]Bothwell, Nucleus, 382-4.

with CGE, undertook the sole responsibility for worldwide marketing of the Canadian nuclear power stations. At the same time, CGE and AECL reached an agreement whereby AECL would use the Company's nuclear systems engineering group for a period of five years. AECL would use this group of approximately two hundred technical people primarily in support of its foreign marketing activities, but also as required to back up its own engineering team at Sheridan Park on active Canadian nuclear projects such as Pickering, Gentilly, and Bruce.

The terms of this five-year agreement guaranteed full employment of the Company's nuclear systems group for a period of one year and permitted the repurchase by the Company of any engineering time required for pre-agreement commitments such as the KANUPP contract and the contract for the NPD replacement fuelling machines. The agreement also gave AECL the right, after expiry of the first year, to turn back to the Company on reasonable notice any personnel deemed surplus to its work requirements and furthermore, to cancel the agreement completely after six months' notice to the Company.

Although AECL undertook a sincere and costly marketing campaign for the sale of a Canadian power plant, the end of 1969 arrived with tightening federal budget controls and no certain foreign sale in sight. In addition, AECL had not experienced any increase in its Canadian domestic commitments for nuclear power. As a result of this unfavourable situation, AECL informed the Company that approximately one-quarter of the contracted nuclear systems group personnel were surplus to its requirements and that it would not receive financial support from AECL after the end of January, 1970.

In the face of this situation, the Company also accelerated the evaluation of its future in the nuclear business. The conclusion was that CGE's best opportunity lay in capitalizing on its expertise and resources by specializing in the design, manufacture, development, testing, installation, commissioning, and servicing of the fuel handling systems for all of the Canadian designed power reactors, while retaining its separate fuel design and manufacturing operations.

In March 1970, an agreement was reached between CGE and AECL whereby CGE's nuclear systems engineering group was divided into two groups: a Fuel Handling Systems Group and a Nuclear Systems Group. Employees in the latter group were offered employment by AECL. The Fuel Handling Systems Group remained a Company component whose services were contracted to AECL. The manager of this component had a dual responsibility in that he also reported to the AECL fuel handling systems branch, with responsibility for making the AECL-designed fuel handling system work.[30]

The dual management role continued until 1975. However, the Company's Fuel Handling Group continued to work under a new contract from AECL which included the design, development, and installation supervision of the Bruce A and B fuel handling systems together with some work on AECL's 600 MW projects. Negotiations led to direct contracts with Ontario Hydro for the supply of the Bruce A and B fuel handling system equipment. This was followed by

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[30]K.G. Zimmermann. Personal Interview, February 17, 2001. (For title see p.161)

further negotiations with Ontario Hydro leading to CGE obtaining the contract for the complete design, development, manufacture, supply, testing, and installation of the Darlington fuel handling system. This contract, resulting from the successful operations of the Bruce fuel handling systems, re-established a more normal commercial role for the Company, and enabled CGE to make an important contribution to the Canadian nuclear program.

This brief history of CGE's activities in the nuclear field leads to mixed conclusions in respect to what the optimum responsibilities might have been. Unquestionably, AECL had a major and necessary role to play. Without its deep expertise in physics, chemistry, and metallurgy, and its unparalleled developmental capability, there would not be a unique Canadian reactor today. The nature of the development was also such that no Canadian private company or group of companies could have undertaken the risks without government support. AECL was the logical channel for that support.

The early exclusion of the private nuclear system's designer from the domestic market, and thus the export market, left Canada with an AECL that was technically strong but initially lacking in the marketing experience essential for success in the international arena.

In 1977, recognizing the risk that overseas contracts might exclude or severely limit any equipment supplies from Canada, CGE with some other manufacturing companies formed the Canadian Nuclear Equipment Supplies Ltd. (CNES). Working with the federal government and AECL, this group was influential in the establishment of a government Task Force, in May 1978, to identify export opportunities and to define how to utilize all of Canada's considerable resources in nuclear power to participate profitably in export contracts. The Task Force's work was concluded and its report issued in October 1978. The report recommended the strengthening of AECL's marketing capabilities together with increased support and involvement from the federal and provincial governments, utilities, and private industry in the export marketing of CANDU nuclear steam supply systems. Increased industry support was provided by the formation of the Organization of CANDU Industries (O.C.I.) in June,1979, with CGE taking a leading role amongst the 50 founding members. [31]

Over the forty-year period covered in this thesis, the Company has made a significant contribution to the success of the CANDU system. Originally a full partner in the development of the CANDU system, and at one time having the capability to design and construct a complete nuclear station in Pakistan, it now retains a presence in a relatively narrow, but important, segment of nuclear technology and production capability. The foregoing has been merely an outline of APD's history. The following sections of this chapter describe in more detail the department's formation, structure and evolution, and record its accomplishments, successes and setbacks during this period.

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[31] K.G. Zimmermann. Personal Interview, February 17, 2001.

3.2 THE FORMATION OF CGE'S CIVILIAN ATOMIC POWER DEPARTMENT

On April 1, 1955, the Peterborough Examiner's front page headlined: "CGE Plant In PeterboroughTo Build Atomic Power Plant" followed by: "Ian McRae Named To Take Charge Of Development." It then explained that this would be an all-Canadian experimental nuclear power station probably to be located near AECL's Chalk River development in the Ottawa River valley. The plant was expected to produce 20 MW of electrical power and cost between $13 and $15 million. Of this total cost, Ontario Hydro's share would be between $3 and $3.5 million, CGE would absorb a "sizable" portion and the remainder would be paid by AECL.

For most of the city's residents this was the first news of an enterprise which would play a very significant part in their city and province during the next forty years. The next day, Examiner editor Robertson Davies welcomed the news in his editorial: "The Beginning Of A New Peterborough Future: Yesterday's announcement that Canadian General Electric . . . would design and develop the nuclear reactor in Peterborough is as great news for Peterborough as the project is for the whole of Canada." Of McRae's appointment, he added, "We cannot help but believe that his influence, advice and the warmth of his feeling for Peterborough have been significant in the company's decision to concentrate their great new assignment in this city."[32]

The company's selection of McRae to form and head the nuclear department not only virtually ensured its initial success, but also laid the groundwork for

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[32] Peterborough Examiner , April 2, 1955, 4.

many years of successful operations. McRae was vice-president of CGE and had already proven his management skills as Works Manager of the whole Peterborough plant. He had a formidable reputation in Peterborough and was tremendously popular and respected by CGE's workforce. During the Second World War, he had overseen the great expansion of the Peterborough Works and the creation of its wartime division, GENELCO, to manufacture 3.7 inch anti-aircraft guns, searchlights, and other military equipment in addition to its regular production. Later in his career, after leading the company into the nuclear age, he would become Chairman of the Board of CGE, and following retirement, a member of Ontario Hydro's Board.

To start work on NPD, McRae created the Civilian Atomic Power Department (CAPD) and assembled the initial team of approximately thirty experienced scientists, engineers and draftsmen in Building 21 of the Peterborough plant. The nucleus of the design team consisted of former employees of AECL's Chalk River Laboratories who had "nuclear experience" by virtue of having worked on the research reactors there. They moved to Peterborough for the project, but most of them stayed on after its completion, became long-service CGE employees and finished their careers with the company.[33]

Heading the design team, as Manager of Engineering, was Ian MacKay who had led the NRX and NRU team at Chalk River, and who had also been a member of the select Power Reactor Group study team set up in 1954 to determine the feasibility of competitive nuclear power in Canada. Prior to joining

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[33]Ralph Lloyd. Personal Interview, February 11, 1997. (For title see p.161)

AECL, he had served in the Canadian navy as a lieutenant commander and Deputy Director of Naval Ordnance in World War II.[34] Mel Thurling, a long-time CGE employee and senior manager, joined CAPD as its first Manager of Manufacturing. Finance operations were headed by Balfour Duder.

Many difficulties faced McRae and his section managers. First, they had to form a departmental structure suitable for the design, manufacture and construction of this new major project, and staff it with people from various parts of the company, plus new hires from AECL's Chalk River Laboratories and other companies. Second, they did not have a totally free hand in the design and manufacturing phases but had to work on these in partnership with the representatives of AECL and Ontario Hydro, some of whom were seconded personnel working alongside the APD employees. Third, the basic design guidelines were not finalized but evolving. In short, the department was new, many of the staff were new, and the work was new in nature.

However, in September 1956, under the headline "Our Country's First Atomic Power Plant Making Good Progress In Peterborough," the CGE Works News reported the ceremonial sod-turning at the Rolphton construction site by C. D. Howe and Ontario Premier Leslie Frost. Also in the party were Ontario Hydro Chairman Dr. R. L. Hearn, and CGE's Chairman of the Board H. M. Turner. The newsletter described the rapid build-up of the CGE design and manufacturing team which was composed of representatives from many areas of the company,

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[34]Ian N. MacKay. "Peterborough in the Atomic Age," Peterborough Land of Shining Waters ed. Ronald J. Borg (Peterborough: City & County of Peterborough, 1967) 517.

and its editor, Berkely Boyle, described the enthusiasm of the new department as follows:

> It's easy to catch the spirit of this young group. They feel that they have the answer to the greatest challenge that faces many areas of Canada: Where is our electrical power to come from, now that our hydro resources are all but exhausted?[35]

3.2.1 APD's IMPACT ON THE PETERBOROUGH COMMUNITY

The formation and long-term operations of APD in Peterborough have had a major impact on the city and surrounding areas. Although a part of of the large GE presence already existing in the city, APD's rapid growth made it, in effect a new industry employing several hundred people most of whom were newcomers to the area. These employees, mostly professional engineers and scientists or highly-skilled technicians and tradesmen, not only enhanced the operations of the GE plant, but also those of the city. The sudden influx of so many well-paid people, mostly in their late twenties or early thirties, plus their families, had significant effects on residential housing, schools, churches, businesses, medical services, recreational facilities, etc.[36] To accommodate Peterborough's burgeoning population during this period -- mid-1950s and through the 1960s -- hundreds of new homes were built , and quickly sold in the north, west, and southern outskirts of the city. Many of the APD staff who purchased homes at that time still occupy those same houses today. New schools and churches

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[35]Berkely Boyle, "Our Country's First Atomic Power Plant." CGE Works News September 26,1956, 2.

[36] Sangster, Joan, Earning Respect: The Lives of Working Women in Small-Town Ontario, 1920 - 1960. (Toronto: University of Toronto Press, 1995) 15 - 24,

sprang up in these areas to meet the needs of the incoming families, plus a community college (Sir Sandford Fleming) and Trent University. CGE figured prominently in the establishment of Trent. The chair of its founding committee, C.K. Fraser, was a CGE engineer, and company president Walter G. Ward (also an APD General Manager at one time) was an early supporter. In 1962, CGE generously donated 40.5 hectares (100 acres) of land north of the city at Nassau Mills on which to build Trent's main campus, and long before construction started, plant employees had signed up for weekly payroll deductions totalling more than $320,000 to show their support and help fund the university. The company also made a corporate donation of $250,000. [37]

Another way in which APD affected Peterborough was in the numbers of visitors from around the world brought to the city to hold discussions with departmental managers, review APD's facilities, and also to receive training -- especially from Pakistan during the design and testing operations at APD of the KANUPP equipment .

APD people and their families have played a large part in the community's municipal and cultural affairs, serving on City Council, the Utilities Commission, Boards of Education, Peterborough Business Development Commission, the Theatre Guild, Concert Band, plus all kinds of athletics and sports activities serving as organizers, coaches, referees, umpires, etc.

In addition, APD personnel have taken an active part in programs at Sir

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[37] A.O.C. Cole : Trent: The Making of a University, 1957-1987 (Peterborough: Trent University Communications Department, 1992) 12, 23-4.

Sandford Fleming College, serving on advisory boards and lecturing. Several have volunteered their services as classroom aides in local schools, assisting students with mathematics, computer studies and science projects.

In summary, the establishment of APD in Peterborough has had a very beneficial affect on the community, economically and culturally.

3.3 CGE'S NUCLEAR DEPARTMENT : ORGANIZATION & CULTURE

As noted in the previous section, the formation of CAPD is described and recorded in newspaper and journal articles, but the department's own organizational format and listings of its staff for that early period do not appear to have survived. To rectify this problem I have had to rely on the personal recollections of a number of the people involved for this information. [38] In addition, John Foster (former President, AECL) provided valuable material which contains a listing of the initial organization, complete with names and job titles: [39]

Ian F. McRae (CGE)	General Manager
Ian N. MacKay (AECL)	Manager of Engineering
John S. Foster (Montreal Engineering)	Head of Design
Wm. M. Brown (AECL)	Reactor Design
Ian Herd (CGE)	
Les. R. Haywood (PNL- AECL)	I & C Design

[38]Interviews and discussions with Alex Hoyle, February 14, 1997, Ralph Lloyd, February 11, 1997, Don Medd, August 1958.

[39]John S. Foster and G. L. Brooks, CANDU Origins and Evolution -Part 1 of 5, (Mississauga: AECL Retirees Group, 2001) 4-5.

Gord Davis (CGE)	
Ralph Flemons (CGE)	I & C Design
Warren Brown (CGE)	
Alex Hoyle (AECL)	Process Design
Lou Bissell (AECL)	Services Design
Dave Coates (CGE)	Fuel Design
Chick Whittier (AECL)	Chief Physicist
Fred Boyd (AECL)	Shielding
Dave Morgan (AECL)	Operations Advisor
Doug. G. Boxall (AECL)	Metallurgist
Wm. H. Bowes (AECL)	Stress Analyst
Mac McNelly (new hire)	Analyst
Ray Brown (new hire)	Electrical Design
Roy Tilbe (AECL)	Head of Development
Dick Johnston (CGE)	
Anse Taylor (CGE)	Chief Draftsman
Mel Thurling (CGE)	Manager, Customer Services
Tod Willcox (CGE)	Purchasing
John Mathews (CGE)	Estimating
Jim Graham (CGE)	Construction
Ralph Candlish (new hire)	
Otto Laderach (CGE)	
Roy Olsen (CGE)	

Dick Duder (CGE) Accounting

In addition, an important member of the team was:

Lorne G. McConnell Ontario Hydro Superintendent, NPD

Using this core group as the cornerstone for the department he was building, Ian McRae, assisted by his managers, rapidly created a well-rounded organization and as work progressed brought cohesion to its operations. His enthusiastic approach was infectious, passing on to the staff the concept that they were a select group of bright people assembled in Peterborough to work on a challenging new project. His approach to the work at hand planted the seeds of a strong feeling of solidarity and collective achievement in the department. Bolstering the feeling of belonging to a special group was the location of the department in a separate building away from the rest of the plant, with strictly enforced security and limited access. Yet while being a separate group, the department could still draw whenever necessary upon the plant's large pool of people and manufacturing resources.

Plant location was beneficial for APD. Compared to Toronto, Peterborough is a small and isolated city with few manufacturing companies able to offer similar work opportunities or to compete for its skilled technical staff. If employees chose to leave CGE, they faced the probable disruption of pulling up roots, selling their homes, and moving themselves and their families away from the city. In addition, most employees liked the Peterborough area, finding it to be a pleasant place to live and work. As a result, APD benefitted from a very stable workforce and the continuous availability of experienced personnel from project to project. This was an important factor in the highly technical and specialized nuclear industry, and helps explain APD's long history of successful operations.

3.3.1 ORGANIZATIONAL STRUCTURE & STAFFING ACTIVITIES

Other than the names and titles of the core group listed on the preceding pages, the earliest listing of CAPD personnel I have been able to trace only covers the Engineering Section -- but fortunately at that time it was by far the largest component of the department -- and is dated November, 1958. [40] This is followed by an updated version dated February, 1959. [41] These provide the names of most of the people working in the department during its early years -- 120 or so out of a total staff of approximately 150 -- and are useful in determining which people stayed with CAPD and whose names appear on the organizational charts for the subsequent decades, the 1960s, 70s, 80s, and a few into the 1990s.

Comparisons with the later charts illustrate how the departmental structure changed and evolved as the department adapted to its changing business situations and roles. Some units disappeared as their usefulness ended, e.g., those dealing with turnkey operations following the department's exit from such work. Other units greatly expanded to meet the changing and growing demands for their services, e.g., Fuel Handling which evolved into a major section. In

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[40] See Chart No.1, Appendix 3, pp. 146-148.
[41] See Chart No.2, Appendix 3, p. 149.

addition to organizational changes, close examination of the charts reveals the movement of staff members within the department to quite different, but related, responsibilities. This can be explained by a number of reasons, such as promotions, dictates of the business, and the desirability, whenever possible, of retaining talented and experienced individuals when their workload or jobs drew to a close. Naturally, not all employees remained with the department for the remainder of their careers, but a surprisingly large number did. The largest exodus occurred following the company's decision to leave the turnkey business after the KANUPP project. Many of these people, while leaving CGE's employ, elected to stay with the CANDU program by joining the ranks of AECL, Ontario Hydro and the AECB.

Of the total of 118 staff members listed on the 1958 personnel chart (No. 1), 44 stayed with APD until leaving due to retirement or career-ending illness. At first glance that figure (37%) does not appear high, but it should be noted that many of the people who did not stay more than a few years left because their work on NPD or KANUPP was finished, and their particular talents were no longer applicable to the new types of work. In this category were station design engineers, structural engineers, physicists, etc. whose expertise was not of use in the design and manufacture of fuel and fuel handling equipment. Another group of employees who did not stay were the draftsmen whose skills were not needed due to the reduced scope of the department's workload. As in the case of of the professional staff, a number of these people transferred to AECL and several were transferred to other drafting units within the Peterborough plant.

This pattern of employee retention and loss can be explained. Over the years, fluctuating workloads across the various departments in the plant often resulted in the movement of draftsmen in and out of the different drawing offices. While not always an efficient arrangement because of the differences in the nature of the work, it gave the company great flexibility in its operations. Because this was a unionized workforce, seniority rights applied, and if manpower layoffs were necessary the more-senior draftsmen could normally find a job placement in the plant, and it would be the junior draftsmen with the fewest years of service who would eventually and temporarily lose their jobs. When workloads picked up again, drafting supervisors would negotiate to arrange the return of draftsmen experienced in their particular types of work -- for example, nuclear component design -- as needed.

Although a number of draftsmen left APD due to the reasons given above,of the 39 who were listed in 1958, 20 (50%) remained with the department until the end of their careers. In addition, a review of subsequent organizational charts (Charts No. 3-6 inclusive) reveals the names of many more personnel who joined APD during the 1960s and 1970s who chose to stay on and become long-service employees.

By the early 1960s, (see Chart No. 3) [42] the department's organization had changed significantly to accommodate its role following the completion of NPD and the potential for new business. Many of the managers and supervisors who would play such a prominent part in the future of APD, especially for the

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[42] Chart No. 3, Appendix 3, pp. 150-1.

KANUPP, Bruce and Darlington projects, were now in place. For example, managers W.M. (Bill) Brown, Ed Adams, Konrad Zimmermann, Gord Davies, Alex Hoyle and John Pawliw, fit this pattern. Although the change to a "specialization" role had not yet taken place, already the fuel and fuel handling segments of of APD's operations had greatly expanded in importance and staffing. [This is somewhat misleading because these are the names of just the professional engineers in those units; a number of drafting personnel were also involved, especially in the design of the fuelling machines.]

By 1963, as can be seen in Chart No. 3, the "Fuel Engineering and Manufacturing Development" group had expanded and become one of the department's six major engineering components reporting to Ian MacKay. Another of the six, "Equipment Engineering", contained two engineering units, "Reactor Structures" and "Fuel Handling" plus a large drafting unit consisting of two sub-units corresponding to the two engineering units. The manager of this engineering component, W.M. Brown, and his two supervising engineers (later managers), Ed Adams and Konrad Zimmermann, were responsible from that time on -- the1960s through the 1980s -- for overseeing the successful expansion of the fuel handling segment of the department's operations, generating and maintaining its reputation for high quality innovative work, and ensuring its full participation and prominent role in the CANDU program.

At the start of the 1970s, Bill Brown became manager of the merged AECL and CGE Fuel Handling Systems Section, (Power Projects, Peterborough) alternating duties between CGE's Peterborough plant and AECL's Mississauga offices. [43] Later, Konrad Zimmermann succeeded him when Bill Brown was appointed Marketing Manager of CGE's Power Generation Department. [44]

Konrad Zimmermann and Ed Adams remained with APD until retirement in the 1980s, together with a number of other fuel handling veterans including managers Dick Beck, Gord Davis, Syl Dragan, and Alec Hoyle, senior design engineers Stan Janusz, Ralph Lloyd and Ralph Flemons, plus Drafting Group Leaders Don Medd, Maurice Harris, and Stan Howden.

A number of other senior managers left APD due to advancement within the company, for example Ian McRae who reached the highest levels of CGE before becoming a Commissioner of Ontario Hydro. Dick Johnston (a CGE Vice-President) moved to Head Office as Manager, Corporate Technology, and Les Haywood returned to AECL's Chalk River Laboratories as Vice-President, Engineering.

In a farewell article addressed to APD personnel in 1975, Dick Johnston expressed his feelings about the department, its work and its people:

> I was privileged to be one of the original members of CAPD and to spend these exciting and eventful yeras working in the forefront of a new and exciting technology . . . . The dedication and competence of our nuclear group has always been accompanied by an outstanding willingness to share special expertise and to assist others to learn the new technology. This experience of working as part of a totally integrated and dedicated

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[43] See Chart No.4, Appendix 3, pp.152-3

[44] In January 1975, as the result of a major restructuring of the company, the Nuclear Products Department (APD) was transferred from the former Nuclear Products and Chemical and became a part of CGE's Power Generation Department. [Resulting from that reorganization, APD lost the sevices of two of its most senior managers, first Dick Johnston, and later, Bill Brown, both of whom had joined the department at its inceprtion twenty years earlier.]

> team and the close personal associations that arose out of it leave me deeply grateful that I havehad this opportunity. [45]

In July 1975, the five-year Merger Agreement between CGE and AECL combining the two Fuel Handling Systems groups ended and was followed by a similar arrangement under which development work was performed by CGE in Peterborough on behalf of AECL. At that time, Bill Brown was quoted as saying 'that the new arrangement would provide a future opportunity for greater participation in the nuclear market by allowing CGE to sell fuel handling systems engineering directly to customers other than AECL." [46]

It was evident that this was a critical time for APD and its large staff because they would soon need another major design contract to follow the Bruce A project work which was nearing completion. Development work spanned the gap between the end of the Bruce A project and the start of work on the next major contract the department was hoping to win, the design and supply of the Bruce B fuel handling system. Having assembled a large team for the Bruce A contract, APD needed a similar package of work to keep its workforce busy in the years ahead, and was busy negotiating with Ontario Hydro to that end. The fuel handling design staff alone consisted of approximately 100 people (60 engineering plus 40 drafting personnel.) These were augmented by a Project Operations group of around 20 individuals (project engineers, estimators and schedulers), a Test and Service Operations group of about 50 persons, plus a Finance Section of around 20 individuals, and a clerical staff of 10 in

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[45] CGE Nuclear Products "Future" magazine, Peterborough, January 1975.
[46] CGE Nuclear Products "Future" magazine, Peterborough, July 1975.

Office Services, for a total staff of 200 at that time. [47]

The contract for the design and supply of the complete fuel handling system for the Bruce B project was awarded to APD in 1976, and design work began immediately. As noted, APD had the required staff in place, already familiar with the type of equipment, having worked on the very similar Bruce A project. Two years later, and midway through the Bruce B project, APD was awarded the design and supply contract for the Darlington fuel handling system. With work proceeding simultaneously on the Bruce and Darlington projects, AECL's 600 MW projects, plus miscellaneous development and service work, the years spanning the late 1970s to the mid-1980s were the busiest in the department's history. Total manpower in APD reached approximately 400 during this period.[48]

Following the Darlington project, no further reactors were built in Canada and APD's workload dropped sharply after the mid-1980s. Work continued on the major projects for Ontario Hydro and AECL but mainly consisted of site support, manufacturing, test and commissioning, plus service work. As the project-type work dwindled, the design and and manufacture of special service equipment became the main line of business for the fuel handling group. Some of the new types of reactor inspection and servicing equipment for site use on fuel channels -- such as the "SLAR" machines (Spacer Location and Replacement) were major packages of work handled jointly by APD and Ontario Hydro personnel. For the

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[47]See Chart No. 4, Appendix 3, pp. 152-3.
[48]See Chart No. 5, Appendix 3, pp. 154-5.
and Chart No. 6, Appendix 3, pp. 156-7.

Fuel Handling section of APD, service work in all of its variations, and site support operations were its principal business during the 1990s.

The Nuclear Fuel section continued to receive its share of the replacement fuel bundle market as new orders arose. Manufacture of fuel bundles has been an ongoing activity by APD at the Peterborough plant -- with pelletizing operations performed at its Toronto plant and tubing manufacturing at its Arnprior facility -- since the department's inception. Manufacturing and assembly operations in the Peterborough plant, at one time very labour-intensive, were converted during the 1980s into largely automated operations requiring a smaller workforce on the shop floor. However, the nature of the product is such that extensive technical support and quality control staff are still required. The design of the bundles has evolved considerably since the relatively crude-looking format of the NPD era to current standards as the designers constantly strive to improve bundle in-reactor service performance and durability. To achieve these goals, APD has retained its fuel bundle design and manufacturing engineering organizational arrangement, and staffing, at a fairly consistent level. [49]

To summarize, the department began with a small core of personnel for the design of the NPD project, and expanded rapidly. New units were formed to handle other segments of APD's prime contractor role: supply, manufacturing, etc. As the design phase neared completion, the emphasis moved to these other activities and the design staff moved on to development studies and proposals

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[49]See Chart No. 7, Appendix 3, pp.158-9.

for new projects, plus manufacturing liaison and test support assignments.

Many new employees who were hired in the late 1950s, and early 1960s, stayed with APD for the balance of their careers. Included in this group were most of the future managers and supervisors who would later play major roles in the department's operations. Building on the experience gained working on the early projects -- NPD, Whiteshell, and KANUPP -- their efforts played a large part in the subsequent successful receipt and handling of the design and supply contracts for the 600MW, Bruce and Darlington projects.

Summarizing the manpower profiles:

An examination of the APD Organizational Charts for the period covering the 1950s through the 1980s reveals the names of the many employees who were members of APD during its early years and remained with the department for the next ten, twenty, thirty and more years. Almost all of the most-senior managers stayed for the first eight to ten year period, leaving due to career advancement reasons (e.g. Ian McRae and Les Haywood) or upon reaching retirement age, e.g. Mel Thurling. Tables 1 and 2 (pages 49 and 50) illustrate the large number of long-service members in the department by listing two groups of employees:

(a) Management and Professional Staff,

(b) Drafting Staff,

whose names appear on the charts across the decades.

[Note: the 1990s are not listed because they are not representative due to the many staff members who joined APD during its early years, and left the Company during the1980s after reaching retirement age or for health reasons.]

Table No. 1

LENGTH OF SERVICE IN APD: MANAGEMENT AND PROFESSIONAL STAFF

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1950s          1960s          1970s          1980s

McRae ---------
MacKay --------------------------
Thurling -----------
Haywood -----------
Johnston --------------------------
Brown (W. M.) ---------------------
Adams ----------------------------------------------
Beck -----------------------------------------------
Hoyle -----------------------------------------------
Pawliw ---------------------------------------------
Davis -----------------------------
Pritchard ------------------------------------------
Erwin ------------------------------------------------
Scott ------------------------------------------------
Tarasuk ----------------------------------------------
Eaton ------------------------------------------------
Zimmermann     --------------------------------------
Janusz         --------------------------------------
Shaw           --------------------------------------
Ashdown        --------------------------------------
```

Table No. 2

LENGTH OF SERVICE IN APD: <u>DRAFTING STAFF</u>

1950s 1960s 1970s 1980s

Taylor ------------------------------

Dennison --

Hough --

Cantello ---

Medd --

Burgess ---

Freeburn ---

Veenman --

Ferris ---

Gerrard --

Gifford --

Goslin ---

Harris ---

Howden ---

Lefley ---

Lupton --

Pickles ---

Weller ---

Eley   ---

Similar examples of long-service staff members for other areas of the department can be observed by reviewing and comparing the organizational charts. For example, the Test Laboratory, the Metallurgical unit, and the fuel manufacturing facility listings all contain names of employees who joined APD in the 1950s and 1960s and stayed on until the 1980s. As with the design group members, many of these people moved within the department to other sections and responsibilities, but the department retained their skills, experience and expertise in nuclear-related work. [50]

For example, John Irvine, Manager of the Test Laboratory during the 1970s and 1980s, had started his APD career working as a design engineer. Similarly, Test Laboratory Supervisor John Bowman, moved to his Laboratory position from APD Drafting in the 1950s. Drafting lost a number of its people over the years due to their being selected to join other groups, especially Engineering design units but also to positions in Marketing, Project Operations, and Purchasing. Test Laboratory technicians progressed to jobs in Manufacturing Engineering units, and Engineering personnel were frequently selected for management positions in manufacturing sections, all within the department. Two notable examples are Ed Adams and Jim Pritchard both of whom successfully handled the major move from senior management roles in design engineering to equivalent positions in the Manufacturing segment of the department, and remained there until retirement in the 1980s.

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[50] Tracing names in the organizational charts is complicated by these moves.

An interesting feature of APD's manpower make-up, starting at the formation of the department and continuing throughout its history, is the significant number of employees -- many of them in management and key technical positions -- who were newcomers to Canada and had received most of their education, training, and previous work experience in other countries before emigrating here. This applied across the various departmental units, but was most notable in the Engineering and Drafting areas, for example:

Engineering:		Drafting:	
H. Alting-Mees:	South Africa	G. Cantello:	U.K.
D. Boxall:	United Kingdom (U.K.)	W. Darby:	U.K.
W. Cashen:	U.K.	J. Eley:	U.K.
J. Condon:	Eire	J. Gerrard:	U.K.
A. Daniel:	U.K.	H. Glaus:	Germany
A. Hoyle:	U.K.	J. Goethel:	Poland
S. Janusz:	Poland	P. Goslin:	U. K.
J. Matthew:	U.K.	J. Henry:	U.K.
P. Patell:	India	S. Howden:	U.K.
W. Shaw:	U.K.	S. Ray:	Bermuda
D. Tilbe:	U.K.	G. Weller:	U.K.
K. Zimmermann:	Germany	J. Szakony:	Hungary

It can be argued that the population of Canada largely consists of immigrants and that the number of APD employees from other countries is not an uncommon situation in the Canadian workplace. However, what makes the APD situation somewhat unusual is the high concentration of management, professional, technically expert and skilled employees with non-Canadian backgrounds in the department. There are a number of explanations for this fact, the two most important being:

(a) During the 1950s and 60s Canada had a very limited pool of technical workers, and especially those experienced in nuclear and associated fields, so it had to draw upon immigrants from other countries who possessed the required education, skills and talents.

(b) These immigrants were readily available and quite willing to move to a new job and location. Fortunately for APD, many of these people chose to stay with the department, became long-term employees, and imparted their expertise to their associates.

As an example of the important role played by newcomers to Canada in the founding of the department, it can be noted that when CAPD was formed in 1955, among the thirty senior employees listed as members of the original contingent,[51] at least seven can be tentatively identified as "New Canadians": Alex Hoyle, Lou Bissell, Doug Boxall, Mac McNelly, Roy Tilbe, John Matthews, and Otto Laderach.

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[51] John S. Foster and G.L. Brooks, CANDU Origins and Evolution: An Overview of the Early CANDU Program Prepared From Information Provided by John S. Foster. (Toronto: AECL Retirees Group, 2001) 3 - 4.

The departmental charts show that the basic organizational structure of the new department followed the typical hierarchical arrangement of the GE company, and most North American industrial companies in that period. The general manager (initially Ian McRae) was at the top. Reporting to him were three section managers, heading up the engineering, manufacturing and marketing, and finance sections. Below them were the unit managers, then the supervisors and their staffs.[52] The major difference between APD and the other departments of the Peterborough plant was the disproportionately large size of the design group in relation to the manufacturing section. Usually an industrial operation has a relatively small design staff and a larger number of manufacturing workers. However, in highly technical businesses such as the nuclear industry, and for major engineering projects, the proportions are often reversed, as in APD.

The initial emphasis in staffing was the hiring of professional engineers, draftsmen, and laboratory technicians, together with physicists and other scientific personnel. The original small core group quickly expanded. In the fall of 1958, manager Mel Thurling observed that the current staff level of 160 employees was equivalent to a new industry for Peterborough.[53] By the end of 1960, the design and test staff had grown to approximately 200, nearly 50% of whom were professional engineers, the largest engineering unit in the Peterborough plant and most probably, the company.[54]

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[52]See Charts No. 3 to 6, Appendix 3, pp150-157 .

[53]Mel Thurling, "Jobs For Today and Tomorrow," CGE Works News, September 19, 1958, 2.

For the NPD project, the Engineering Section of APD was divided into a number of units with specific areas of responsibities covering the various components and each aspect of the station's design and construction. All of the engineering, development and testing work was handled by APD personnel in house. By contrast, most manufacturing operations, for everything except fuel bundle fabrication, were performed by other departments or sub-contracted to outside companies. The "manufacturing" component within APD consisted principally of manufacturing-engineering, methods-men, planners, production controllers, quality control and purchasing personnel. They were, however, very actively involved in all of the manufacturing operations wherever performed, providing detailed planning, monitoring, quality control, and liaison with the engineering designers. APD personnel were very much in control of any manufacturing operations, in house or elsewhere.

Doing engineering, assembly and test work within the department, and manufacturing elsewhere within the plant or on sub-contract by outside manufacturers has proven to be efficient and cost-effective. During periods of low manufacturing activity, APD has not suffered from many of the high overhead costs and idle equipment problems faced by other manufacturing companies. In addition, this arrangement, still in place in the 1990s, has provided a steady flow of work for other areas of the Peterborough plant. In particular, the Experimental Unit, an adjunct of the Toolroom especially established to handle precision work of a non-routine nature, has been successfully employed on the manufacture of

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[54]See Chart No.3, Appendix 3, pp. 150-1.

APD-designed equipment almost continuously from 1955 onwards. Its toolmakers, machinists, and inspectors became very familiar with the high quality standards of workmanship and documentation demanded by the nuclear industry's specifications and did not require instruction at the start of each order or contract.

An exception, starting with the aluminum calandria for NPD, is the welding fabrication of nuclear components which has always been handled in house by APD employees. This is largely due to the special non-standard materials often used in the welded assemblies, and the American Society of Mechanical Engineers (A.S.M.E.) code requirements for nuclear pressure vessel welds. To ensure the quality of its welded components, APD established a new sealed-off welding area with improved lighting, cleanliness, and special equipment, in Building 26. This facility and its welders have undergone regular testing by inspectors from AECL, Ontario Hydro and the provincial government, to demonstrate their conformance with the jurisdictional standards for nuclear-quality work. Due to these stringent and demanding quality requirements, this work could not be assigned to the regular welding units in the plant, units which were not accustomed to the special materials used, the unusual weld-joint configurations, and the intensive engineering input required.

The special nature of much of the work in APD has in many ways set apart its workforce from those areas of the plant not regularly engaged in its operations, and has resulted in a feeling of collective achievement and solidarity, of belonging to a special group with its own operating culture. This can be borne out in at least one way: APD's large number of long-term members over the forty-year period as can be seen in the employee listings.[55] With the exception of those people who moved away when their jobs became redundant due to the department downsizing from turnkey to specialization operations, most elected to stay with APD. This form of loyalty applied across the whole department, and not just with the original core group. As the organizational charts demonstrate, the department frequently rearranged itself to adapt to changing conditions, markets, etc., but from the days of NPD through the construction of the Whiteshell and KANUPP stations, and until the conversion to a specialization role, retained the same basic organization, Engineering, Manufacturing, and Finance.

One element shaping APD's culture has been the dominant role of professional engineers (P. Eng.) in the management and operations of the department. The only exception was the finance section, which has always been staffed and managed by people with a financial background, accountants, analysts etc.; its manager, however, reported to the department manager, and he was a professional engineer. Elsewhere, every section manager, unit manager, and almost all supervisors were engineers. In addition to the engineers in managerial positions, APD staff included mechanical, electrical and instrumentation design engineers, manufacturing, marketing, welding, quality assurance, metallurgical, test and service, systems, process, and project engineers, PEng stress analysts, and heat transfer specialists,

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[55] Refer to the Organizational Charts and Tables listed in Appendix 3, p. 145.

As a result, every aspect of the department's operations was shaped by an engineering approach. Every product was analysed, assessed, built to detailed engineering specifications and PEng-approved drawings using certified materials, checked and double checked, tested, measured, and fully documented; the constant goal to produce the very best designs backed up by the highest quality manufacturing of the end products. In many ways the nuclear industry has resembled the aircraft industry, with both industries very aware of the potential hazards in the operation of the equipment they designed and produced. To minimize those hazards, both groups have striven for perfection in producing the safest equipment possible, and by incorporating in their designs fail-safe and back-up devices to overcome unlikely but possible system failures.

There exist very rigid and demanding requirements for nuclear work, especially for pressure vessels such as the fuelling machine heads. For example, these must conform to the regulations of the nuclear sections of the A.S.M.E. pressure vessel code for acceptable materials, stresses, weld configurations, inspection procedures, documentation, etc. An indication of how much the code is used by the nuclear industry is that as far back as 1979, "the Society's [A.S.M.E.] annual income from codes and standards publications was well over $10 million, most of them from the nuclear power industry." [56] To ensure that code requirements are completely met, intensive engineering input is

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[56]Bruce Sinclair. <u>A Centennial History of The American Society of Mechanical Engineers 1880-1980</u> . (Toronto: University of Toronto Press, 1980) 217.

required at all stages, accompanied by rigid manufacturing standards, quality control and documentation, a very expensive way to operate, but, with the potential hazards involved, almost certainly the only way. Any company planning to become a major participant in the nuclear industry had to recognize the costs and the resources required to establish the necessary organization to control and integrate the design, manufacturing, and quality control activities of such an enterprise, and also the time involved in acquiring the necessary expertise. When CGE made its bid for the NPD project it recognized -- as far as possible at the time -- the commitment in resources and time needed to achieve success. The company demonstrated its commitment by investing in the project and establishing a new department (CAPD) organized for sustained involvement in the industry. Although the department's role and its organization have changed and evolved, the basic culture of teamwork and striving for excellence in all of its operations remained constant. [57]

3.4 APD'S EVOLUTION

As previously noted, CGE's nuclear power department adapted to changing circumstances and its place in the nuclear industry by a constant process of evolution, its organizational structure changing to suit its varied roles as a) prime contractor in partnership with AECL and Ontario Hydro, to b) independent supplier of complete stations, to c) specializing in designing and building fuel

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[57] A natural fit with GE's subsequent quality program "Six Sigma," which measures, and works to reduce to an absolute minimum, the number of errors in one million discrete operations. See: Robert Slater. Jack Welch and the GE Way, (New York: McGraw Hill, 1999) 209-223.

bundles, complete fuel handling systems, and nuclear service work.

When the company established its nuclear department, it was not only the start of a new department of the company, it was also the beginnings of an entirely new industry for Canada. Fortunately for the department, it started so strongly in management, staff, and company resources, that once it overcame its initial teething problems on nuclear work, it was able to adapt and evolve efficiently and quickly, at least well enough to survive in a sometimes uncertain environment. Ian McRae had enlisted a number of exceptionally competent engineers and managers, for example, Ian MacKay, Mel Thurling, Les Haywood, and Dick Johnston. These people combined strong engineering skills with astute business sense, as later borne out by their promotions to the most senior levels of management.

Many difficulties faced McRae and his managers from the outset. First of all, the department was in the process of being formed as the work began, many of the staff were new to nuclear work, and the project itself was almost completely new in nature. Second, the company did not have a free hand in the design and manufacturing phases of the project but had to work on these in partnership with the representatives of AECL and Ontario Hydro some of whom were attached personnel working alongside the APD employees. Third, the basic design guidelines were not finalized but constantly evolving. Not surprisingly under such conditions, major cost overruns soon resulted, generating criticism of CGE's estimates and performance by AECL's top management . Bothwell describes in detail how this lack of firm design parameters and the split in design responsibilities between Peterborough, Chalk River, and Toronto, adversely affected the project's progress, and CGE's estimates.[58]

However, despite significant delays not of its own making, including the start of a completely new design in 1958, APD in cooperation with the staffs of AECL and Ontario Hydro successfully brought NPD on-line in 1962. It had the distinction of being the first nuclear power station in the world to be refuelled while operating under full load. The refuelling system was designed and built in Peterborough.[59]

From the outset, APD management used its business skills to negotiate favourable contracts -- often on a cost-plus basis -- seek out new work and guide the department through its various evolutionary phases. These phases were the direct results of the department's initiating, and reacting to, major differences in project designs and requirements, for example, between NPD and WR-1, followed by the completely new design for the KANUPP project and subsequently the Ontario Hydro Bruce and Darlington generating stations.

Ian MacKay's pursuit of an organically-cooled reactor eventually led to the contract for the design and construction of the Whiteshell research reactor, WR-1. This contract, for a very different style of project from NPD, provided several years of work for the department and served as a valuable follow-up to the NPD contract. In providing new work for APD's staff, such contracts enabled

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[58]Bothwell, 228-238.
[59]MacKay, 489-490.

the company to keep the team together for future projects such as KANUPP.

During the periods between the winding down of design work on one major project and the start of design of the next, APD continually prepared new conceptual designs, layouts and specifications of equipment for potential use on future projects. These were incorporated into proposals for development programs, to be handled by CGE, and submitted to prospective customers for approval and financing. Some of these led to significant packages of development work for the department followed by contracts for the design and supply of the ensuing site equipment. For example, as the design work on WR-1 was nearing completion, APD proposed and received a contract from AECL for the design, development and testing of the key components of a completely new fuelling machine design concept -- employing electrical drives and ballscrews -- the department had originated.[60] The test results of this major development package proved to be so successful that the basic design was later incorporated by APD into the design of the KANUPP fuelling machines.

When Ontario Hydro's Bruce A generating station was being designed, a larger version of the KANUPP-style fuelling machine was conceived by APD for proposed use in the station. The successful test results of the ensuing development program led to the design's selection by Ontario Hydro for service in the BruceA station, followed by the Bruce B and later the Darlington stations. For each of these projects, although basically similar in design, there were enough differences in the portions of the project handled by APD -- the complete

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[60]Details of this design are provided in Chapter 4.2

fuel handling system design and supply -- to provide several years of work for the department. When CGE first decided to enter the nuclear power industry, formed an atomic division, and made a major investment in the enterprise, it anticipated and intended that NPD would be just the first of a number of projects for which the company would be the prime contractor. McRae had set the organization in place for NPD and subsequent projects. However, as described in Section 3.1, Ontario Hydro in conjunction with AECL had other plans. Even before NPD had been completed, they were planning to design and construct future stations as a two-member partnership, leaving out CGE.

This major set-back to the department's fortunes, taking place just three years after it had entered the nuclear business as the prime contractor for the first power reactor, forced the department to evolve into a different form. Although the completion of NPD work would keep APD busy for another three years, new work would be needed very soon for the design section's engineering staff. The work they had expected to come to Peterborough for the next project would be handled by NPPD's newly-established group in Toronto.[61] APD would have to aggressively pursue new work wherever it could find it, in Ontario, other provinces, and in other countries. Greater emphasis would be placed in its marketing activities, and as a result, its previously small marketing section expanded considerably, adding marketing engineers, project engineers, technical writers and illustrators.

An organically-cooled reactor concept conceived by Ian MacKay was

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[61]Rae 200.

already being investigated by APD designers and looked promising as the next major project for the department. A lot of test laboratory work and preliminary design studies, conceptual layouts and drawings were needed to assess the feasibility of this new type of reactor, and that would help balance the department's workload as NPD work dropped off. MacKay initiated this work by convincing the company that paying for a design study would be in its best interests. Eventually, CGE expended $250,000 on this study in the hope that a large-scale reactor contract would result. However, AECL, while interested, balked at CGE's proposal and in turn proposed a smaller organically-cooled test reactor to be designed and constructed by CGE. Funding -- $500,000 -- was made available by AECL so that CGE could proceed on the design and development of an "Organic-Cooled Deuterium-Moderated Reactor-Experimental" (OCDRE). From that design study, and after many twists and turns, an organically-cooled reactor project eventually emerged. In the spring of 1962, CGE received the contract from AECL to design and construct a 60 MW test reactor, "WR-1", for AECL at Whiteshell, Manitoba.[62]

The Whiteshell Nuclear Research Establishment (WRNE, but now named Whiteshell Laboratories) is located along the Winnipeg River, approximately 100 km east-northeast of Winnipeg. Construction of the research reactor, WR-1, started there in 1963, and it first achieved criticality on November 1, 1965. Designed and built by CGE at a cost of $14 million, it was planned and operated as a test reactor for the proposed larger organic-cooled CANDU power reactor.

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[62]Bothwell 262-270.

WR-1 was very different in design from the NPD and Douglas Point reactors. It featured vertical fuel channels and the fuel was cooled by an organic liquid -- a type of oil -- rather than water. It did not use fuelling machines but inserted and removed fuel rods by means of a hoist contained in a shielded flask which in turn was moved from channel to channel by the station crane.

Although WR-1 was fully successful in operation, the organic-cooled program was discontinued in 1972 after a BLW reactor design was chosen for the next major project, Hydro-Quebec's "Gentilly-1". [63] However, although the "organic" reactor program had ended, operation of WR-1 continued for several more years during which it was used for various experimental and testing purposes, also in heating the WNRE site. During its twenty-plus years of operations, the reactor was extremely busy, usually working around the clock, and had an availability of 85%, an exceptionally high rating for a test reactor.[64]

It was shut down for the last time in May 1985, defuelled and largely dismantled. However, the successful operation of WR-1 demonstrated that organic-cooled reactors are feasible and have certain advantages over water-cooled reactors -- greater thermal efficiency and lower operating pressure -- and the concept is still a contender for future reactor designs.

The end of the organic-cooled reactor program was a serious blow for APD. The new Gentilly-1 project was being designed by AECL's NPPD group in Toronto, and APD was not involved. The search for new work was intensified as

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[63]Rae 202-204
[64]WR-1 bulletin, Canadian Nuclear Society, Manitoba Branch.

remaining tasks on WR-1 drew to a close.

Throughout the 1960s, APD actively sought new business in Canada and around the world. Design proposals and bids for new complete nuclear power stations were prepared, submitted and discussed with representatives of Finland, Argentina, Romania and Korea. It was necessary to secure overseas contracts because in the domestic market APD was handicapped by direct competition with AECL's design branch, NPPD. Meanwhile, design work continued at APD on a variety of projects it hoped to market on a "turnkey" basis, meaning that APD would design, manufacture, test, install, and commission all of the equipment. On completion of the commissioning operations, the station would be handed over to the customer to "turn the key" and start generating power. The department needed to sell one or more of these projects on a regular basis so that it could maintain its staff and continue operating.

Preparing nuclear design proposals is an extremely expensive operation requiring hundreds of engineering man-hours to produce conceptual design specifications, drawings, manuals, cost estimates, etc. tailored to suit each customer's requirements. With very limited prospects for the sale of a turnkey project in Canada in the near future, APD was forced to expend hundreds of thousands of dollars striving for offshore sales. Finland was one country which came tantalizingly close to finalizing a deal with the company, only to back away at the last moment. A huge amount of work had been done by CGE trying to satisfy all of the requirements and demands of this potential customer because completion of the sale appeared imminent. Senior company officials had flown to

Finland on numerous occasions to meet with the Finnish representatives, but eventually to no avail. CGE ended up with a huge bill, and no sale.[65]

The explanation is simple: the main problem in selling reactors abroad is not the product -- Canadian reactors and APD's technical expertise are well respected -- but the enormous costs involved. Nuclear power stations cost many millions of dollars to construct, and few countries can afford to pay for them without financial assistance. Potential buyers are more likely to be government agencies than private companies or local power utilities. Further complicating sales efforts for CGE was the fact that governments prefer to deal with other governments rather than private companies. National governments are in a better position to provide financial guarantees and offer long-term loans than private concerns.

CGE could not ignore this reality; early in 1965 it turned to the federal government for assistance with its export program. Not to AECL, which was actively pursuing sales for itself, but to the federal Department of Trade and Commerce. The department was sympathetic, and did assist CGE financially. It also set up a committee to review Canada's nuclear industry in general, and in particular the questionable role of AECL, as a crown corporation, in competition with private industry, CGE, for export sales. One committee spawned a second. Their draft reports, issued in September 1966, tended to favour CGE. They were critical of the virtual exclusion of CGE from the domestic market and the lack of adequate assistance in the company's export program. However, AECL

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[65]Bothwell, 387-390.

president Lorne Gray and his policies had the full support of the minister responsible, Jean-Luc Pepin, so no significant policy changes resulted. Due in part to the continued lack of AECL support, CGE's current sales prospect, a reactor for Finland, did not materialize.

When the first reactor for Hydro Quebec was contemplated in the summer of 1965, a CANDU-BLW design was proffered by AECL. This was a new and untried design, but that fact made it a "pilot" project and therefore eligible for funding by the federal government. A new division was set up by AECL to work on this reactor, reporting to Les Haywood the vice-president of Engineering at Chalk River, and not Toronto's NPPD. Just a few months earlier, Haywood, concerned about the state of Canada's nuclear industry and trying to get more work transferred to the private sector, had made a strong case to AECL's board for CGE getting the BLW project, but the board had not accepted his recommendations. Its members -- Lorne Gray, Ontario Hydro chairman Ross Strike, and Manitoba Hydro chairman D.M. Stephens -- were not interested in spending money on a project "whose design rested with a single manufacturing organization."[66]

There was one good marketing prospect at the time, however, which looked very promising for APD, namely a turnkey station for Pakistan. AECL had supplied India with two Douglas Point type reactors, RAPP I and II, and Pakistan was anxious not to fall behind its principal hemispherical rival. Several factors worked in APD's favour in securing the Pakistani project. For example, the

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[66]Bothwell, 385.

reactor size the Pakistanis were seeking -- 80, later 132 megawatts -- was within the size range APD was offering; Pakistan wanted the station completed as quickly as possible and at a competitive price; and NPPD had more work than it could handle at the time so was glad to let CGE have this project. [67]

After lengthy negotiations over such matters as pricing, adequate heavy water supplies, and nuclear safeguard concerns, the contract between CGE and Pakistan was finally signed. In mid-1965 work started in the Peterborough plant on the detailed design. The new station, to be constructed at Karachi, was named KANUPP, an acronym for the Karachi Nuclear Power Project.

A number of Pakistani engineers arrived in Peterborough, for a lengthy stay, initially to assist in the detailed design phases, and then to familiarize themselves with the equipment during the subsequent manufacturing and testing operations. Later they were joined by teams of Pakistani technicians who assisted in the assembly and testing of the reactor fuelling machines and related equipment. This was an excellent arrangement because it not only accomplished hands-on training for the Pakistanis, it also generated close working relationships and trust between the visitors and APD personnel. This process was later reciprocated during the installation and commissioning phases at the reactor site when a number of APD engineers and technicians were despatched there to assist and oversee these operations.

Work progressed well, both in Canada and Karachi. KANUPP was completed very nearly on schedule and within budget. [68] The outbreak of war

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[67] Bothwell, 269.

between India and Pakistan, in 1971, forced the hasty evacuation of the Canadian staff and put a crimp in the scheduled completion. Shortly before the start of hostilities, Canadian Prime Minister Pierre Trudeau visited KANUPP, and at a reception for him at the station, shook hands with each member of the APD staff and praised their accomplishments in the successful completion of the station.

The appreciation of the Pakistani people was expressed by their presenting to the APD a large, specially-made, and most beautiful hand-engraved ornamental copper tray.

3.5 INTERACTION WITH AECL AND ONTARIO HYDRO

The successful start-up and operations of the NPD station had demonstrated the feasibility of the CANDU system. It also proved that its on-power refuelling concept was sound and a worthwhile feature for inclusion in the larger reactors to follow. The experience gained by the Peterborough group in the design and manufacture of the fuel handling system, in particular the fuelling machines, would prove most useful in the design of fuel handling systems for future large-scale reactors. Equally important, they had acquired an enviable reputation for competence within the nuclear industry and with its customers. [69] It was fortunate that they had because in the years to follow they would face some formidable competition and challenges in their search for new markets.

For NPD's successor, the 200MW prototype reactor to be built at Douglas

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[68]A.C. Hoyle, Personal Interview, February 14, 1997.
[69]Bothwell 269.

Point, AECL's NPPD decided to employ a totally new, fuel handling system including the very important fuelling machines. The two fuelling machine designs were almost completely different largely due to differences in fuel bundle diameters, and the change in concept to the "fuelling with coolant flow" refuelling arrangement selected by chief designer W. Wilson.[70] The design contract for the Douglas Point fuelling machine heads was assigned to a private engineering consulting firm, Dilworth, Secord and Meagher. The resulting design turned out to be completely different from that conceived, and proven in operation, by APD for the NPD station. Although CGE was not involved in this design, it was awarded the manufacturing and supply contract by AECL thus giving the department the significant advantage of knowing the design and manufacturing details for both types of F/M heads. The major differences in design concept and approach to refuelling operations of the two fuel handling systems, AECL's and CGE's, have been perpetuated by both companies, each electing to use its own design for the subsequent reactor projects in Canada and overseas.

Part of the reason behind the continuing existence of this dichotomy were the conflicting roles of AECL's NPPD and CGE's APD, changing from collaborators to competitors and back to collaborators again as the two companies competed for the same potential markets. Inevitably, given the nature of the work, that is the "nuclear"details, even when the two companies were in the competitive phase there was a certain amount of collaboration. Douglas Point is a case in

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[70] CANDU Origins and Evolution - Part 1 of 5 , 9-10. John S. Foster and G.L. Brooks.

point. [71]

. The Ontario Hydro and AECL/NPPD partnership followed-up the Douglas Point project with the four 500MW Pickering 'A' power reactors, and not surprisingly continued the use of the NPPD-designed fuelling machine/fuel channel system. When the four 750MW reactors for Bruce 'A' were first conceived following Pickering 'A', the AECL fuelling machines and system were again part of the station design. However, senior management at Ontario Hydro and NPPD reversed that decision in favour of using the CGE machines, and fuel handling system. Initially, APD was awarded only the design contract, but later this was amended to include the supply of all of the fuel handling equipment, including testing and commissioning. Several reasons lay behind this major change in fuelling plans. These included: a) the very successful operations of the new KANUPP machines, b) keeping together the APD team which had designed and built them, and c) the NPPD fuelling machine staff were still fully engaged on the Pickering and Douglas Point projects. [72]

Following precedent, when the second four units for the Pickering Generating Station -- Pickering 'B' -- were authorized, the AECL fuel handling system was again selected. Later on, when Hydro decided to build the Bruce 'B' reactors and the Darlington Generating station, it again chose to use the CGE machines, channels and complete fuel handling system.

The awarding of this work to APD was a major breakthrough for the

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[71]MacKay 490.
[72]J. S. Foster, memo to K. G. Zimmermann, April 25, 1983. [APD Archives]

department, resulting in many years of work for the Peterborough plant. For example, the work on the Bruce 'A' and 'B' fuel handling systems, from the start of design until Hydro's formal Acceptance Test of the sixteenth and last fuelling machine head, covered a period of almost exactly thirteen years. [73]

With several years of work on its books, APD was able to retain its core group of design engineers, draftsmen, stress analysts, metallurgists, etc. with its supporting complement of technicians, welders, quality control personnel, purchasing and production staff. Many of these people, numbering around 400 in the department's peak years, had a wealth of experience in the nuclear field, and some had worked continuously on nuclear projects since NRX in the late1940s. Retaining this staff group in Peterborough was important to CGE for the work in hand, and also to assure potential customers of the department's more-than-adequate capabilities, expertise, and experience. For the same reasons it was also important to Ontario Hydro, and to a lesser extent AECL, that this group be preserved.

Although APD's fuel handling group was only marginally involved in work for AECL's Pickering, BLW and India projects, it collaborated with NPPD staff on the design and supply functions of fuel handling equipment for other AECL projects including those for nuclear generating stations in Korea, New Brunswick, Argentina, and for Quebec's Gentilly-2. These four projects, often referred to collectively as the "600 series", required CGE personnel to work in very close collaboration with their counterparts at AECL. So close at times that the CGE

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[73]K.G. Zimmermann, memo to APD staff, April 15, 1983.

design engineering staff often "wore two hats." That is, while they were still CGE employees they also served as AECL design representatives in their day-to-day dealings with the staff of other units of CGE, and other companies, involved in the supply and manufacturing of equipment for those AECL projects.

Similar use of CGE's nuclear design staff was made by Ontario Hydro when they were asked to "wear a Hydro hat," impartially representing the utility and looking after its best interests in their manufacturing liaison activities with CGE and other suppliers' personnel. Although an apparent conflict of interest with lots of potential problems, these duties were handled conscientiously with meticulous documentation of all concessions, etc., and to the complete satisfaction of both AECL and Hydro management. This should not be too surprising because the engineering design staff's main concern at the time was to ensure that the equipment they had designed was built to specification and drawing requirements, so that it would perform properly when installed at the station.

A further illustration of the close collaboration between AECL and CGE's fuel handling design staff can be found in the periods when the two groups came under the same manager. At one period it was an AECL individual, at another time the two groups were headed by a CGE manager. In both cases, the manager would divide his time between AECL's office in Mississauga and the CGE office in Peterborough, spending two or three days each week at each location. Surely, this was a unique arrangement for competitors. That arrangement, useful at the time, ended in the 1970s. Since then, the two fuel handling groups have worked cooperatively, but as separate entities. CGE design staff have assisted AECL by designing various segments of the fuel handling systems but not the AECL fuelling machines. The design of those is complete except for updates and minor improvements.

However, the manufacturing and assembly of the AECL fuelling machines for South Korea and Romania have been performed by CGE staff in Peterborough. AECL does not have manufacturing facilities so subcontracts this work to private companies. On completion of assembly, inspection, and initial test operations, the machines are shipped to the AECL laboratories at Sheridan Park in Mississauga for final test and shipment to site.[74]

The AECL fuelling machines, like their CGE counterparts, are sophisticated and complex equipment designed for remote operations in conditions of high temperature and pressure. To ensure their reliability they must be manufactured to very high standards, and assembled in special "clean rooms" to prevent their contamination by dust, dirt, and other matter. The nuclear facility in Peterborough, set up for the CGE machines, meets all of the AECL requirements and has successfully completed work on all of the work assigned to it by AECL.

Summarizing: APD survived and succeeded by constantly adapting its organization and operations to suit the current business conditions. When its attempts to win turnkey projects failed --KANUPP was its only success -- it was forced into drastically downsizing its workforce, temporarily joining forces with AECL's fuel handling group, then successfully evolving into a separate business specializing only in certain lines of nuclear work -- its "niche" in the market.

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[74]Doug Mahler, Personal interview, Feb. 27, 1997. (For title see p.161)

4.0 SPECIALIZATION/TECHNOLOGIES

Unfortunately, KANUPP would be be APD's last turnkey project. Near the end of 1966, president Herb Smith decided that following the the completion of KANUPP, CGE would no longer seek the sale of complete nuclear power stations. The problems, financial risks, and expense involved in such sales were not, in his view, in the company's best interests.[75] In the future, APD would operate only in those fields over which it had the most expertise and control, namely, the design and manufacture of nuclear fuel handling equipment, reactor servicing and maintenance equipment, special instrumentation, and the design and manufacturing of nuclear fuel bundles. These were areas in which APD had formed and maintained excellent design, development and manufacturing groups dating back to the founding of the department.

[Details of these specialization technologies are provided in Sections 4.1 - 4.4]

The result of this major change in the department's operations was a drastic reduction in its staff levels. No longer needed by APD were many highly skilled and experienced engineers, physicists, and other technical personnel. Fortunately for those concerned, NPPD had lots of work and could make good use of their services. An agreement was reached between NPPD and CGE to establish a new division of NPPD in Peterborough, and for AECL to retain some of these people by employing them as AECL employees working for this new division. Although they were no longer APD employees per se, they were working alongside their APD colleagues in the same Monaghan Road office.

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[75]Bothwell, 389.

Some elected to leave Peterborough and work for NPPD in Mississauga, and others decided to leave the nuclear business altogether.

Since1972, APD has specialized in the design, manufacture, supply and testing of:

a) Nuclear Fuel

b) Nuclear Fuel Handling Systems

c) Fuel Channels and Associated Equipment

d) Nuclear Service Equipment

These were the nuclear business segments in which the department expected to achieve and maintain profitable operations based on its experience and expertise. Successful specialization would enable the company to continue its role as the predominant private sector business in the CANDU program and potentially the only participant in its chosen areas of specialization.

The CGE decision to specialize in these areas was sound. It led to a succession of major contracts from AECL and Ontario Hydro which not only provided continuous employment for the department's staff for many years, but also helped the company to maintain its predominant private sector position in Canada's nuclear industry.

In its areas of specialization, APD continues to handle all of the design work -- the preparation of specifications, engineering drawings, quality control procedures, etc. -- and govern the manufacturing operations of all components whether built in the department or elsewhere. Although not all of the components are actually built in-house, most of the assembly and testing operations are performed within the department. This is particularly important for complex assemblies such as the fuelling machines whether of APD or AECL design. Following is a listing of the types of nuclear components actually built in the department, either completely or in part:

1) Fuel bundles

2) Fuelling Machine Head's pressure vessel components

3) Fuelling Machine drives and internal components

4) Fuelling Machine Suspensions

5) New Fuel Equipment

6) Irradiated Fuel Equipment

7) Service Tooling

8) Auxiliaries Equipment

9) Nuclear Flasks and Tanks

10) Test Equipment

11) Development Equipment

12) Specialized Instrumentation Systems

Detailed descriptions of these types of equiment are given in the sections covering the individual areas of specialization which follow:

4.1 NUCLEAR FUEL OPERATIONS

Nuclear fuel for the CANDU reactors is a highly sophisticated product resulting from many years of detailed design, analysis and development by AECL and private industry. It has to meet a very demanding set of criteria, described by A.S. Bain (former head, AECL Fuel Development) as follows:

a) Operation must be safe, with a very low chance of release of radioactive products to the reactor systems;

b) The fuel assembly must have a low parasitic absorption of neutrons;

c) It must operate to the required performance specifications of power output, residence time, dimensional stability and mechanical integrity under all postulated normal and abnormal operating conditions of the reactor;

d) It must have predictable performance under all potential accident conditions;

e) It must be capable of being easily and safely handled before and after irradiation, during temporary storage and, eventually, during more permanent storage or disposal;

f) It must be economical to fabricate.[76]

To meet these criteria the designers and manufacturers had to identify suitable materials, establish a design, develop fabrication techniques, supported by laboratory and in-reactor experiments and testing. These tasks were complicated initially by an almost total lack of information within Canada on aspects of fuel for power reactors. However, the considerable amount of pre-existing data on research reactors provided a basis from which to start work on the CANDU fuel.

In addition to the above criteria, fuel design was governed by the design of the particular reactor in which it would be used, initially NPD. The original

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[76]A.S. Bain. "Fuel," Canada Enters the Nuclear Age, (Montreal: McGill - Queens University Press, 1997) 254.

reactor design for NPD (1955) was based on a vertical pressure vessel with core-length fuel elements inserted by hoist from above the reactor face. In 1957 this design was abandoned and the pressure vessel replaced by an array of horizontally oriented pressure tubes. In addition, on-power fuelling was adopted in a bi-directional arrangement using fuelling machines to insert fresh fuel and displace irradiated fuel in the reactor core while the reactor was operating at full power. Essentially, NPD was redesigned to make use of the latest technology developments, and to incorporate design features which could be extrapolated for use in the much larger reactors which were to follow a few years later.

These major changes in reactor design and operation radically changed the original fuel assembly concept. New fuel bundle designs were created to conform with the new requirements and be compatible with the pressure tubes and fuelling machines. The new-design bundles were much shorter in length for ease of handling by the fuelling machines and to permit movement along the core in short bundle-length increments for controlled fuel burn-up.

The new NPD fuel bundles were approximately 50cm (20 inches) long, 8cm (3.25 inches) in diameter, and contained either seven or nineteen tubes (also called pencils or elements) filled with uranium oxide pellets. The number of elements was governed by the bundles' location in the reactor core. Seven-element bundles were used in the 80 outer or lower-power channels, and nineteen-element bundles in the 52 inner channels where the power output was greater. Both types of bundle had the same overall diameter, but the element diameters differed -- 2.5cm (1 inch) for the seven-element bundle and 1.5cm (0.6

inch) for the nineteen-element bundles.[77]

As the CANDU program evolved and reactor power ratings increased, it was accompanied by the demand for increased power per reactor channel. To accomplish this, the fuel bundles also evolved, with an increase in diameter -- but not length -- and in the number of fuel elements per bundle. Governing the geometry of the bundles, for both a low or high number of elements, was the requirement that they allow sufficient coolant to flow through them to remove the fission heat. This necessitated very ingenious design and manufacturing techniques to achieve the desired operating performance while meeting all of the criteria listed at the beginning of this section.

The NPD fuel bundles were state of the art when designed in the 1950s. Since then, continuous design modifications and development have greatly improved bundle performance to meet the increased power demands of each successive CANDU reactor, and make the NPD design appear quite rudimentary. [Figures 10 & 11]

The 8cm diameter, 19-element bundles manufactured in Peterborough for service initially at NPD and later at the Douglas Point prototype station were followed by a 10cm (4 inch) diameter, 28-element design for the full-scale Pickering reactors. Subsequent bundles produced by APD to meet the higher power ratings of the larger Bruce, Darlington and CANDU 600 reactors were the same overall diameter and length as the Pickering bundles but the number of elements increased to 37. Although small enough to be easily handled and

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[77] "Nuclear Power Demonstration Reactor". Nuclear Engineering, Oct. 1962.

transported before entering the reactor core, and weighing only 23kg (50 lb.), once irradiated each bundle can generate as much heat as approximately 400Mg (400 tons) of coal or 1,700 barrels of oil.

Nuclear fuel bundle design and manufacture is a very specialized business. It requires technical expertise and ingenuity plus rigid quality control during every stage of manufacturing to ensure conformance with very stringent specifications. These were established to detect defective bundles and prevent their installation in the reactor core. Fuel bundle defects, such as sub-standard tubing, low-quality joints, etc., could result in bundle failure during service and cause very serious problems and hazards for operations personnel. For example, problems could include damage to reactor and fuelling machine components, inability to move fuel in or out of the reactor, and the potential spread of highly radioactive bundle fragments throughout the reactor cooling systems. Problems such as these could quickly lead to reactor shutdown for safety reasons, proving extremely difficult and expensive to resolve.

When APD was first formed it set up a new facility in the Peterborough plant to manufacture and assemble fuel bundles, initially for NPD. Special-purpose machines, fabrication equipment and tooling were designed and constructed in the plant for this work. As the bundle designs evolved, this machinery and equipment kept pace, also improving in capability and efficiency to meet the increasing demand for bundles required to fill the growing number of reactors. Not all of the components were manufactured in Peterborough due to space limitations within APD, and the availability of existing facilities elsewhere. For instance, fuel pellet production was assigned to a CGE plant in Toronto, and the tubing elements to a plant in Arnprior, Ontario, but all of the parts came together for assembly operations in APD Peterborough.

The total number of bundles produced to date by the APD fuel group runs into the hundreds of thousands. Each reactor contains approximately four hundred fuel channels -- for example, 390 channels for the Pickering design and 480 for Bruce --and twelve of these bundles are required, placed end to end, for each channel. The initial fuel charge, therefore, is between five and six thousand bundles per reactor unit. The in-service life of the bundles varies in accordance with their locations in the reactor core, from a few months for the central channels to one or two years for the outer sites. Location and time data are monitored for optimum performance, and bundles are replaced by new bundles, when necessary, during routine on-power refuelling operations.

When fuel bundle production in Peterborough started it was very labour-intensive, but this dramatically changed as new equipment was developed and incorporated into the production process. By the mid 1990s, APD had converted its facility to a highly automated state-of-the-art system, consistently producing top-quality bundles, in large quantities, to its customers' specific requirements.

4.2 FUEL HANDLING SYSTEMS

This section of APD specializes in the design, manufacture and testing of nuclear fuel handling systems and associated equipment. Its field of operations covers all of the mechanical, instrumentation and control equipment needed to handle the complete fuelling requirements of a nuclear power station. This includes the receipt and handling of new fuel, the refuelling operations at the reactor, and the handling of the irradiated fuel bundles discharged from the reactor. [Figures 2 to 9]

Fuel handling systems equipment covers the gamut from basic mechanical tooling and devices, to highly complex robotic-type machines designed to operate remotely and safely in the harsh environments of high-temperature, high-pressure, and high-radiation conditions. The design and later the manufacture and testing of this type of equipment, has been ongoing at the Peterborough plant since the formation of CAPD.

The heart of any nuclear fuel handling system is its "fuel changing" segment. It contains the equipment for transporting new fuel to the reactor; the insertion of the fuel into, and the removal from, the reactor core; and the transportation of the irradiated fuel to its initial disposal point. Typical names for this equipment are: fuelling machine, charge-discharge machine, and the fuel transfer flask. Its principal requirements are governed by safety and reliability factors.[78]

The basic design of the fuel changing equipment is also governed by the reactor's fuelling requirements, operating function, and design. Early reactor designs featured vertical cores located beneath the reactor building floor. Fuel rods were installed and removed by means of a shielded flask containing a simple hoisting mechanism, usually under reactor shutdown conditions. This

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[78]K.G. Zimmermann. "Fuel Handling for Nuclear Reactors" lecture notes. Lecture presented to post-graduate students of nuclear engineering at the Ecole Polytechnique, Montreal, November 20, 1970, 2.

type of design is suitable for, and works well, in research reactors such as at Whiteshell's WR-1. In the CANDU power generating program, starting with NPD 2, the design has been based on a system featuring a horizontal reactor core, and two identical fuelling machines operating simultaneously on opposite ends of the same reactor fuel channel to perform refuelling operations with the reactor operating at full power, i.e. "on-power" fuelling.

To accommodate changing reactor designs/requirements, and to improve operating performance plus reliability, fuelling machine design has constantly changed and evolved. The fuelling machines in service at the Pickering, Bruce and Darlington generating stations are radically different from those installed at NPD due to increased fuelling demands requiring improved concepts and the gradual incorporation of newer techniques, materials and components.

The original fuelling machines at NPD started service in April 1962, and performed routine refuelling operations from January 1964 until March 1969. However, during service they experienced excessive maintenance problems, operating problems, and equipment failures. Most of the problems and equipment defects were due to the use of heavy water hydraulics for the fuelling machine head's internal component drives. In the original design, this was dictated by the scarcity of suitable rotary shaft seals which would have permitted external drives to enter the pressure vessel boundary. In addition, few hydraulic components were available suitable for use with heavy water under the temperature, pressure, and radiation conditions existing at the reactor face. These components were forced to operate without conventional lubrication in a fluid and under conditions untried and unfamiliar to the component manufacturer. Other problems were due to the machines' internal component position sensing and positioning devices, and component creep due to aeration, fluid leakage and pressure fluctuations. [79]

The incorporation of component and system modifications improved matters considerably, but unacceptably high maintenance requirements and system inadequacies remained. Unacceptably high, that is, in relation to the very stringent performance targets the fuel handling equipment must meet to reap the benefits of on-power refuelling operations. These targets are based on high availability of the fuelling system, and the low incapability of reactor operation due to the fuelling system:

Fuelling System Incapability = Unit Incapability caused by Fuelling System (%)

where

$$\text{Unit Incapability \%} = \frac{\text{Net Energy Unit Incapable of Producing} \times 100}{\text{Net Energy with Perfect Continuous Operation at Full Capacity}}$$

For NPD, during the period January 1964 to June 1966, the station incapability due to the fuelling system was 5.16 %, much higher than the long-term operating target of 1.00% per annum. However, at no time did the fuelling system contribute to a forced outage (reactor shutdown) during this period, and while the operating target of 1% was met for 1966, system inadequacies and high maintenance requirements remained. [80]

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[79]Zimmermann, 18-20.
[80]E. Sawchuk: "Analysis of Station Capability Factor as Affected by Fuel Handling Systems at NPD G.S. from January 1964 to June 1966" , In-Service

The encouraging results of an APD design study by S.A. Janusz et al on the use of all-mechanical drives for the fuelling machine internal components in 1963 led to a CRNL- sponsored development program at APD in 1964. [81] This program was designed to develop and proof-test drive components under reactor operating conditions for high reliability, low maintenance, and ease of operation. Included in the development work were ball bearing leadscrews, ball and conventional splines, gears, bearings, shaft seals and fuel carriers.

The excellent development test results in APD's laboratory, combined with the continuing difficulties with the NPD system led, in 1965, to the awarding of a contract by AECL to APD for the design, test, and supply of replacement fuelling machine heads incorporating:

a) all-mechanical drives,

b) continuous position read-out,

c) positive position detection,

d) the fuel carrier concept,

all designed to reduce maintenance requirements and station incapability.

The basic design of the second generation NPD fuelling machine heads -- the "Replacement Heads" -- evolved into the design used by APD for its KANUPP fuelling machines. Although many changes and improvements were incorporated into these machines' design, the proven success of the mechanical

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Report No. IR 352.2 -10, Fuel Handling, Ontario Hydro.

[81] S.A. Janusz and R.W. Blackburn, "Adaptation of NPD Fuelling System and Standardized End Fitting Concept." Technical Data Folder, Canadian General Electric Company Limited, APD No. DF63CAP78, November 1, 1963.

drives/fuel carrier format justified its retention for the next generations of APD-designed fuelling machines.

The success of the KANUPP fuel handling system eventually led to Ontario Hydro awarding APD the design and supply contracts for the F/H system for the Bruce A Generating Station, followed by the Bruce B and Darlington stations. Although these later designs have changed dramatically from the earlier ones, essentially, the basic design principle employed in all of these machines evolved from those used on the NPD replacement heads.

In service, all of the fuelling machines, operating in pairs, load-up with new fuel, traverse the reactor face, find and lock-on to the designated fuel channels, remove and replace fuel bundles, then transport and discharge the used (irradiated) bundles to the storage bays. All of these operations are designed and scheduled to routinely take place with the reactor operating at full power, on a day-to-day, year-to-year basis.

The fuelling machine for KANUPP consists of the following assemblies:

a) a head, with magazine, internal mechanisms, external drives and connections,
b) a head suspension, for flexible support of the head on the carriage,
c) a carriage and tracks for locating the head in horizontal (X) and vertical (Y) coordinates, also for advancing it to the reactor end fittings (Z) direction,
d) controls and auxiliaries (heavy water, air and oil) with catenaries.

The head is approximately six metres in length and weighs four tonnes when filled with heavy water. The magazine and the internal mechanisms required for fuel shifting are enclosed in a stainless steel pressure housing with an open snout which forms an extension to the fuel channel when the head is sealed to the channel. A homing mechanism is mounted on the snout to provide signals to the carriage drive motors for accurate alignment of the head with the end fitting of the channel.

The snout of the housing is fitted with a replaceable metallic seal and a locking mechanism consisting of three jaws drawn together by a screw tensioning device to connect the head to the channel end fitting.

The rotary magazine has seven storage positions and can accommodate:

a) a channel closure plug with its adapter,

b) a spare closure plug with adapter,

c) a shield plug when removed from the end fitting,

d) four fuel carriers.

All of these components are positively locked within the magazine.

The fuel ram and charge tube mechanisms use ball screws to provide the necessary axial and rotary motions required for fuel shifting and component actuation. Drives to the magazine, ram and charge tube are by input drive shafts which penetrate the walls of the housing and are sealed with rotary shaft seals.

An external drive gearbox is attached to the rear of the head from which shafts connect to the four input drives and the snout lock.

Head Suspension :

The fuelling machine is mounted by its trunnions on a pair of gimbals to permit the head freedom to tilt in all directions and to float in the axial (Z) direction. The flexible suspension system reduces the misalignment effects between the machine and the fuel channel end fitting and compensates for thermal expansion. (See Figure 6)

Although the fuelling machines are the heart of the fuel handling system, the other segments of the system are major packages of work in design, manufacture and operation, for example (KANUPP) :

<u>New Fuel Storage and Handling</u> :

Equipment under this section comprises:

a) New fuel storage equipment in the service building,

b) Equipment for new fuel transfer to the reactor building,

c) New fuel cleaning and inspection equipment in the reactor b uilding,

d) New fuel ports for transfer of fuel into the fuelling machines.

<u>Spent (Irradiated) Fuel Handling and Storage</u> :

Equipment under this section comprises:

a) Spent fuel discharge equipment,

b) Spent fuel transfer equipment,

c) Spent fuel bay equipment.

<u>Booster Handling Equipment</u> :

a) Shielded flask -- used to transfer booster and absorber rods to the Spent Fuel Bay,

b) Components to engage the flask with the booster rod channel,

c) Underwater equipment -- used in the decontamination bay to remove rods from flask,

d) Assembly cradle and hangers for new rods.

Fuelling Machine Service Facilities

Equipment under this section comprises:

a) Check-out port,

b) Service port,

c) Head transfer and storage equipment,

d) Head decontamination and maintenance equipment,

e) Remote viewing equipment.

Fuel Handling Control Equipment :

The F/H Control System comprises:

Two separate control systems, one for each fuelling machine, consisting of separate computers which with their peripheral equipment can provide entirely automatic fuelling of the reactor, control consoles, communication and logging devices, simulators, and timers, etc.

The evolution of the APD-designed fuel handling systems, from NPD through the KANUPP, Bruce and Darlington projects, resulted in major changes to every segment of the systems to meet the fuelling, maintenance, and other in-service requirements of each station. The NPD and KANUPP fuelling systems were not designed to, and could not, handle the greatly increased fuel demands of the larger power reactors at Bruce and Darlington. New fuelling machines were needed to handle the new and larger fuel bundles and to carry a larger number of bundles in their magazines. In addition, the station design specified a different fuelling arrangement. Instead of one pair of fuelling machines specific to one reactor as used at NPD and KANUPP, the Bruce GS would feature a duplicated refuelling system which would service all four reactors by either of two fuelling machine systems, each of which consisted of two fuelling machines and their auxiliary systems mounted on a transport trolley travelling on rails in a duct between the fuelling and service areas of the service building and in each reactor vault. [82]

This arrangement, initially designed for the Bruce A GS, was repeated for the subsequent Bruce B and Darlington stations. Everything was on a much larger scale than the KANUPP fuel handling system, these being generating stations nominally rated at 4 x 750MW (Bruce) and 4 x 850MW (Darlington) compared to 1 x 137MW for KANUPP. Although considerably larger fuelling machine heads -- the magazines, a nine-channel design capable of holding twelve 10cm (4 inch) diameter fuel bundles versus a six-channel design and four 8cm (3.25 inch) diameter bundle capacity -- the Bruce and Darlington heads employ the same basic design as the KANUPP heads, using ballscrews and external, electrical drives.

Following the major change from the KANUPP fuel handling system to the Bruce A system, the next step, from Bruce A to Bruce B, was considerably simpler. The one evolved into the next with relatively minor changes, mostly the incorporation of modifications resulting from manufacturing, supply, test and operating experience.

Altogether, sixteen heads were supplied to Ontario Hydro by APD for the

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[82]Bruce GS Safety Report, APD for Ontario Hydro, 1970. (APD Library)

Bruce A and Bruce B stations over a period of thirteen years from the start of design to the successful completion of acceptance testing in the Peterborough test laboratory on April 14, 1983, prompting a number of congratulatory memos between Ontario Hydro, APD and other agencies involved in the work.[83]

It was a major achievement, providing an extra sense of accomplishment for the staff at APD, because, although it had been awarded the fuel handling design contract in the early stages of the Bruce A project, it had had the difficult task of persuading senior management at Ontario Hydro that it should also be awarded the supply contract for the equipment. APD had proposed this move in August 1970, but although it had made a strong case for the benefits to Hydro of an integrated design and supply operation at Peterborough, it had to convince a sceptical management team at Ontario Hydro before winning this major supply contract.[84] In addition, gaining and successfully handling the Bruce A design and supply contracts later led to APD receiving corresponding contracts for the Bruce B and Darlington projects.

Since its formation, the fuel handling group has had exceptionally capable and effective management. It was first headed by W.M. (Bill) Brown, followed by Konrad Zimmermann, and Dave Erwin, all of whom are well known and respected within Canada's nuclear industry for their abilities and contributions to

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[83] P.R. Stratton (O.H.) to K.G. Zimmermann (APD), April 22, 1983.
J.S. Foster (Monenco Ontario Ltd.) to K.G. Zimmermann, April 25, 1983.
D.E. Anderson (O.H.) to K.G. Zimmermann, May 3, 1983.

[84] Memo W.G. Morison, Assistant Director Generator Projects, Ontario Hydro, to R.C. Johnston, Manager, Nuclear Energy Project, CGE, September 15, 1970. (All four memos located in the APD Archives)

that industry. These managers, all of whom have a background in design engineering, worked extremely hard to build and guide a strong organization with competent staff at all levels. They led this organization in seeking and achieving technical excellence in all of the work they undertook. The success of their efforts is attested to by their customers, and borne out by the performance of the equipment they have produced.[85]

Supporting and complementing the efforts of these managers have been the unit managers, such as Ed Adams, Dick Beck, John Condon, Gord Davis, and John Irvine, to name just a few. All of the above each had over thirty years experience in nuclear work in Peterborough, and played a significant part in the successful design and performance of the CANDU operations.

While managers such as these have led the various units, the frequently dedicated performance of individual contributors, usually working in product teams, partiallly explains the reasons behind the Fuel Handling group's success and longevity. Under Konrad Zimmerman's direction, teamwork has been a number one priority for many years. This has been effectively achieved by establishing and implementing the "product team" approach on all contracts. These teams, consisting of a representative from each of the departmental units involved in a particular phase of the work, hold short informal meetings on a weekly basis to monitor progress, define priorities, identify potential and real problems, and assign tasks and dates for their completion, etc. By using such a

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[85]Memo P.R. Stratton, Director Supply Division, Ontario Hydro, to K.G. Zimmermann, April 22, 1983 (APD Archives)

cooperative approach, all participants are made fully aware of all of the operations involved for the work in hand, and how each unit's operations interact with those of the others. Team members, by participating and contributing to the team's results, know that their individual efforts are important, affecting those of their colleagues and the whole project. Properly organized and supported by all levels of management, the results obtained from teamwork approach, in complex operations involving many units and disciplines, are invaluable. CGE's Fuel Handling Systems group, a pioneer in establishing product teams as a key part of its normal operating procedures, owes much of its success to their efforts.

After forty years in the nuclear field, GE Peterborough remained the only company in Canada with an integrated engineering and manufacturing group able to design and supply complete nuclear fuel handling systems. Further, in 1995 it was the only company in Canada still engaged in the manufacture of nuclear fuelling machines, of either CGE or AECL design. Several other companies which were in the business -- for example, Standard Modern Tool Company (of Toronto) which manufactured the Pickering machines -- left the field, but CGE remained. [86]

This can be explained to a large extent by the fact that having a fully integrated design-supply facility gave CGE a tremendous advantage over its competitors in the efficiency of its operations, with the potential for significant cost savings and improved performance to schedules. For example, APD design staff -- working in close collaboration with their manufacturing colleagues

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[86] Doug Mahler, Personal Interview, February 27, 1997.

-- could provide immediate assistance in the resolution of problems on the shop floor by seeing the problem first-hand then quickly authorizing concessions on dimensional tolerances, materials, etc. By contrast, companies not having such close design back-up faced costly manufacturing and scheduling delays in first contacting the appropriate individuals, then awaiting the resolution of their shop problems by a design group located some distance away. Close design support to manufacturing operations saves a company and its customers considerable time and money and is especially valuable in nuclear work which often requires the use of new types of material and equipment, plus tight dimensional tolerances. Nowhere is this more apparent than in the design, supply, test and installation of the fuelling machines and their associated equipment.

The CGE-designed fuelling machines, in service at the Bruce and Darlington power complexes, in similar fashion to the KANUPP machines, consist of two major assemblies plus associated instrumentation and control equipment. These assemblies are: the fuelling machine head, and its suspension. The head can be compared to a giant revolver complete with its own internal magazine, but loaded with fuel bundles, and other components, in place of bullets. The head sits within, is supported and driven by the suspension, but is free to move and align with a reactor fuel channel during refuelling operations.

In operation, a pair of heads, remotely controlled, moves to a pre-selected fuel channel, locks on to each end and makes a leak-tight seal with the channel's end faces. To accomplish this operation without damaging the channel, each head must be aligned very closely with the channel's end fitting before clamping to it. Next, the head, utilizing its drive mechanisms, removes the channel's end fitting closure and shield plug and stores them in its magazine. Once the channel closure is removed, the fuelling machine becomes in effect an extension of the channel with its circulating flow of high temperature, pressurized heavy water. Then the machines, working in conjunction with each other, start refuelling operations. One machine pushes two new fuel bundles into the channel, displacing the string of bundles already in the channel until two irradiated bundles enter the magazine of the other (accept) machine. These operations are repeated until the predetermined number of new fuel bundles have been installed. After reinstalling the channel's shield plugs and closures, the machines unlock from the channel, move away from the reactor face and discharge the irradiated fuel bundles.

To accomplish all of these operations safely and reliably, the head employs a series of interrelated drive mechanisms to provide required axial and rotary movements of its components. It also uses control systems to monitor the drives and keep the operator informed at all times of the exact position of the drives, the channel components, and the fuel. For the NPD machines, these drives were hydraulically operated. The AECL-designed fuelling machines for Douglas Point also featured hydraulic drives. Hydraulic drives, however, are susceptible to leakage and other problems so the CGE team (as noted in Section 3.4) designed and developed an all-electric drive system for its next generation of fuelling machines. In addition, the head's homing and locking mechanism was completely redesigned to incorporate a different type of seal capable of withstanding many more operations before requiring maintenance shutdowns for seal replacement.

Extensive testing at CGE's laboratory verified the feasibility and value of these significant design improvements. It was decided that they, together with many other modifications would be incorporated into the design of the radically different fuelling machines to be produced by CGE for Pakistan's KANUPP reactor. Following the excellent performance of the KANUPP fuelling machines, Ontario Hydro selected this design, scaled up in size for larger diameter fuel bundles, for its Bruce A reactors. [87] [See figures 6 and 8]

This was a very significant move by Ontario Hydro management with long-term implications for the Peterborough group. The AECL-designed fuelling machines were in service at all of Hydro's Pickering reactors and so were a logical choice for the subsequent Bruce A station. Instead, Hydro chose the CGE-designed machines and their associated fuel handling system components for the Bruce A reactors. By so doing, the utility not only endorsed the design, but also displayed its confidence in the capabilities of the Peterborough nuclear department by awarding it the supply contract.

Following the successful performance of the Bruce A fuel handling systems in reactor operations, the design and supply contracts for the fuel handling systems at Bruce B and Darlington generating stations were also awarded to APD. These multi-million contracts, spread over several years, enabled the

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[87] Konrad Zimmermann et al., Nuclear Engineering Course: Nuclear Fuel Handling In Canada's Power Stations. (Peterborough: CGE, 1981) 18.

Peterborough group to keep together an integrated group dedicated to nuclear work, primarily for Ontario Hydro projects but also for those of other utilities.

The tangible benefits of having an integrated design and supply group working together on the manufacture and testing of this type of equipment were realized at an early stage in the manufacturing of the fuelling machine heads. Increasing the size of the heads from the Kanupp design to meet the Bruce requirements proved more difficult than anticipated and created some unexpected problems for the APD group. The most difficult of these concerned the large forgings used for the head's magazine housing and flat head, the main components of its pressure-containing shell. The material used, a special type of steel alloy called AM 355 selected for its unique properties, had lower than expected ductility in its weldments resulting in the development of multiple minute cracks after welding and heat treatment. These cracks, only visible after a liquid-penetrant-inspection (LPI), had to be completely ground out and weld-repaired followed by another lengthy heat treatment. Subsequent LPI tests revealed another batch of minute cracks and the whole process repeated again and again. This was a major set-back resulting in serious scheduling problems and cost overruns. Research and testing by CGE metallurgists and engineers finally identified the cause of the problem. Microscopic examination of material samples revealed minute particles of retained austenite in the base metal. During the heat treatment operation, required to ensure ductility in the weldments, these particles initiated the cracking process. Most of the forgings tested had this problem in varying degrees, and the rest were suspect. The decision was made to scrap the defective forgings, find a replacement material, modify the design to suit, and order new forgings. This was an expensive solution, but the safest. A replacement material, Inconel 600, was found, and new forgings manufactured. These proved to be completely satisfactory, and Inconel has been used for all subsequent magazine housings manufactured by CGE.

There is an interesting sidenote to this story:

The supply contract for the new forgings was awarded to the Ladish company of Milwaukee. A special feature of the magazine housing's elliptical-head forging was the incorporation into the design of a forged snout cylinder or nozzle. In previous heads, the nozzles had been separate components requiring very difficult welding and inspection operations. Eliminating these operations by going to an integrated forged nozzle was a major improvement in both design and supply, but, although the Ladish representatives foresaw no great difficulty in producing the new design, APD engineers were concerned as to its feasibility. On completion of the first forging, the writer, representing design engineering, and the manager of Quality Control were despatched to Milwaukee to inspect this critical component. To their surprise, the viewing area contained a number of huge forgings for the Space Shuttle's fuel tanks, plus some very large elliptical forgings with integral nozzles being produced for the U.S. Navy's nuclear submarines, all of these completely dwarfing APD's one-metre diameter forgings which looked very insignificant by comparison! Needless to say, Ladish produced all of the head forgings as promised, the quality was first-class, fully meeting APD's rigid specifications, and satisfactorily ending the forging saga.

The normally close liaison between CGE staff and their counterparts at Ontario Hydro had been maintained throughout this difficult stage. It was recognized by the Bruce engineering team at Hydro that CGE could not have anticipated the material problem, and had resolved it in the best way possible. As a result, although CGE had suffered a serious manufacturing setback, it had not lost the confidence of the customer, Ontario Hydro. This was borne out by the subsequent contracts for very similar machines and all of the fuel handling equipment for the Bruce B and Darlington projects. [88]

An important aspect of the unique contribution made by Peterborough's APD is the design, assembly and testing of the special instrumentation and control equipment required for the fuel handling and other nuclear plant systems. Of particular note is the "DICON" (Device Installation and Connection) system. This pioneering series of computer programs was started in 1965 by two members of APD's Nuclear Systems Engineering unit, Hector Griffin and Mel Townsend. The programs provide complete engineering and drafting information for the pulling and terminating of cables, cable inventory, device listing, panel manufacturing, and materials handling. They also permit project control by furnishing precise status reporting of design, construction and commissioning operations. The system permits access by construction site personnel to data placed in the computer system by the designers. It was designed specifically for use with electrical connection information on large projects such as

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[88] Dave Erwin, Personal Interview, February 14, 1997. (For title see p. 160)

generating stations and has been extensively utilized by CGE on its nuclear projects. It has also been adapted and widely used by other companies including AECL, Ontario Hydro, and the Bechtel Corporation, in Canada and around the world. DICON has had a history of continuous enhancement since its inception, incorporating ideas and suggestions from several major design and construction groups making it one of the most versatile systems of its kind available. [89]

APD engineers and technicians in its Special Instrumentation and Control unit have designed and developed unique instrumentation for many different applications. These include ultrasonic leak detection systems, fluid flow measurement by ultrasonic techniques, and other special measuring devices for use in inaccessible locations and hostile environments, such as high radiation fields.

4.3 FUEL CHANNELS AND ASSOCIATED EQUIPMENT

The CANDU reactor fuel channels are much more than just tubes used to contain fuel bundles in the reactor core. In fact, they are extremely important parts of the reactor and its fuelling system. They are in effect small pressure vessels through which flows the pressurized reactor coolant, transporting away the heat generated by the irradiated fuel bundles. Each fuel channel consists of a thin-walled zirconium alloy pressure tube, the length of the reactor core, with a stainless steel forging -- called the "end fitting" -- attached to each end. Zirconium alloy is used as the pressure tube material because it provides the

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[89] Mel Townsend, Telephone Interview, March 14, 1997. (For title see p. 161)

best combination of the required metallurgical properties: strength, low neutron absorption, and high corrosive resistance. [See Figure 8]

It is not feasible to satisfactorily weld the thin-wall alloy tubing to the heavy end- fitting forgings so a boiler-type rolled joint technique is used to join them. The soundness of the seal made in the process is critical to provide adequate strength under pressure and heat, and to prevent any leakage of the heavy water coolant.

The decision to use individual pressure tubes for the CANDU reactors was made in 1957 as part of the redesign and changeover from the NPD-1 configuration to its replacement, NPD-2. Starting at that time, work began in Peterborough on the fuel channel design and has continued -- with AECL -- on subsequent reactors. As noted earlier, it was recognized that the soundness of the rolled joint between each tube and its associated end fittings is critical, requiring a great deal of experimentation, engineering design and analysis, manufacturing expertise, and laboratory testing. Special tooling is required to reach through the length of the end fitting body and extrude the pressure tube material into the grooves pre-machined in the end fitting bore. This is another area in which the Peterborough group specialized. Over the years, its teams of engineers and technicians became the recognized experts in the design of the joint configurations and the associated tooling. Their expertise in fuel channel installation and removal created a demand for their services at CANDU sites all over the world.

It is very specialized and demanding work because the joint area cannot be seen during the rolling operations, the amount of material extrusion to make a sound joint varies, and every joint has to pass a pressurized helium leak test and maintain zero leakage. Close to one thousand joints are required for each reactor, and each one has to be 100% sound. A defective joint would mean the scrapping and replacement of an expensive pressure tube, plus delays to installation schedules, etc. Leakage during reactor operation would be hazardous and result in an extended reactor shutdown costing hundreds of thousands of dollars.

Despite all of the problems, real and potential, the fuel channel installation crews have successfully completed the “tubing” of reactors for forty years. In addition, they have also handled retubing operations on reactors requiring such work due to problems such as pressure tube creep.

Mechanical “creep” is the condition of the slow stretching or elongation of metals due to stress at high temperature. The rate of stretching is accelerated by nuclear radiation, exactly the conditions the pressure tubes experience in operation. While the reactor designers knew of this phenomenon early on, they did not, and could not, know how greatly the high radiation fields in the reactor core would increase the creep rate. Predictions were made, and various test simulations performed, but this would only be accurately determined after several years of reactor operation.

The potential effects of a much greater than predicted creep rate are serious. The pressure tubes’ design life could be shortened, and refuelling operations compromised. The fuel channel and fuelling machine designers in Peterborough and at AECL made allowances in their designs to accommodate the maximum predicted growth of the pressure tubes. Modifications of the components were designed which could be incorporated later if necessary to handle greater than the maximum predicted creep.

To date, the preparations made to adjust to pressure tube creep have proved to be adequate and satisfactory. However, pressure tube failures due to other problems, such as vibration and cracking, have resulted in very costly reactor shutdowns for tube replacement. Retubing a reactor entails many months of work in tube removal and replacement and a cost of millions of dollars. This is very specialized work requiring the design and use of special-purpose tooling by skilled personnel. Channel retubing, and other types of service work, have become an important part of APD's day-to-day operations -- see section 4.4

4.4 NUCLEAR SERVICE

Most of the CANDU reactors have been in operation for several years, some, such as at the Pickering and Bruce stations, for decades. During these years of service, scheduled inspections and maintenance work have been performed on a routine basis. However, after years of service and as the equipment ages, major and unanticipated problems emerged which required more than routine-type service. A prime example was the discovery of cracking in some of the fuel channels, which eventually resulted in reactor shutdown and channel replacement.

When reactor shutdowns due to equipment and operating problems occur, the loss of generating capacity and its replacement by other sources quickly result in expenditures of hundreds of thousands of dollars. Once the cause of the problem has been identified, corrective service work must be started and completed as speedily and safely as possible. Personnel experienced in this type of work must be involved to handle the design, manufacture and installation aspects of the repair operation. In many cases the station operators do not have sufficient staff, or do not have the facilities to fix the problem, and require assistance from other organizations. As a result, APD, which has both an experienced staff and the facilities, is frequently called upon to help, and nuclear service work, of all kinds, has become a major segment of the department's operations.

In the case of removing and replacing the irradiated fuel channels, large numbers of special-purpose tools were required. Also required were detailed knowledge of the equipment, radiation hazards, and proven capability on this type of work. Ontario Hydro awarded APD the contracts for the design and supply of this tooling.

The term "tooling" in this context refers to a range of devices widely varying in size and complexity depending on their function. Some are very basic tools with few if any moving parts, others are extremely complex machine-type equipment. The designers were handed the twin objectives of making the tooling as uncomplicated as possible, but at the same time functional and reliable.

However, some of the tasks were so challenging that they could not be accomplished using simple devices. One of the most complex tooling devices was required for the difficult task of locating and moving the garter spring spacers located in the annulus between the ouside diameter of the pressure tube and the bore of the calandria tube. Known by the acronym "SLAR" (Spacer Locating and Repositioning) device, this was more of a remote operating machine than a tool. [90] [See Figure 12]

The garter springs were originally installed at a number of equal spaces along the pressure tubes to prevent them sagging and contacting the calandria tubes. Unfortunately, during reactor operation the spacers migrated along the tubes -- probably due to vibration -- allowing the pressure tubes to sag. This was not realized until the sagging tubes touched the calandria tubes and developed hairline cracks. Getting at the the springs and relocating them was very difficult , requiring great ingenuity in design. The APD designers met this challenge and produced a design for the SLAR tooling which met all of the specified requirements. The supply and testing of this equipment was also handled by APD personnel in Peterborough, to a very tight schedule. Subsequent operations at the reactor face have borne out the effectiveness and reliability of the complete SLAR packages to the satisfaction of Ontario Hydro.

In performing this specialized type of service work, the APD people involved have received numerous patent awards for the uniqueness of their designs and applications. In addition, the value of their pioneering work and their contributions to Canada's nuclear industry in general have been officially recognized by the Canadian Nuclear Association. For example, the first

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[90] Bill Knowles, Discussions, February 18, 1997. (For title see p. 162)

"CNA Outstanding Contribution Award" was presented to long-time APD employee Ernie Farris, in 1993. Referring to this award, the 1994 CNA Yearbook notes that:

> Ernie has had a wealth of experience with CANDU reactor fuel channel technology. The success of his career is perhaps measured by the fact that he has no less than five patent awards with GE Canada for his design work and innovation with respect to fuel channels. He has become one of the nuclear industry's top experts in fuel channel design and replacement. [91]

The dedicated efforts of Ernie and his associates in their day-to-day service work on CANDU projects have brought great credit to APD and to Peterborough. In addition, and very importantly for both concerns, it has won and retained a steady share of the industry's business during the last forty years.

More recent major service work is APD's design and supply of the "Universal Delivery Machines" which handle a variety of fuel channel inspection tasks. These complex machines, have much greater capabilities than SLAR, in fact, SLAR is just one of the chores they perform. Another task is "SCRATCH" which performs a type of biopsy on a fuel channel bore to detect problems such as hydrides. The first machines are for the Bruce G.S. to be followed by machines for the Pickering and Darlington stations.[92]

In summary, nuclear service work is an extremely important segment of APD's operations which is growing in scale and scope as the in-service reactors age.

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[91] Canadian Nuclear Association, Nuclear Canada Yearbook 1994, (Toronto:CNA, 1994) 21. The company gives awards of cash and stock to its personnel who are credited with work that leads to government granting of patents to the company. In addition, APD's inventors are honoured by having their portraits permanently displayed in the department. (See Fig. 13)

[92] Discussion with APD design engineer Michael Gray, July 19, 2000.

5.0 ANALYSIS AND CONCLUSIONS

This chapter analyses the reasons behind APD's successful operations and longevity based on the department's history and performance described in the preceding chapters. From this analysis, conclusions are drawn and explained.

5.1 ANALYSIS OF PERFORMANCE AND ROLE

. The forty-year period covered in this thesis saw tremendous changes in the nuclear industry including frequent changes in direction, markets, and roles. By the end of the period, APD emerged as one of the few companies which had survived this turbulent business out of the many which had participated in it earlier. There are many reasons behind APD's initial and lasting success, the key ones being as follows:

(i) CGE entered the field in a bold way, demonstrating its commitment by offering a large financial contribution as part of its initial bid. Although other companies were interested and probably capable of handling the private-industry portion of NPD's design and manufacture, CGE was the only one that made such an offer; it may well have tipped the scales in CGE's favour when the bids were reviewed.

(ii) CGE backed up its financial commitment with the next bold moves:

a) Assigning one of its top executives, Ian McRae, to establish and head the new department.

b) Hiring and bringing to Peterborough a senior AECL nuclear engineer, Ian MacKay, to head the new Engineering section.

c) Hiring engineering personnel with nuclear experience at Chalk River to help form, as rapidly as possible, CAPD's design team.

d) Moving selected and experienced non-nuclear technical staff from other CGE departments to join their AECL colleagues.

e) Having senior AECL and Ontario Hydro engineers attached to the new department, working alongside APD staff in the early phases of NPD's design and manufacture.

(iii) CGE started its nuclear operations as an equal partner with both AECL and Ontario Hydro rather than a subsidiary participant. This gave the company invaluable authority and influence in the burgeoning nuclear industry plus access to information and people it would not otherwise have been permitted. For instance, from the start APD personnel were fully involved in all of the major design and manufacturing decisions for NPD rather than being simply a sub-contractor with limited access to information and data. This privileged status continued -- although was somewhat curtailed after the formation of NPPD -- throughout the history of the department.

(iv) CGE, as a major Canadian manufacturing company with many other product lines in addition to APD, and its largest plant already in Peterborough, was large enough to withstand and dampen the effects of low business levels occuring in its nuclear products' market. Surplus manpower could be absorbed temporarily in other departments of the plant if needed. On the other hand, when APD experienced high business situations it could recall or borrow personnel from other departments. This capability was a major consideration giving APD a huge advantage over its competitors. These companies had much more difficult staffing problems especially acquiring and retaining skilled "nuclear" people.

(v) APD was aided by the large pool of manufacturing skills -- machinists, toolmakers, technicians, etc. -- and the considerable manufacturing resources of the Peterborough plant. With these manufacturing resources to support its operations, APD did not have to bear the overhead costs associated with establishing and maintaining its own machine shops, tool rooms, etc. especially during periods of low business activity. An additional advantage this provided was that APD engineers could draw upon the wide range of manufacturing expertise existing across the plant to assist them at all stages of the design and manufacturing phases, for example, to receive input and advice on ease-of-manufacture, machine capabilities, manufacturing processes, and the resolution of manufacturing problems. This support was not so readily available to the design staff at NPPD and Ontario Hydro, or at many private companies, thus putting them at a considerable disadvantage.

(vi) At no time did APD spend extravagantly on equipment, facilities, or buildings. For example, CAPD was first established in a small area on the second floor of a former warehouse, Peterborough plant's Building 21. As the department grew, it stayed in the same building gradually taking over more space until it occupied the entire building. For its welding operations, it set up shop in one end of an adjacent building (Building 26) and again gradually expanded. Both buildings were of 1940s vintage and needed upgrading. Minor improvements were gradually implemented but major renovations did not take place until the receipt of the Bruce A contracts. At that time, the welding area was completely revamped to conform with current nuclear quality standards of lighting, material controls and isolation. A large area on the ground floor of Building 21 was transformed into a "clean room" to meet the required standards of cleanliness, lighting and limited access for the assembly of fuelling machines and related equipment. The office areas in general were not brought up to contemporary standards until later, and then only as budget limitations permitted. For example, most of the desks and drafting machines purchased in the mid-1950s were still in service until superseded by computerized equipment in the late1980s. By comparison with the offices and equipment of its publicly-funded partners, APD's reflected the prudent financial management policies of its private-company management.

(vii) When APD converted to its specialization role, it wisely selected four areas it would pursue rather than being dependent on just one. This strategy enabled the department to take advantage of the fluctuating business/operational cycles of the nuclear business and its limited markets. Major fuel handling design and supply contracts, such as for the Bruce projects, were large and lengthy to complete but also few and far between. Other packages of work were needed for APD staff to compensate for the peaks and valleys in its workload. Nuclear service work was especially useful in this regard, particularly large tooling equipment such as SLAR which required the same type of knowledge and skills as fuel handling work plus all of the associated manufacturing content. Additional advantages gained by APD over its competitors in having four areas of specialization were the reduced costs resulting from their sharing common facilities, buildings, documentation registry, drawing office, drawing files, printing equipment, financial section, etc. and management.

(viii) A very important factor in APD's successful performance was its ability to retain its invaluable reservoir of experienced personnel and benefit from their store of accumulated knowledge unbroken from project to project. Obviously, this is not to say that all of the core group stayed on for the next forty years; they did not. However, although many members left the department at the start of the specialization program, sufficient numbers stayed to provide continuity and they were joined by a group of new employees during the late 1950s and early 1960s. These included many people -- for example, E.J. Adams, W. Ashdown, W.Cashen, J. Condon, J. Irvine, J. Pritchard, and K. Zimmermann -- who were involved in NPD and stayed on through the KANUPP, Bruce and Darlington projects. These were the quintessential years of APD operations during which the "CGE-design" fuelling machine was conceived and incorporated into the fuel handling systems of those projects. The early success of the KANUPP machines earned APD's designers the respect of their peers in the industry and led to the subsequent long-term contracts for their services.

(ix) From the beginning of its existence, APD's management was successful in negotiating very favourable financial arrangements with AECL and Ontario Hydro. Many of these, such as for NPD, were on a cost-plus basis due to the newness of the work and the difficulties associated in estimating costs of conceptual design programs. CGE could not provide firm price estimates for such work until a sufficient proportion of the design details had been established. In the case of NPD, early predicted cost targets were soon overrun and friction resulted between top management at AECL and CGE. In fairness to the company, it was attempting to estimate costs of equipment completely outside of its field of expertise and of a design which was still evolving. In addition, earlier and similar AECL projects such as NRU, designed and built by others, had experienced the same type of cost and schedule overruns. APD's estimating performance on cost and schedules was much improved on later projects over which it had full control, such as KANUPP and WR-1

Further, nuclear work is subject to increasingly more demanding standards and codes introduced for safety, environmental and other reasons. These usually resulted in higher costs and scheduling problems as they were incorporated into the equipment design and supply phases. In such cases, and once aware of these difficulties, management at AECL and Ontario Hydro were agreeable to renegotiating these items with CGE management, generally resulting in financial settlements satisfactory to APD.

(x) To a certain extent, AECL and Ontario Hydro needed to have CGE remain in the CANDU program. For example, APD's services and resources were extremely useful in assisting AECL when the crown agency had more design work than it could handle as in the case of the overlapping Pickering and Bruce projects. In addition, the sparsity (and later lack) of qualified manufacturers for the Pickering-type fuelling machines made APD's involvement very important to AECL.

APD provided service back-up to Ontario Hydro station personnel for many years acting at various times in design, manufacturing and site support roles in addition to its regular project fuel and fuel handling functions. Personnel from APD assisted Hydro on extended site assignments performing installation, design and quality control duties. Also when needed, APD provided a valuable service in acting as a pool of people on call to assist site in maintenance operations, their role as extra helpers whose short radiation exposure time helped minimize radiation burn-out of Hydro's own technicians.

At times in APD's history, for example when AECL established its Power Projects Department, and later when APD and AECL were competing for markets, CGE had good grounds for feeling that it was being squeezed out of the nuclear business by AECL and Ontario Hydro. CGE's top management reacted by appealing to government officials in Ottawa on the basis that government agencies should not be in competition with private companies, and reminding them of C.D. Howe's plans for private industry's continuing role in the CANDU program. [93] Politically, AECL looked bad, CGE's lobbying was partially successful, and subsequently AECL assured the company that it had plans for some of its future business to be offered to CGE for competitive bidding. Although CGE never regained its former status as an equal partner of AECL and Ontario Hydro, both public corporations recognized the value of APD's past and potential contribution to the industry and the need to keep the department in business.

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[93]Bothwell, 386.

That recognition was more than justified by the large part APD played in the nuclear business during the ensuing years. It would support AECL and Ontario Hydro with its unique capability to handle the design, supply, testing and commissioning of complete systems for them on a continuing basis.

(xi) Throughout its history, APD looked to the future, planning for the next project and work package attempting to ensure a continuous and plentiful stream of work for its staff. To accomplish this end, it always assigned teams of its designers to the pursuit of new concepts, design improvements of existing equipment accompanied by development programs. These often arose from the need to produce equipment with longer in-service life, less maintenance, improved reliability, etc. When a need was identified, by CGE or its customers, initial conceptual design would be started eventually leading to proposals and authorization for development programs to be performed at APD. Typical examples were the programs for the fuelling machine ballscrew drive systems, and the machine's homing and locking mechanism. Demonstrated improvements resulting from these programs would lead to the incorporation of the new designs into existing or future equipment.

These development programs had several advantages, for example they:

-- kept APD designs current and state of the art,

-- improved site operations and reliability,

-- demonstrated APD's design capabilities and value to the customer,

-- could lead to back-up work if current work delayed, etc.,

-- provided work for APD staff, at the time and possibly in the future.

By looking ahead and not resting on its laurels, APD continued to demonstrate its value to its customers and its readiness to support and improve their operations.

(xii) APD's long association with AECL and Ontario Hydro resulted in good interaction at all levels and generally harmonious teamwork with all of its associated benefits. In addition, APD personnel became very familiar with their colleagues' designs, equipment, drawing systems and procedures, which gave them a huge and growing advantage over its competitors, existing or potential.

5.2 CONCLUSIONS

In 1955, CGE was the right company, at the right time, in the right place, with the right commitment and the right bid to enter the Canadian nuclear power program. Forty years later, it had demonstrated this was true and its nuclear department had survived the turbulent history of nuclear power, successfully, due to a number of factors as outlined in the body of this thesis. These can be summarized here as follows:

-- Strong, capable and efficient management from the start.

-- Flexible organizational structure able to adapt and evolve in response to changing business situations and markets.

-- Extremely competent design group, recognized as such by its peers, and able to spearhead the department's operations.

-- Excellent manufacturing, test, commissioning, and service capabilities.

-- Correctly identifying, at the right time, the best fields in which to specialize.

In addition, several fortuitous events helped APD. For example, the mix of nationalities and their skills brought together in Canada in the years following the Second World War; also the technical personnel who joined APD following the demise of the Avro Arrow program in 1959. [94]

On the other hand, losing its place as an equal partner of AECL and Ontario Hydro, and the establishment of AECL's Nuclear Power Plant Division only two years after the founding of APD, were very serious set-backs for CGE. The anticipated future major projects to follow NPD, the basis for the company's entry into the nuclear business, would not materialize, and this could have spelt the end for APD. However, the department survived by adapting to its new role and situation by actively searching for new markets and pursuing new design concepts. At the time CGE's reduced role and status may have seemed a tragedy to APD's staff. In retrospect, however, the future lack of growth of the nuclear industry -- not only in Canada, but around the world -- eventually might have forced APD into a service-type role. GE president Jack Welch recognized that fact in respect to APD's counterparts in the United States in 1981.[95] By then, APD's management had been developing its specialized niche for more than a decade.

The forty years of successful operations by CGE, as a major participant in the Canadian nuclear industry, is a remarkable achievement for a private company.

This thesis has recognized and recorded that fact.

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[94] For example, Head Metallurgist D. J. Fleming, and Marketing's S. F. Waldron.
[95] Jack Welch and John A. Byrne. Jack: Straight From the Gut. (New York: Warner Business Books, 2001) 101-103.

APPENDIX 1

PERSONAL ASPECTS:

GERALD CANTELLO'S CAREER AT CGE (1951 – 1989)

During the postwar years of the 1940s and continuing into the 1950s, CGE was extremely busy with more orders on its books than its staff could handle. Although employment levels were bolstered by the many returning servicemen, there remained a severe shortage of skilled and experienced tradesmen, particularly draftsmen, toolmakers and machinists. For many years CGE had filled most of the job openings in these trades, as they arose, using graduates of its excellent in-plant apprenticeship program plus new hires from outside the company when necessary. However, the post-war boom resulted in a greater demand for skilled workers in Peterborough and across Ontario than could be readily met by existing training programs and the limited pool of available new hires.

To speedily rectify this problem, CGE and other Canadian companies sent representatives to Britain and other parts of Europe hoping to draw upon the much larger supply of tradespeople in those countries, find and hire the skilled staff needed, and bring them to Canada to work. This plan was very successful probably because many workers in war-weary Europe were only too glad to escape from their dreary postwar living conditions and start a new life in Canada. In addition, CGE offered attractive salaries and sweetened its employment offer by promising to repay half of the potential employee's trans-Atlantic fare on arrival in Peterborough, with the proviso that the individual signed a contract promising to stay in the company's employ for at least one year. This might not be perceived as an overly generous relocation offer by today's standards, but it was considered to be a very attractive inducement at the time and was accepted by dozens of skilled personnel in the two major hiring waves of 1947 and 1951. Many, perhaps most, of the people hired in the U.K. by CGE during that period liked the city and their new jobs sufficiently well that they spent the rest of their careers with the company, and the one year commitment stretched to 30 or more years -- in my case, 38 years, from 1951 to 1989.

Immigration to Canada at that time entailed -- for me [96] -- a number of medical examinations and several interviews by government officials, including one in which I was informed by my interviewer that "nothing much happened in Peterborough except fishing and hunting" -- how wrong he turned out to be! However, the Personnel department of CGE was very helpful, arranged for myself and several other U.K. types to be met at the railway station in Port Hope, brought by taxi to Peterborough, installed at the American Hotel on Simcoe Street in the early morning hours of Saturday July 7, 1951, and told to report to the plant's Park Street gatehouse at 7:25 am on the following Monday. On Sunday, four of us walked around the downtown area and bought a street map of the city to familiarize ourselves with the general street layout and the

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[96] Born in Bath, Somerset, England, February 13, 1927.
Education: Dartford Technical College, Kent; South-East London Polytechnic, London, England, National Certificate in Mechanical Engineering.

location of the plant relative to the downtown area. On Monday morning, map in hand, we set off towards the plant but soon found that we did not need a map because as we neared Park Street we became part of an unbroken stream of workers, all walking towards the plant for the 7:25 start of the day's operations. [In those days, CGE employed over 5,000 workers in its Peterborough plant, by far the city's largest workforce and a very different situation from the 1980s and 1990s during which employment levels dropped dramatically before levelling off at approximately 1250.]

I had served a five-year apprenticeship with a large British company (Standard Telephones and Cables) graduating as a "machine and tool design - draftsman" followed by a two-year stint at a consulting engineering company (Mechanical Designs Ltd. working on the design of power station mechanical equipment for Babcock and Wilcox) before being hired by CGE. Accordingly, I had the training and experience needed to quickly adapt to working as a design draftsman with the company and making a useful contribution to its operations. I was assigned to the Induction Motors drafting group working on non-standard motor mechanical designs, work which was varied enough to be interesting in the short term, but not to my mind, for a career. However, most of the draftsmen in the plant at that time -- with the exception of apprentices and new hires such as myself -- were long-service employees, apparently content to be engaged in a particular line of work, in a particular drawing office, for their whole careers, often spanning a forty-year period with the company.

My treatment in the Induction Motors drawing office, both by colleagues and management, had always been excellent and I had steadily advanced in job classification and salary, but I felt that I would like to move on to a new and different type of design work. With the formation of the new department, CAPD, although I knew little about the exact nature of its operations, there appeared to be the required opportunity. In the spring of 1958, I applied for a transfer to "the Atomic" (as the department was known in the rest of the plant) and after a wait of several months was interviewed at some length by the Drafting Supervisor (W. Ansell Taylor) and Drafting Group Leader (Don Medd) who were particularly interested in my work experience on power station equipment with Babcock and Wilcox in Britain, and its relevance to the design work on NPD then in progress. Subsequently -- and as I learned later, after an investigation of my background by the RCMP and U.K. police -- I was offered, and accepted, a design drafting position in CAPD's Mechanisms Group (fuel handling) led by Don Medd.

In August 1958 I started work in CAPD, and was quickly introduced to the department's teamwork environment by a warm welcome from General Manager Ian McRae, and Chief Engineer Ian MacKay. Both of these busy individuals invited me to their offices and chatted with me for 30 minutes or so about my background, family, etc., the department in general, and my future role in its operations. In addition, Ian McRae in his capacity as a notary public had me take the oath of secrecy, a requirement taken very seriously in the 1950s and the Cold War era.

It is worth noting here that Ian McRae was a man with great people skills and a very effective motivator. Before I had ever met him, I had heard several personal accounts of the kindnesses he had performed to plant employees and their families. He inspired great loyalty in his associates and on the plant floor. An example of the regard in which he was held goes back to the 1940s when he was the Works Manager and a group of employees hoped to form a pipe band; he provided encouragement, support, and a place to train. By June 1948, the band was trained, fully equipped, and ready to appear in public under the name of the "CGE Pipe Band" and proudly wearing the McRae tartan in tribute to their manager and supporter. Later, as manager of CAPD, he would personally talk to each of the female employees -- the "girls" as they were then known -- at Christmas time, wish them the compliments of the season, and quietly give each one the gift of a silver dollar, something treasured in the 1950s. This, to my mind, was a simple act of generosity and not a token gesture towards the clerical staff. [97]

Physically, the move from the Motors section to CAPD was minor because the two departments were located next to each other on the second floor of Building 21, but operationally the differences were major. The Motors department was typical of the rest of the plant: long-established and with set routines, procedures, and customs, working on familiar product lines.

By contrast, CAPD was newly established, in the process of generating its own procedures and systems for a completely new product -- a nuclear power demonstration reactor (NPD) -- and a newly-gathered team drawn from many

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[97] Sangster, Earning Respect, 21, 66 - 75.

areas and disciplines to work on its design and construction. While CAPD could, and did, draw upon many of CGE systems and practices (such as the very logical and proven numbering procedures for new drawings) it was not bound to do so and made use of other systems when appropriate and necessary. This was especially true in the department's interface with its partners, AECL and Ontario Hydro, which had firmly established procedures and systems of their own which at times had to be incorporated, often overriding CGE systems. Formulating new systems and learning to follow others' practices, in a shared manner, helped create and foster the teamwork approach which has characterized CAPD since its inception.

The camaraderie existing among CAPD staff members can be traced back, in large measure, to the early days of the department and the long-standing association of its people. This is borne out by the annual reunions in Peterborough every October attended by retirees from across Canada and from Britain, and not only former CGE employees but also representatives of AECL and Ontario Hydro, many of whom were involved with the design and operations of the NPD station. In addition, a number of former CAPD members meet monthly for breakfast and social get-togethers.

Further reasons for the strong camaradie among CAPD personnel are the teamwork approach and reliance on fellow team members necessary to achieve the objectives of producing nuclear-grade equipment and components which meet the customers' high quality and schedule requirements. These objectives, as CAPD has demonstrated, can only be accomplished on a consistent basis by the successful coordination and integration of many skills, disciplines and activities at all levels, resulting from long-term team-member association.

The type of work in the Mechanisms Group was interesting, varied and challenging, ranging from small mechanisms for fuelling machines to large equipment such as reactor vault shielding gates. Adding to the experience of the day-to-day drawing office duties were the in-plant training courses, test laboratory liaison, and the occasional opportunities to visit the NRU and NRX reactors at AECL's Chalk River Laboratories and the nearby NPD construction site at Rolphton.

In 1963, Don Medd transferred to the engineering design unit and I succeeded him as Group Leader. This was the top classification for design draftsmen with the company; future advancement could only be accomplished by leaving the unionized Drafting group and becoming a member of the Management and Professional (M&P) group. In 1967, after four years in the Group Leader postion and as my personal Centennial Year project, I decided to look for an opportunity to leave Drafting and become an M&P member. A job opening arose in the CAPD Marketing Section for a "Contract Liaison Specialist" an M&P position, for which I decided to apply, and was accepted.

The type of work was very different from my Drafting duties, entailing the administration of customer contracts, monitoring expenditures and performance to schedules, writing reports, drawing-up proposals, keeping the work moving through design, manufacture, test and shipping, plus liaison with customers. It was also different in types of equipment, dealing with fuel channels, rolled joint development, etc. rather than fuel handling equipment. It gave me the opportunity to meet and liaise with other units of the department, other AECL personnel than I had been associated with previously, and to meet with them at their offices in Sheridan Park and at Whiteshell, Manitoba. It was interesting work -- with a fair amount of responsibility but also freedom to perform with minimal supervision so long as the customer's and the department's requirements were met -- and personally satisfying. However, one year later, the Manager of the fuel handling engineering section, Konrad Zimmermann, called me to his office and told me he would like me to join his staff and work on design of fuel handling equipment, i.e., as an "engineering" rather than a "drafting" member. Having changed jobs only one year earlier, I was somewhat reluctant to move so soon again, but Konrad suggested that if the Marketing Section was downsizing in the near future I might then accept his offer. This is exactly what happened, and I joined Engineering.

The project at the time was the design of the complete fuel handling system for the Pakistan reactor, KANUPP. The mechanical design was led by Stan Janusz, a very competent engineer with a firm vision and grasp of the system's requirements, how to meet them and see the project through the design, manufacture and test phases. The department performed well on the KANUPP project, the main glitch being the India-Pakistan war which delayed the final completion. [As a personal footnote, Stan was assigned to go to Karachi to be available for technical support during the commissioning of the fuel handling equipment, I was to be the back-up person and had umpteen needles for cholera, yellow fever, etc. Stan did make it to Karachi, but had no sooner arrived than the war broke out and he was hastily evacuated by sea. He enjoyed the adventure, I didn't.]

Following KANUPP, my design work continued with the development and laboratory testing of KANUPP-type fuelling machine components increased in size to suit the larger diameter fuel bundles for use in future domestic reactors. The successful results of this development work led to the incorporation of this design into the Bruce A fuelling machines, followed by Bruce B and Darlington. For these major projects, my duties included the initial design -- writing design specifications, initiating and following through the design in the drawing office and the sign-off of engineering drawings -- followed by manufacturing and test liaison on behalf of AECL and Ontario Hydro. In this context, liaison meant processing "manufacturing concessions" dealing with records of components, materials and processes which did not conform with the specifications or drawing dimensional tolerances. This work was extensive because it covered the documentation of every dimension, process, finish, etc. of each of the thousands of components involved in the manufacture and supply of the fuel handling systems. Every discrepancy had to be reviewed and assessed to determine acceptance or rejection, and signed-off accordingly, by the design representative -- a CGE employee, acting impartially on behalf of the customer.

In 1979, after eleven years working in the mechanical design engineering unit, I was offered, and accepted, the position of CAPD Drafting Supervisor, replacing Don Dennison who was retiring after a lifetime career with CGE.

Taking over such a large drafting group -- approximately 40 draftsmen and one draftswoman -- was initially very difficult for me because of the large number of different projects underway, including some in which I had never been involved. In addition to the Ontario Hydro projects (Bruce and Darlington) with which I was very familiar, there were the various AECL 600 MW projects (New Brunswick, Korea, Argentina, and Quebec) each having its own discrete specification and drawing numbering system, drawing office manual, etc. In addition, the group handled drawings for fuel bundles, Man-Mate manipulators, miscellaneous laboratory and development projects, plus ongoing drawing changes for existing reactors such as KANUPP. Fortunately, I had the assistance of some very knowledgeable and experienced senior draftsmen who had worked on some of these projects from the beginning and knew the project rules and guidelines.

Extensive liaison was necessary between the CAPD Drafting group and AECL at Sheridan Park, and Ontario Hydro, to ensure complete two-way design information transfer, drawing and documentation routing for new drawings, "As-Built" drawings, and Engineering Change Notices (ECNs), etc. In total, the responsibilities and duties of the Drafting supervisor and group had grown tremendously since the early days of the department. The single project, NPD, had been replaced by numerous projects and types of work. However, the teamwork, camaraderie, and support from management at all levels which existed throughout CAPD, enabled the department to be resilient, adapt to each new challenge, and -- the bottom line -- prove sufficiently capable to operate profitably for over forty years.

One of my last activities before retiring from the company in 1989 was to introduce computerized design and drafting (CADD) into CAPD. At that time, CADD was relatively new and its potential largely unknown. Ontario Hydro had state-of-the-art systems in place and were very helpful in sharing their expertise with us. Today, advances in computer technology permit the reactor designer to "walk through" the station via the monitor and visualize equipment in place, determine that piping runs do not collide or interfere, etc. In addition, mechanical designs such as fuelling machines can be handled completely from assemblies down to the last detail and ordering information using CADD. This method of designing everything from cars to hospitals, is now the norm, saving time, reducing costs and minimizing drudgery, but also taking away jobs.
Only a fraction of the numbers of people formerly working in the department now are employed there, and the days of multi-project operations are over. Virtually every office desk now sports a computer either for drafting or word processing use and drawings are computer-generated. Once again, CAPD has adapted to its changed circumstances, has survived the downturn in nuclear work, and is busy!

APPENDIX 2

ILLUSTRATIONS

LIST OF ILLUSTRATIONS:

Note: These illustrations are proprietary information and are produced here by kind permission of the management of the Nuclear Products Department, GE Peterborough.

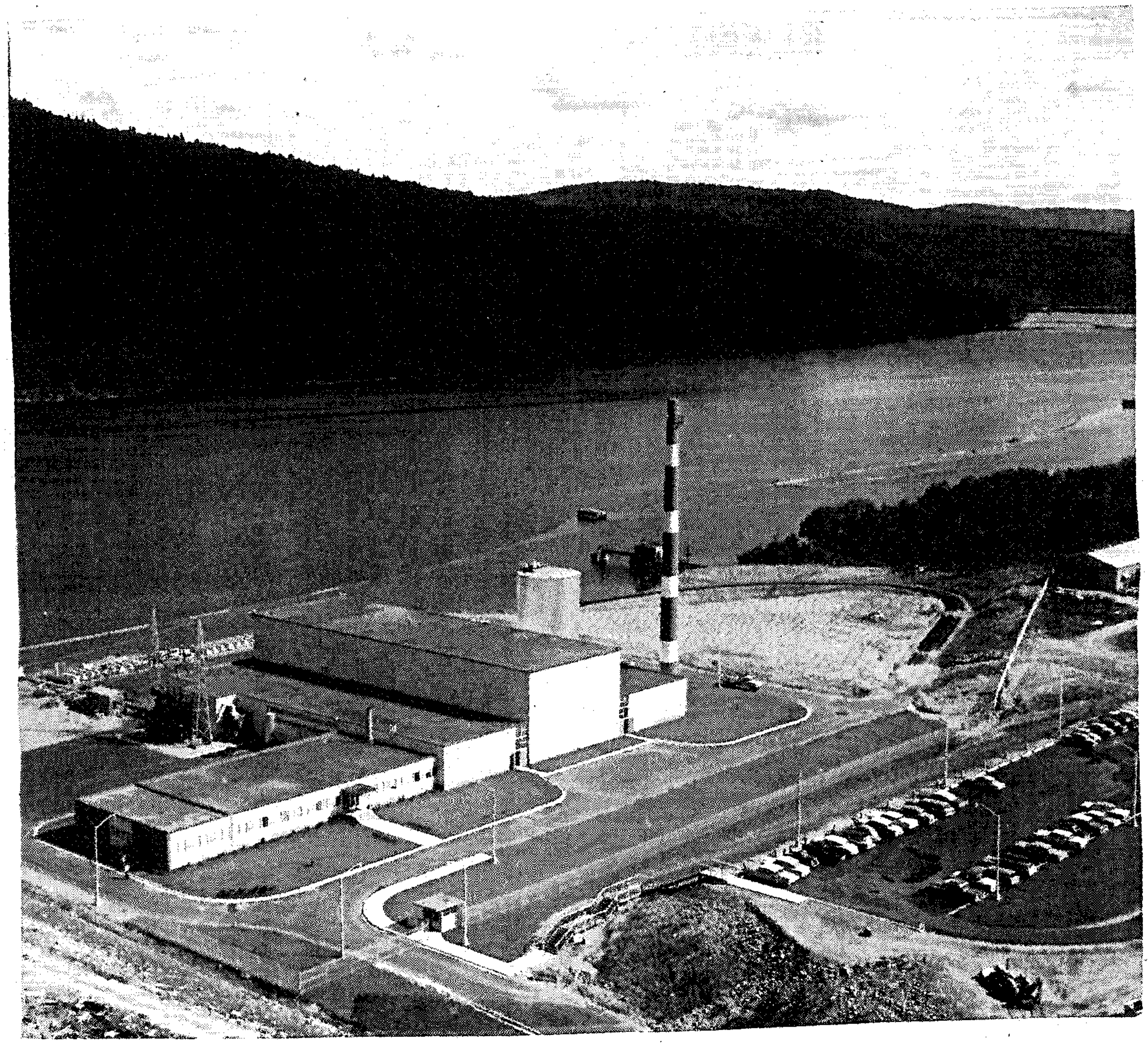


Figure 1: NPD Generating Station, 1962

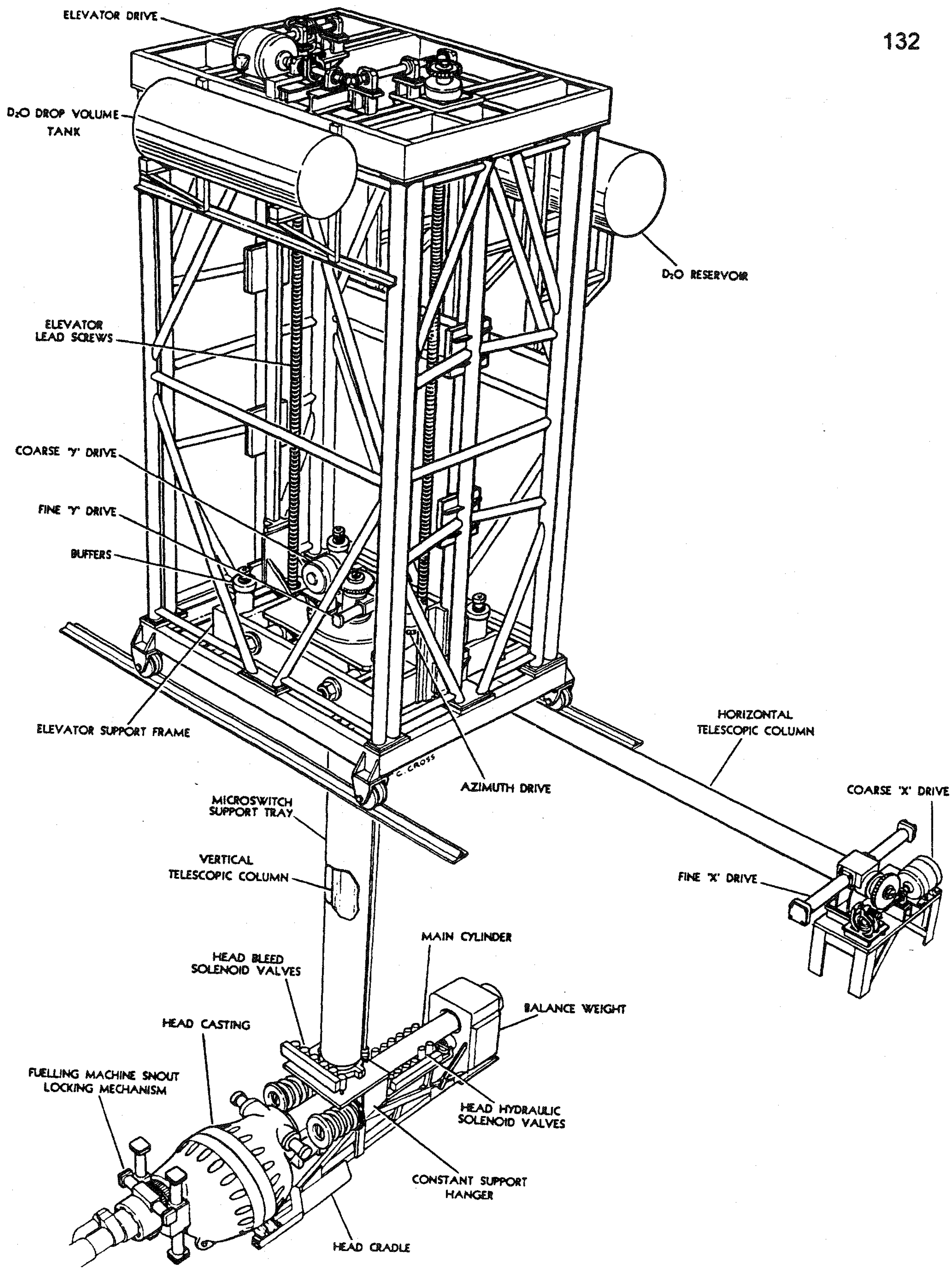


Figure 2: NPD Fuelling Machine (Original Design Head)

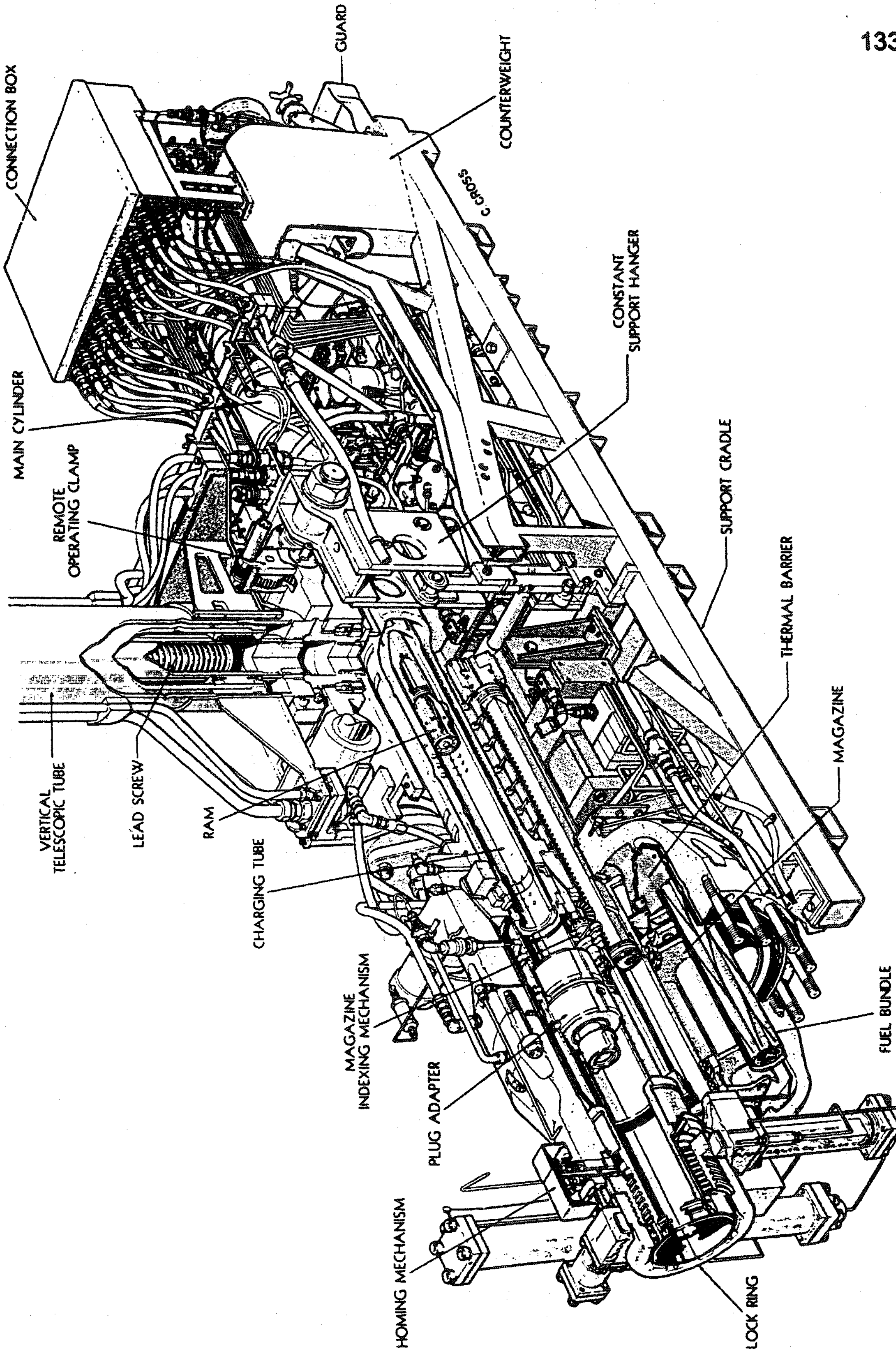


Figure 3: NPD Fuelling Machine Head (Replacement)

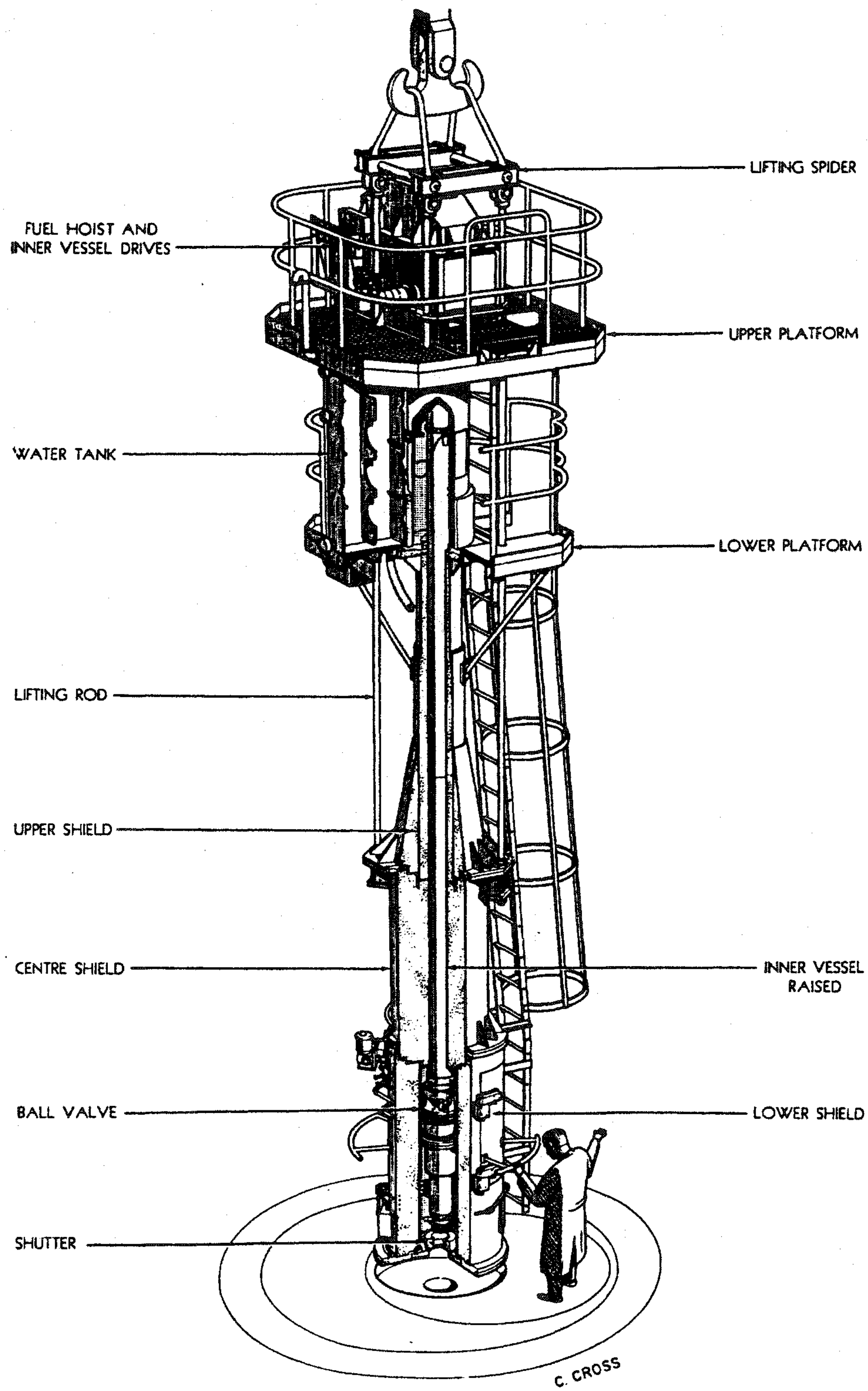


Figure 4: WR-1 Fuel Transfer Flask Cutaway

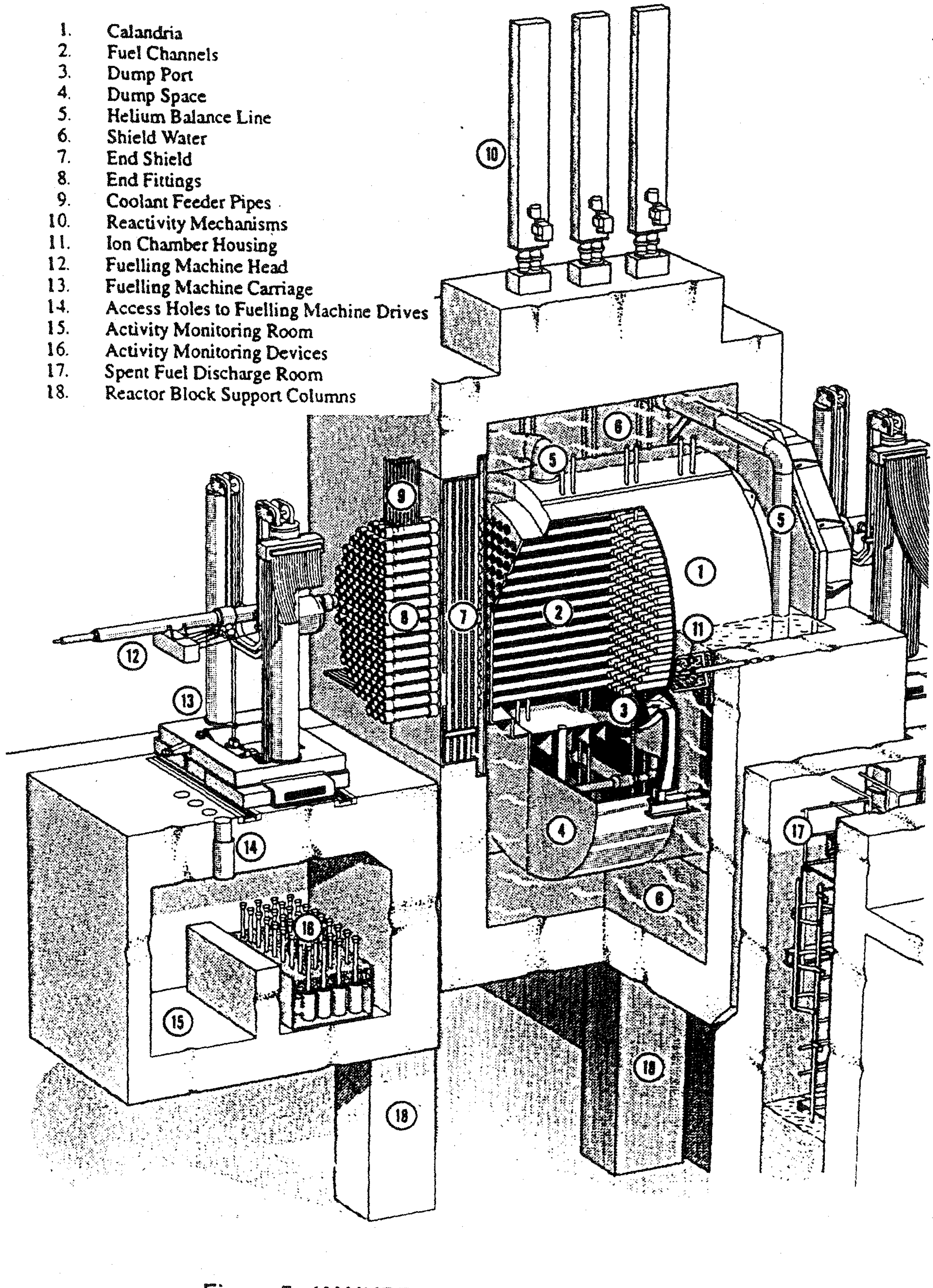


Figure 5: KANUPP Reactor Cutaway

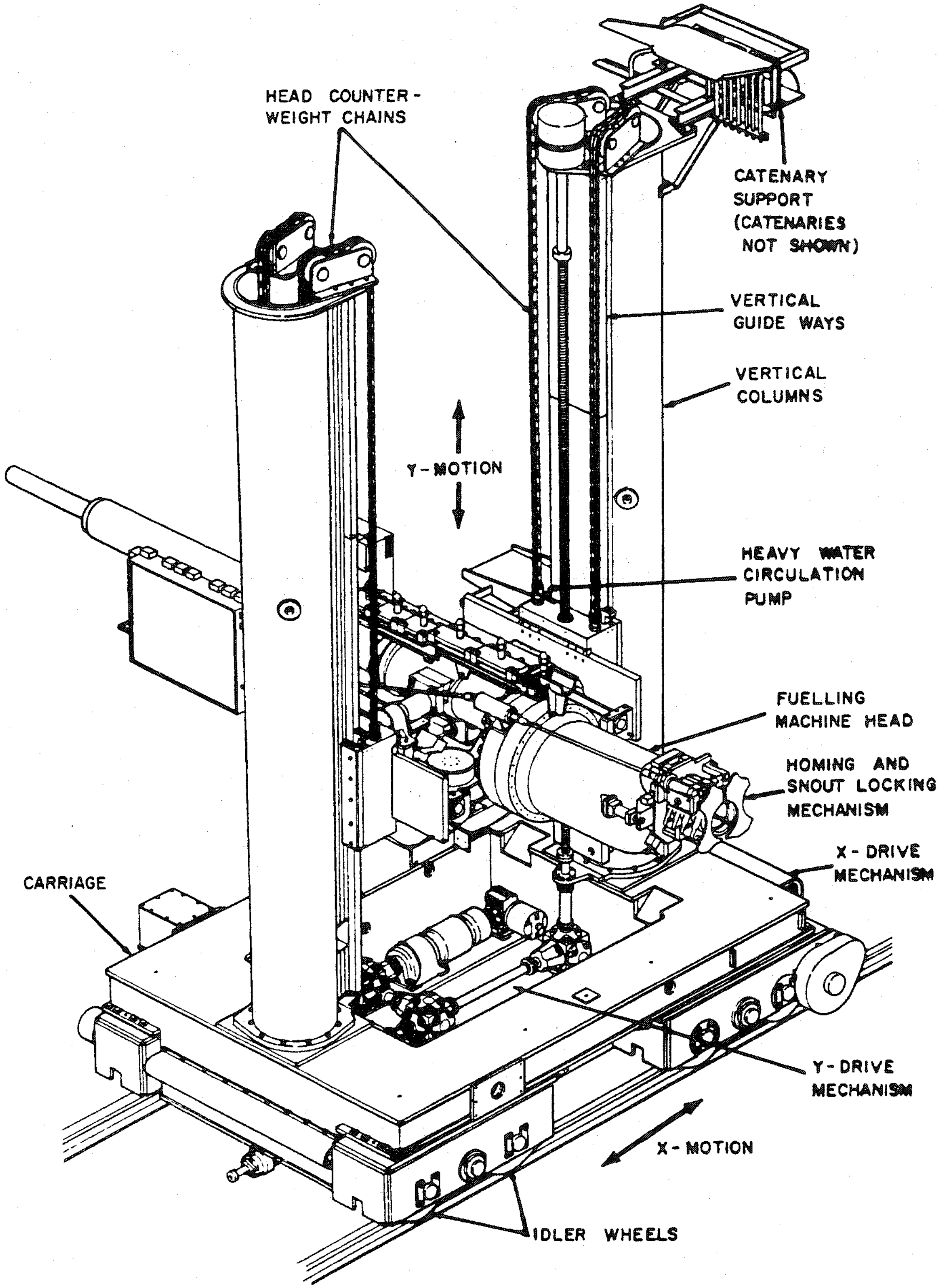


Figure 6: KANUPP Fuelling Machine

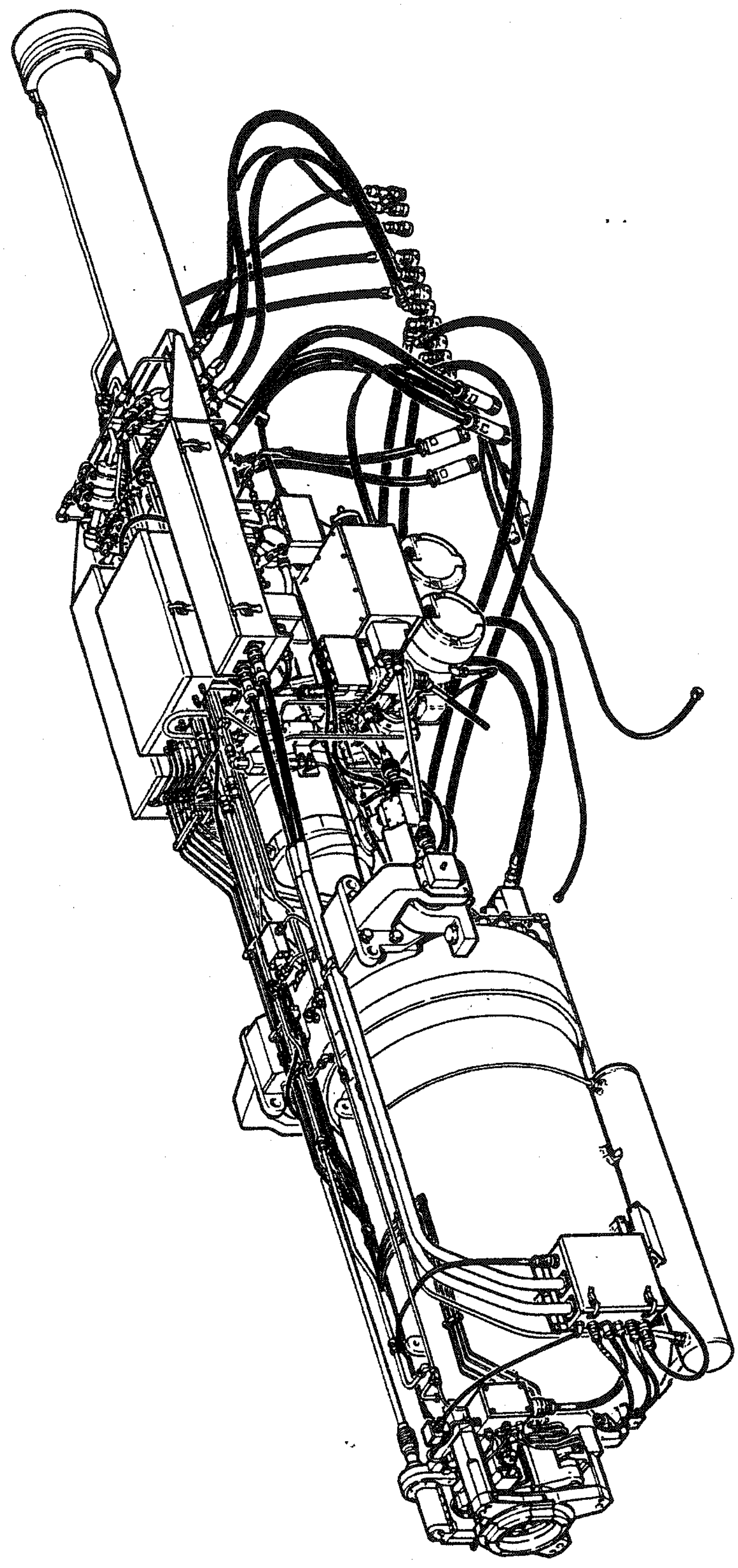


Figure 7: Bruce GS Fuelling Machine Head

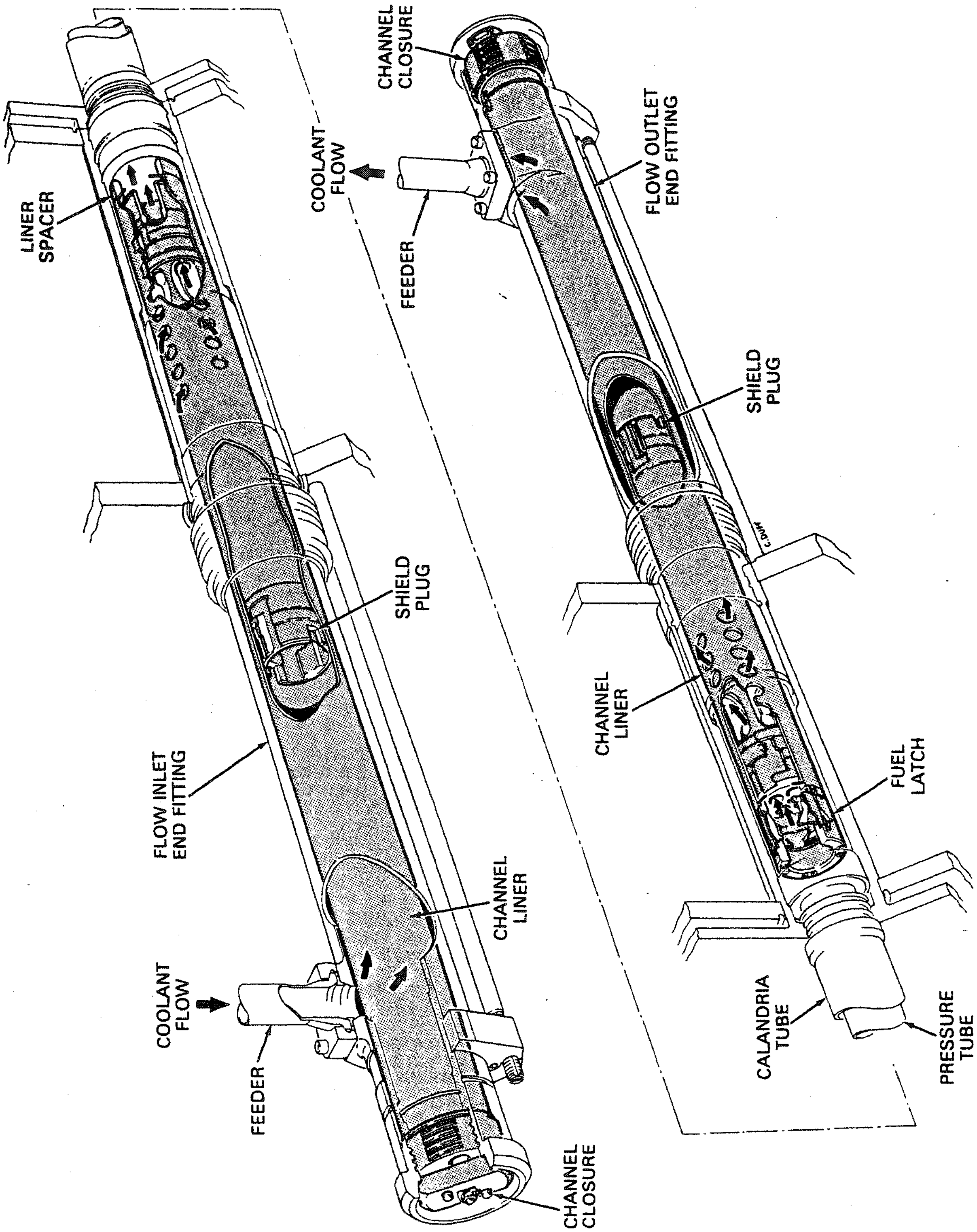


Figure 8: Bruce GS Fuel Channel

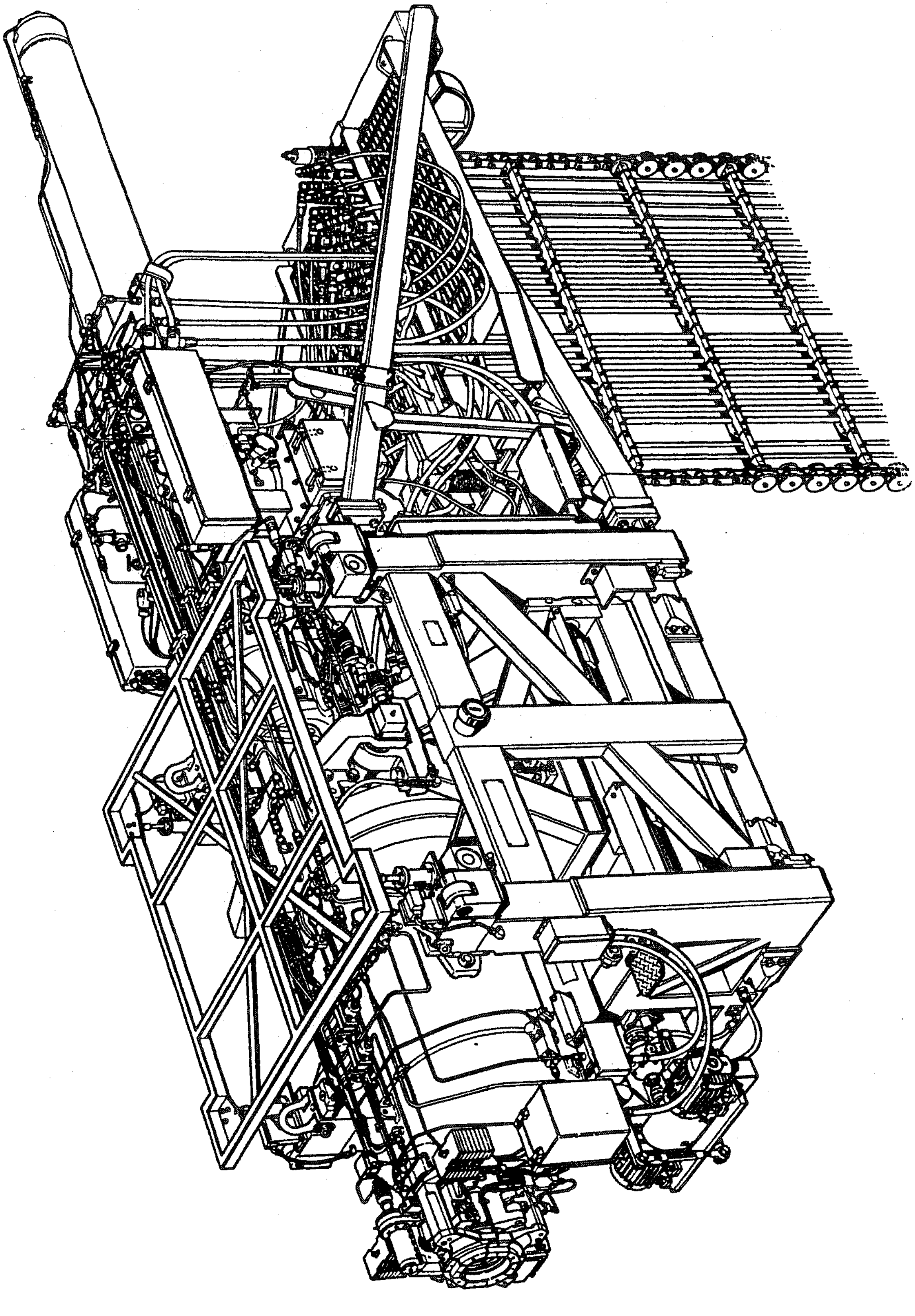


Figure 9: Darlington GS Fuelling Machine

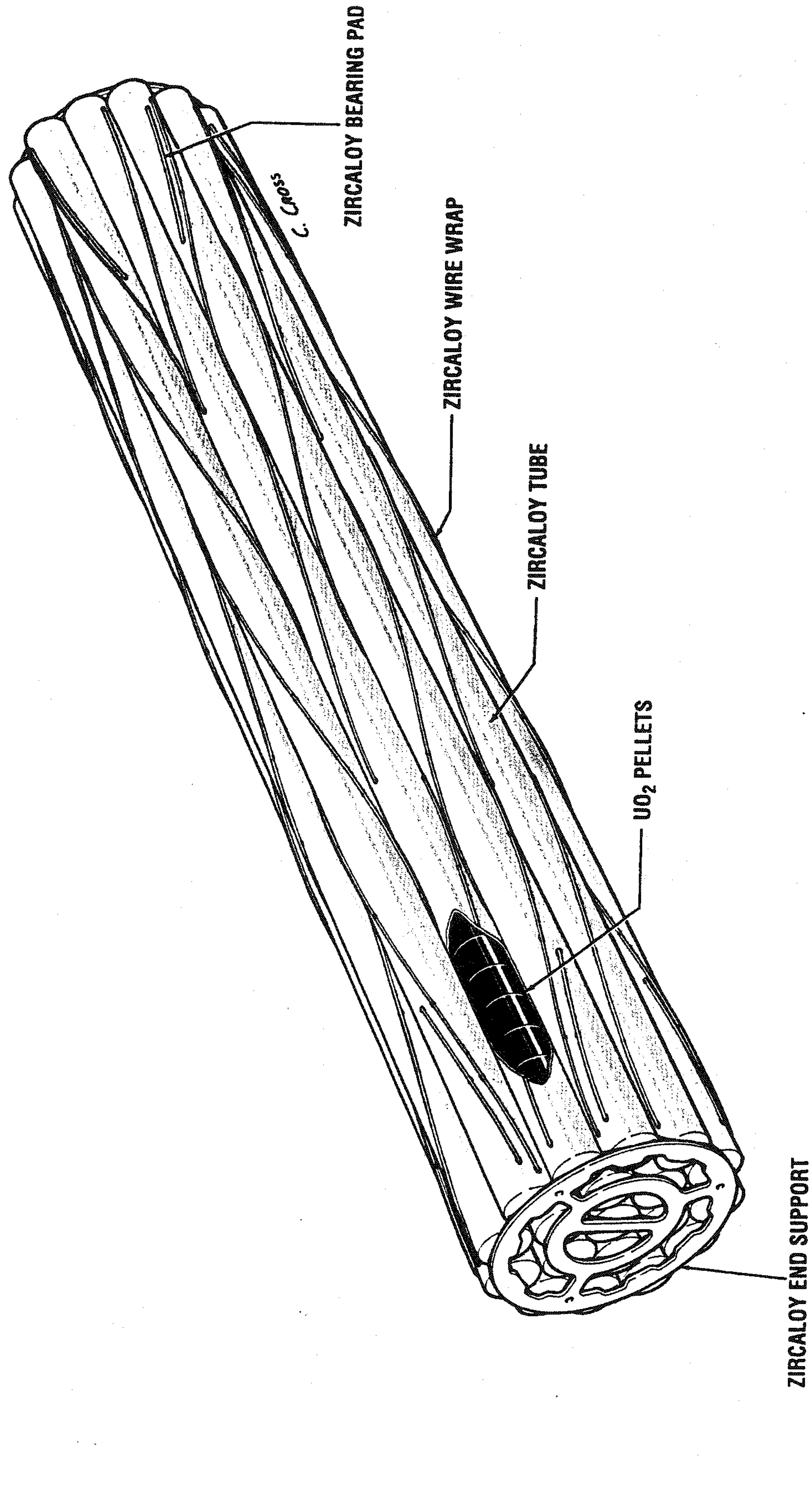


Figure 10: Fuel Bundle -- 19 Element

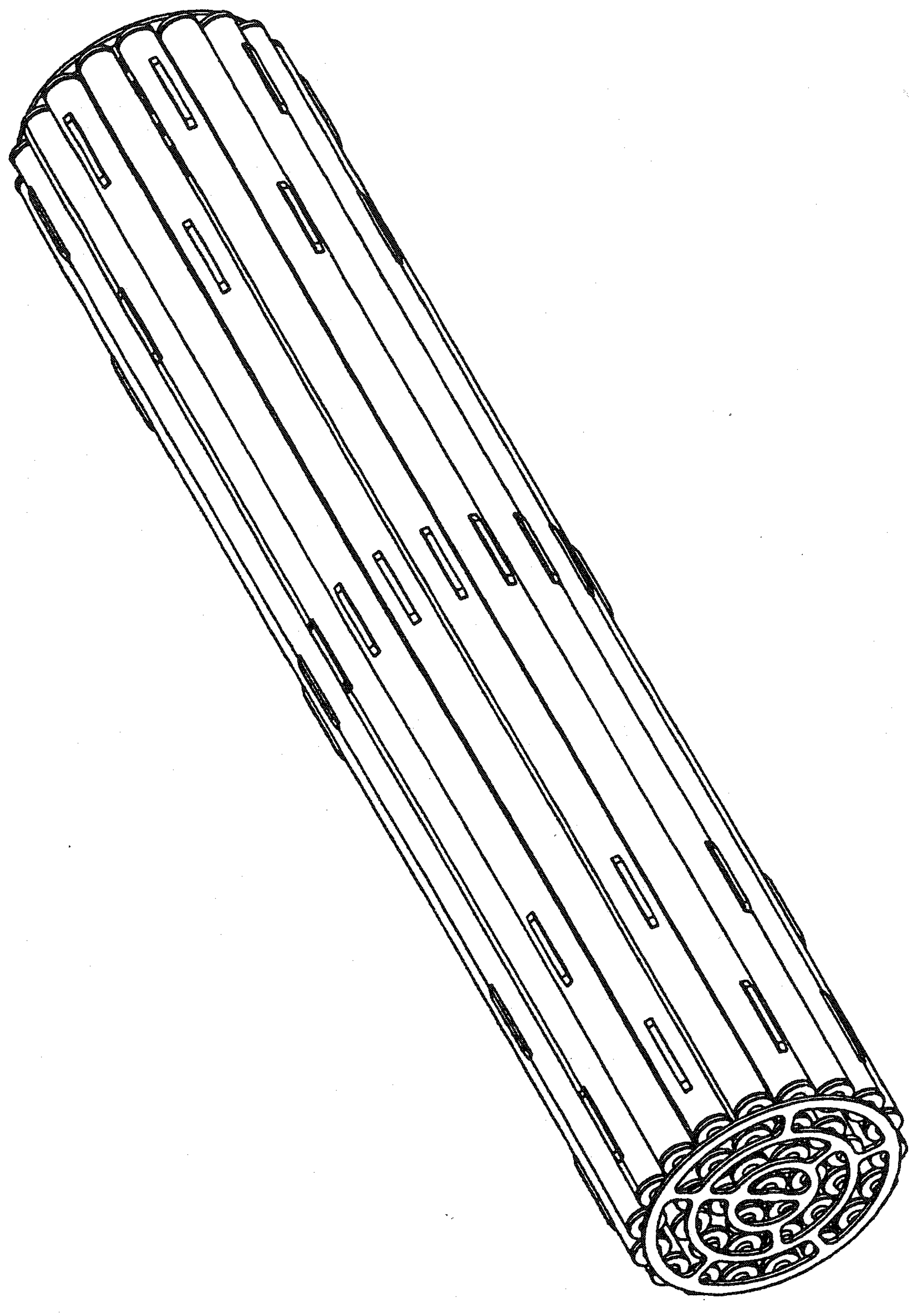


Figure 11: Fuel Bundle -- 37 Element

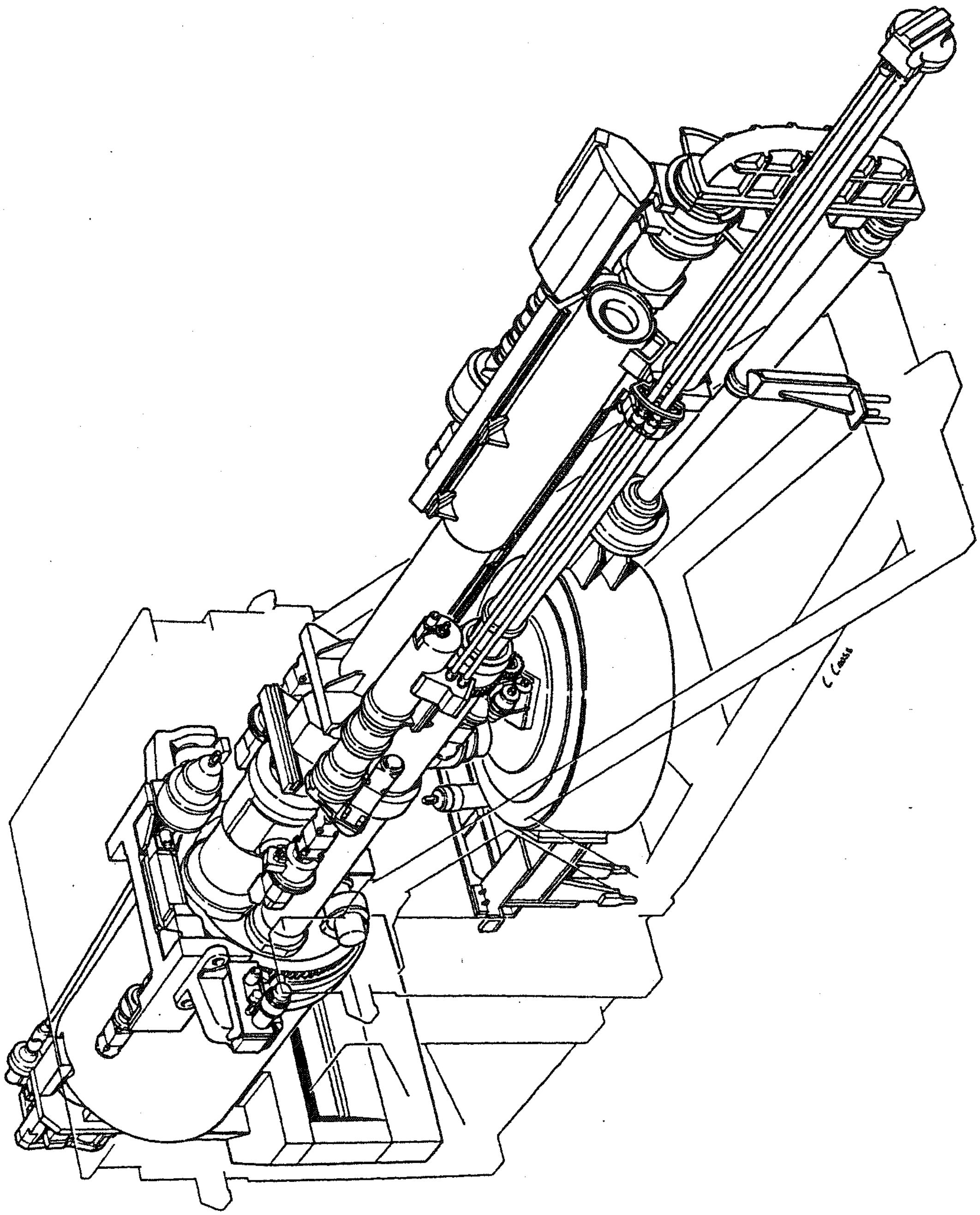


Figure 12: SLAR Head Assembly

February 27, 1975

Many inventions patented by Nuclear people since 1958

In 1958 CGE began activity in the planning and building of the Nuclear Power Demonstration reactor (NPD). Since this was Canada's first power reactor, the design of the station and its components was a healthy field in which to innovate. This led to many inventions being patented and assigned to the Company.

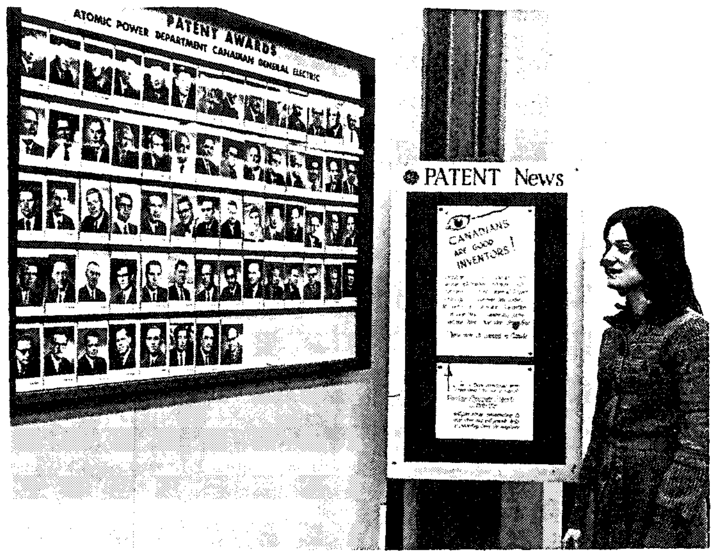
Since that time, 195 Patent dockets have been opened in the Nuclear Products Section.

An employee with an invention that has been patented and assigned to the Company is given a Patent Award in the form of Company stock.

Patents promoted

The promotion of patents is kept in the forefront in Nuclear Products by information placed on a bulletin board, which is moved to different locations, and by a permanent display of inventors' portraits in a showcase.

Patented ideas give satisfaction to the individual and help CGE to remain in a competitive position in the industry.



LORRAINE GUYATT studies showcase of inventors on display in Nuclear Products. Since 1958 there have been 195 patent dockets submitted in that area.

Figure 13: APD Patent Awards Showcase

(Peterborough Plant News, February 27, 1975, page 3)

Best wishes for Christmas and the New Year

CGE

Figure 14: "Fuel Handling in Heavy Water" -- APD Christmas Card

(circa 1975)

APPENDIX 3

ORGANIZATIONAL CHARTS & TABLES

LIST OF CHARTS: PAGE

TABLES:

ENGINEERING PERSONNEL

AS OF 17 NOV. '58

UNIT NO.	COMPONENT		PERSONNEL	CLOCK NO.
X-70	Engineering Section		I.N. MacKay	
X-70	Reactor Physics		A.C. Whittier	6217
			A. Williams	6256
			J.G. Russell	6279
X-70	Metallurgy		D.G. Boxall	6221
			A.R. Daniel	6265
X-70	Reactor Operations		D.N. Morgan	6223
X-70	Stress Analysis		W.H. Bowes	6248
X-70	Advance Engineering		M.J. McNelly	6220
X-70	Engineering Administration		J.J. Dutton	6260
			N.C. Armitage	4251
			S.A. Nice	4213
			M.J. Webb	4266
			R.A. James	4239
X-70	Computations		J.R. Dickinson	6211
			D.W. Bacon	6264
			A.G. Cracknell	6265
			T.A. Daly	6277
X-71	Reactor Design		L.R. Haywood	6222
X-71	Instrumentation and Control		G.T. Davis	6206
			W.W. Cliffe	6246
			W.S. Brown	6227
			G.R. Andrews	6271
			W.H. Cowan	6291
		(Test)	H.N. Klingbeil	6268
			L.R. Woodhead	HEPC
			G.H. Williams	HEPC
X-71	Reactor		W.M. Brown	6235
			C.R. Eaton	6237
			F.M. Warland	6238
			E.J. Adams	6240
			R.E. Lloyd	6230
			J. Pritchard	6280

Chart No.1 (sheet 1 of 3) Engineering Personnel, 17 November, 1958

UNIT NO.	COMPONENT	PERSONNEL	CLOCK NO.
X-71	Process Systems	A.C. Hoyle	6219
		H. Alting-Mees	6242
		J.R. Candlish	6243
		W.M. Robertson	6282
		R.B. McKern	6292
		G.C. Howey	HEPC
X-72	Reactor Development Laboratory	H.E. Tilbe	6218
		L.H. Mensforth	6207
		R.J. Klock	6245
		P.G. Beston	6239
		R.S. Flemons	6213
		H.G. Taylor	6275
		R.F. Fortune	6261
		K.J. Cooke	6290
		V.F. Pond	6297
		K. McConkey	4217
		G.R. Fanjoy	6288
		G.M. Barns	4204
		(Test) G.P. Mallory	6287
		(Test) R.L. Judd	6296
		E.C. Carlick	7668
		T.O. Bailey	HEPC
		A.B. Hennessey	6234
		R.H. Patterson	4203
		L.D. Harper	4273
		P.E. English	4277
		L.D. Read	4206
		J. Hartwick	4231
		P.C. Wolfer	4274
		A. Wsolak	4276
		E.H. Farris	4259
X-73	Drafting	W.A. Taylor	6229
		G.S. Andrew	4257
		J.C. Amos	4236
		R.G. Barnes	4224
		R.J. Burgess	4247
		R.A. Burton	4255
		D.T. Bushell	4210
		G.W. Cantello	4261
		K. Cullen	4264
		W.E. Darby	4233
		D.E. Dennison	4234
		C.E. Freeburn	4270
		J. Gerrard	4263
		H.E. Gifford	4250
		M.G. Harris	4245

Chart No.1 (sheet 2 of 3) Engineering Personnel, 17 November, 1958

UNIT NO	COMPONENT	PERSONNEL	CLOCK NO.
		J. Henry	4249
		G.F. Hickey	4253
		A.G. Hill	4218
		B. Hoey	4205
		D.B. Hough	4238
		S. Howden	4243
		A.E. Hutchison	4232
		H.G. Lupton	4221
		W. MacLean	4254
		E. Markewitz	4272
		D.C. Martin	4258
		D.W. Medd	4244
		J. Mundy	4209
		P.J. O'Farrell	4268
		G.A. Palmer	4229
		R.C. Parkin	4222
		A. Pickles	4246
		S.B. Ray	4256
		R. Robson	4269
		E.L. Shaw	4211
		R. Stanlick	4220
		C.H. Taylor	4219
		J.C. Veenman	4280
		R.D. Wood	4215
X-74	Station Design	R.C. Johnston	6209
X-74	Electrical Power Systems	R.A. Brown	6241
		G.S. Hope	6262
X-74	Mechanical Auxiliaries	L.J. Bissell	6236
		D.H. Pilkey	6272
		O.W. Laderach	6215
		D.G. Berry	HEPC
X-74	Structural	G.M. Locke	6233
		G.V. Windle	6263
		J.O. Jennings	6258
		R.D. Scott	6298
X-74	Fuel	D.E. Coates	6212
		J. Pawliw	6253
X-74	Fuel Handling	D.B. Nazzer	6278
		C.A. Skinner	6232

DISTRIBUTION:

I.F. McRae	W.A. Taylor
M.C. Thurling	J.G. Matthew
I.N. MacKay	J.J. Dutton
L.R. Haywood	R.F. Lane (H.O.)
R.C. Johnston	W.F. McMullen
H.E. Tilbe	Finance (5)

Issued by: Engineering Administration, Civilian Atomic Power Dept., 17 Nov. 1958.

Chart No.1 (sheet 3 of 3) Engineering Personnel, 17 November, 1958

ENGINEERING SECTION
Manager
I.H. MacKay

- **REACTOR DESIGN**
  Manager
  L.R. Haywood
  - Mechanical Equipment
    Supervising Engineer
    W.M. Brown
    - * D.B. Nazzer
    - C.A. Skinner
    - C.R. Eaton
    - E.J. Adams
    - R.E. Lloyd
    - J.D. Pritchard
  - Reactor Control
    - W.S. Brown
    - H.N. Klingbeil
  - Reactor Physics
    - * A.C. Whittier
    - J.G. Russell
  - Fuel
    - J. Pawliw
    - G.C. Hatton
  - Manufactured Components
    Supervisor
    W.A. Taylor
    B. Hoey
    - Static Components Group
      - A.E. Hutchinson
      - ~~G. Andrew~~
      - R. Burgess
      - C. Freeburn
      - J. Henry
      - G. Palmer
      - A. Pickles
      - S. Ray
      - ~~E. Shaw~~
      - C. Taylor
      - D. Harper
      - A. Martin
      - L. Rhame
      - W. Dadson
    - Mechanisms Group
      - D.W. Medd
      - R. Barnes
      - G. Cantello
      - ~~W. Darby~~
      - G. Hickey
      - ~~J. Veenman~~
      - B. Poole
- **SYSTEM DESIGN**
  Manager
  R.C. Johnston
  - Instrumentation & Electrical Systems
    Supervising Engineer
    G.T. Davis
    - * R.A. Brown
    - G.S. Hope
    - W.W. Cliffe
    - G.R. Andrews
    - G.M. Behrend
    - W.H. Cowan
  - Thermal Systems
    - * A.C. Hoyle
    - W.M. Robertson
    - H. Alting-Mees
    - R.B. McKern
  - Auxiliary Systems
    - * L.J. Bissell
    - D.H. Pilkey
  - Structural Layout
    - * G.M. Locke
    - G.V. Windle
    - O.W. Laderach
  - Structural & Radiation Physics
    - A. Williams
  - Systems Drafting
    Supervisor
    D.E. Dennison
    - Structural, Process & Mechanical Auxiliaries
      - S. Howden
      - N. Boatwright
      - K. Cullen
      - P. Goslin
      - M. Harris
      - A. Hill
      - G. Lupton
      - W. MacLean
      - E. Markewitz
      - W. Moulton
      - P. O'Farrell
      - R. Parkin
      - H. Ringvee
      - R. Robson
      - D. Schuls
      - B. Sedov
      - E. Stanlick
      - D. Martin
      - J. McKissack
    - Instrumentation & Control
      - D. Hough
      - J. Amos
      - D. Bushell
      - R. Burton
      - J. Gerrard
      - H. Gifford
      - I. Jaffe
      - W. Lefley
      - J. Mundy
      - J. Norton
      - R. Wood
- **REACTOR DEVELOPMENT LABORATORY**
  Manager
  H.E. Tilbe
  - Applied Mechanics
    - * R.S. Flemons
    - L.H. Mensforth
    - R.J. Klock
    - R.L. Judd
    - G.M. Barns
    - K. McConkey
  - Mechanical Components
    - * H.G. Taylor
    - P.G. Beston
    - E.C. Carlick
    - V.F. Pond
  - Fuel Development
    - * D.E. Coates
    - K.J. Cooke
    - J.R. Canzi
    - F.G. Dance
  - Irradiations
    - G.R. Fanjoy
  - Experimental
    Supervisor
    A.B. Hennessey
    - R.H. Patterson
    - L.D. Harper
    - P.E. English
    - L.D. Read
    - J. Cullen
    - P.C. Wolfer
    - A. Wsolak
    - E.H. Farris
- Computations
  - * J.R. Dickinson
  - D.W. Bacon
  - A.G. Cracknell
  - T.A. Daly
  - M. McCracken
- Materials Development
  - * D.G. Boxall
  - A.R. Daniel
- Stress Analysis
  - W.H. Bowes
- Operations & Safety
  - D.N. Morgan
- Advance Engineering
  - M.J. McNelly
- Engineering Administration
  - J.J. Dutton
  - N.C. Armitage
  - S.A. Nice
  - M.J. Webb
  - R.A. James

* Technical Counsellor
11 February 1959

Chart No.2: Engineering Section, 11 February, 1959

ENGINEERING SECTION
Manager
I.N. Mackay

REACTOR ENGINEERING

	Manager	
X70	J.R. Wickinson	6211

Reactor Physics

	Supervising Physicist	
X77	A.C. Whittier	6217
	A.R. Dastur	6281
	J.J. Penn	5265
	K.R. Shultz	6263
	A.J. Szilvasi	6259
	C.E. Till	6270

Reactor Control & Safeguards

	Supervising Engineer	
X77	W.S. Brown	6227
	R.H. Duncan	5275
	P.J. Gallagher	5246
	H.W. Klingbeil	6268
	E.F. Wagner	5253

Computations

X77	T.A. Daly	6277
	F. Szekely	5270
	Mary L. McCracken	6286
	J.B. O'Brien	6262

Station Engineering

X77	H.S. Irvine	5721
	R.F. Scarth	5228
	J.D. Pritchard	6280

Stress Analyst

X77	J. Van Winssen	5257

FUEL ENGINEERING & MANUFACTURING DEVELOPMENT

	Manager	
X70	D.B. Nasser	6278

Fuel Quality Control

X79	P.E. Bessey	5230
	I.D. Yonemitsu	5218
	R. Riddle	7907
	R.J. Seabrooke	7904

Fuel Engineering

	Supervising Engineer	
X71	J. Pawliw	6253
	A.G. Cracknell	6265
	F.G. Dance	5201
	G.R. Fanjoy	6288
	A.K. Ip	6238
	R.J. Klock	6245
	K.H. McConkey	6228
	A.M. Nicholson	5227
	P.D. Scholfield	6294
	W.R. Tarasuk	5210
	D.E. Teed	6234
	W. Twarog	6266

Fuel Development

	Supervisor	
X79	E.G. Goodwin	6251
	H. Chapman	5229
	J.L. Gassenbeek	5262
	R.C. Hallam	6283
	R.M. Scott	6252
	W.J. Burns	7612
	T.I. Dunford	7982
	K.D. Dunning	7903
	C.C. Heath	7608
	W.J. Olmstead	7959
	W.H. Twist	7964
	G.W. Williamson	6208
	C. Wilson	7906
	G.K. Wong	7938

MATERIALS ENGINEERING

	Manager	
X70	D.G. Boxall	6221
X75	A.R. Daniel	6267
	D.C. Fleming	6292
	D.J.C. Fleming	6248
	P.H. Patell	5261
	J.W. Standish	5208
	K.E. O'Connor	5226
	C.H. Cantrell	7074
	F.E. English	7911
	D.V. Evans	7910
	W.J. Gancher	7935
	G.A. McCurrach	7963

---

* Technical Counsellor
** Dual Responsibility
x Engineering Training Program

Distribution:

General Manager &
Section Managers
Unit Managers
Supervisors
Finance - 12
Engineering Personnel
Salaried Paymaster - 2
H & P Salary Schedules, H.O.
Marketing Administration
Wage & Salary

Issued by Engineering Administration

Revised: 2 Feb 63

Supersedes: 17 Nov 62

Added: I. Bryson, S. Howden, H.C. Mitchell, T. Axford, D.E. Teed, E.P. Wagner, C.C. Adamson, M.J. Zakarow, J. Norton.

Transferred: R.L. Beck, J.G. White, L.L. Bodle, F. Davediuk.

Deleted: B. Cooke, K.E. Stangland, J.A. Phillips, T.G. Kirkpatrick, G.L. Sloan

NOTE: Mktg., Mfg., & Finance - On Back

Chart No. 3 (sheet 1of 2) Engineering Section, 2 February, 1963

ENGINEERING SECTION
Manager
I.N. MacKay

EQUIPMENT ENGINEERING

	Manager	
X70	W.H. Brown	6235
	Reactor Structures	
	Supervising Engineer	
X76	E.J. Adams	6240
	C.C. Adamson	5215
	G.W. Ashdown	6274
	R.W. Blackburn	5237
	W. Cashen	5254
	C.R. Eaton	6237
	R.E. Lloyd	6230
	P.Z. Rosta	5268
	K. Satterley	5267
	R.W. Smith	6220
	Fuel Handling	
	Supervising Engineer	
X76	K.G. Zimmermann	5223
	*S.A. Janusz	5235
	D. Erwin	5213
	T.J. Goethel	6267
	J.L. Irvine	5249
	V.F. Pond	6297
	W. Shaw	5207
	D.V. Williams	5269
	Equipment Drafting	
	Supervisor	
X76	W.A. Taylor	6229
	Bonnie R. Robinson	4236
	Reactor Structures	
	A.E. Hutchinson	4232
	R.J. Burgess	4247
	C.E. Freeburn	4270
	J.L. Henry	4249
	R.H. Leggitt	4276
	W.K. MacLean	4254
	A.H. Martin	4289
	G.A. Palmer	4229
	A.A. Pickles	4246
	S.B. Ray	4256
	E.T. Steele	7604
	C.H. Taylor	4219
	G. Weller	4226
	Fuel Handling	
	D.W. Hadd	4244
	R.G. Barnes	4224
	R. Butcher	4210
	G.W. Cantello	4261
	W.E. Darby	4233
	D. Johnston	7630
	H.C. Lupton	4221
	R. Passey	4218
	H.J. Pollard	4253
	E.P. Roberts	7629
	J.C. Veenman	4280
	R. Willis	4204

SYSTEMS ENGINEERING

	Manager	
X70	R.C. Johnston	6209
	Inst., Cont. & Power Systems	
	Supervising Engineer	
X74	J.T. Davis	6206
	*R.A. Brown	6241
	*W.W. Cliffe	6246
	*R.S. Flemons	6213
	G.R. Andrews	6271
	W.H. Cowan	6291
	F.W. Emerson	6244
	R.L. Fitts	5216
	F.G. Mallory	5209
	B.A. Oliver	6276
	R.D. Scott	6278
	K.D. Trebilcock	5248
	R.A. Ward	5231
	J.A. Luora	4216
	J. Mundy	4209
	Clerical	
X74	Margaret M. Flynn	4269
	Thermal Systems	
	Supervising Engineer	
X74	A.C. Hoyle	6219
	H. Alting-Mees	6242
	R.E. Ells	6258
	H. Zemann	6264
	Station Layout and Services	
	Supervising Engineer	
X74	L.J. Bissell	6236
	D.S.S. Knickle	6269
	D.H. Pilkey	6272
	F.G. Young	5232
	Heat & Mass Transfer	
X74	*J.T. Rogers	5255
	T. Chapman	5265
	L.J. Sairway	5238
	G.M. Barns	4264
	Analytical Laboratory	
X74	T.S. Preciw	5219
	K.J. Webster	5222
	V.G. Bratuhin	7968
	J.L. Chun	7936
	Systems Drafting	
	Supervisor	
X74D	D.E. Dennison	5203
	Structural, Process & Mechanical Auxiliaries	
	M.S. Harris	4245
	G.A. Brown	7618
	N.J. Boatwright	4248
	I. Bryson	4217
	P. Coslin	4286
	S. Howden	4243
	J.J. Lis	4220
	H.G. Mitchell	4251
	H. Ringvee	7603
	K.M. Salamon	4268
	J. Szakony	4260
	M. Titmuss	4296

ENGINEERING PROJECT

	Manager	
X70	K.H. Campbell	6202

CONTRACT LIAISON & APPLICATION ENGINEERING

	Manager	
X73	**J.L. Olsen	6208
	Contract Liaison Engineering	
	Supervising Engineer	
X73	A.F. Fortone	6261
	L.L. Bodie	5251
	R.L. Cohen	6279
	M.J. Cox	6255
	C. Cross	7534
	Margaret E. Brown	4207
	D.M. Hatherley	4257
	Application Engineering	
	Supervising Engineer	
X82	W.L. Williams	5226
X73	R.L. Beck	6257
	D.B. Chase	6273
	J.O. Holt	5257
	Engineering Administration	
X70	J.J. Dutton	6250
	G.C. Hatton	5201
	Muriel F. Adams	4277
	Lillian E. Blackshaw	4235
	Ruth S. Bolton	7622
	Brenda J. Clayton	4282
	Maureen S. DeNoble	4205
	Shirley E. English	7625
	Joan C. Hunt	7529
	Judie M. Townsend	7614
	Joan B. Watson	7503
	Mary Jean Zakrow	4281
	Instrumentation & Control	
	D.E. Hough	4234
	T. Axford	4267
	R.A. Burton	4255
	J. Gerrard	4243
	H.E. Gifford	4250
	I. Jaffe	4237
	W. Lefley	4275
	E. Karkowitz	4272
	J. Norton	4277
	R.D. Wood	4215

Chart No. 3 (sheet 2 of 2) Engineering Section, 2 February, 1963

Functional Accountability

AECL ENGINEERING & DEVELOPMENT
GENERAL MANAGER
G.A. PON

X70 FUEL HANDLING SYSTEMS SECTION
MANAGER
W. M. BROWN

AECL
FUEL HANDLING
MECHANICAL ENG'RG
SHERIDAN PARK

SUPERINTENDENT
C.A. SKINNER

AECL
FUEL HANDLING
CONTROL ENG'RG
SHERIDAN PARK

SUPERINTENDENT
H. ADAMS

X70 FUEL HANDLING SYSTEMS ENGINEERING

MANAGER
K.G. ZIMMERMANN 6223

X71 SYSTEMS ENGINEERING

MANAGER
G. T. DAVIS 6206

Marcella Fontaine 4273

X74 FUEL HANDLING CONTROL ENGINEERING
Supervising Engineer
H.A. Martin 6272

D.O. Baird 6244
W.G. Cowan 4242
R.F. Fitts 5216
A.F. Green 4228
L.D. Harper 5294
M. Hoerig 6270
D.B. Hough 5226
G.D. Pearson 5205
J. Pomeranz
T.C. Tsai 6273
H. Young

SPECIAL SYSTEMS ENG'RG
Supervising Engineer
*G.T. Davis 6206

H.W. Alting-Mees 6242
D.M. Closs 6207
W.H. Ernst 5202
D.L. Freeman 6243
H.E. Gifford 6295
H. Soepangkat
M.I. Townsend 5267
Sharon Vangalis 6211
J.B. Young 5240

Digital Control Engineer
G.R. Andrews 6271

Special Instrumentation Eng.
R.S. Flemons 6213

Power Systems Engineer
R.D. Scott 6298

Special Controls Engineer
H.N. Klingbeil 6268

X84 Patricia Prest 7620
Sylvia Warner 7602

X71 MECHANICAL EQUIPMENT ENGINEERING

MANAGER
E.J. ADAMS 6240

X73 Fuel Handling Engineer
S.A. Janusz 5235

X73 Fuel Channel Engineer
R.E. Lloyd 6230

X73 Fuel Handling Technical Service Engineer
J.D. Wilford 5238

X73 Stress Analyst
J. Van Winssen 5257

X84 Helen Horn 4258
Joanne Reynolds 4285

X73 FUEL CHANGING ENG'RG
Supervising Engineer
D. Erwin 5213

Fuelling Machine Engineer
* D. Erwin 5213

G.W. Cantello 6281
W.S. Cashen 5254
J.P. Condon 6209
T.I. Dunford 5282
T.A. Hunter 5272
W.J. Knowles 6291
D.G. Linton 6284
D.C. Mahler 6241
J.T. Wisniewski 5253
A. Wuerscher 6290
J.M. Young 6203

X73 FUEL TRANSFER ENG'RG
Supervising Engineer
G.W. Ashdown 6274

Fuel Transfer Engineer
W. Shaw 5207

R.J. Burgess 5280
G.R. Campbell 5285
E.H. Farris 6260
B.R. Gaertner 6289
B.L. Hildebrandt 6246
D.S. Knickle 6269
D.W. Medd 5256
E.E. Vardy 6288
J.A. Vissers 5255
J.R. Williamson 6292

R.P. De Gregorio 5236

X71 FUEL HANDLING SYSTEMS DRAFTING

SUPERVISOR
D.E. DENNISON 6203

X75 T.R. Axford 4293
G.H. Baskerville 4298
D. Booth 4253
G.A. Brown 7618
W.J. Downey 7615
J.G. Eley 7613
R.G. Essex 4232
C.E. Freeburn 4248
H. Glaus 7637
E.C. Harnden 4234
M.G. Harris 4245
J.L. Henry 4249
S. Howden 4243
D.J. Hughes 4236
D.S. Johnston 7630
R.G. LaBrash 4240
W.L. Lefley 4295
H.G. Lupton 4221
A.H. Martin 4289
D.W. Maynard 4231
J.L. McInnes 4204
H.G. Mitchell 4251
R.T. Munnings 4259
P.C. Offierski 4237
M.T. Ouellette 7638
A. Pickles 4246
L.W. Porter 4294
A. Pickles 4246
R.N. Reed 4235
H. Ringvee 7603
E.P. Roberts 7629
J.A. Sharpe 4292
J. Szakony 4260
E.J. Tanner 4220
D.H. Thomas 4247
J. Vollans 4238
G.D. Weller 4226

Elizabeth Goethel 4278

* DUAL RESPONSIBILITY

REVISED: 10 May 1975

SUPERSEDES: 26 November 1973

Chart No. 4 (sheet 1 of 2) Nuclear Product Section, 10 May, 1975

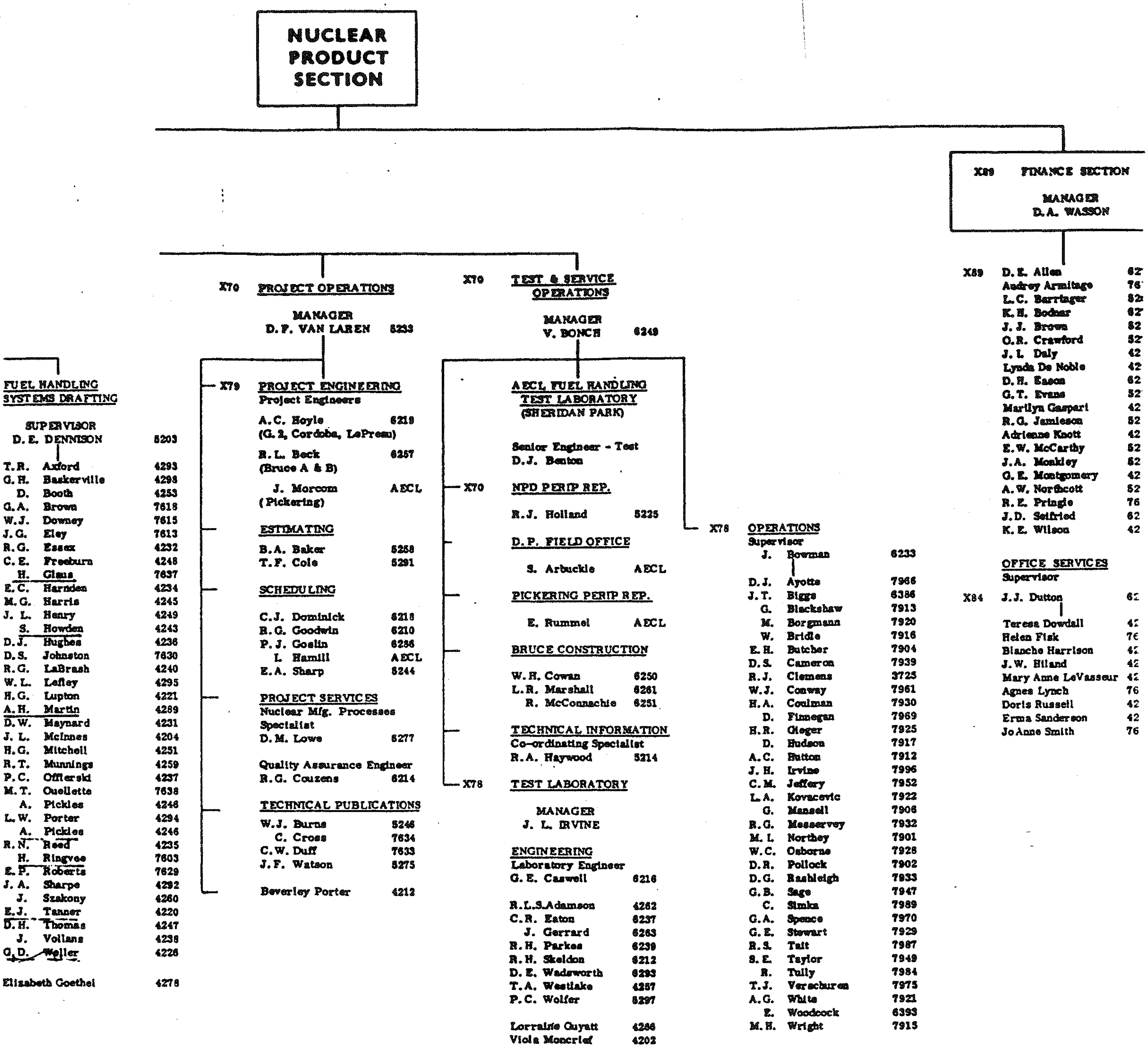


Chart No. 4 (sheet 2 of 2) Nuclear Product Section, 10 May, 1975

Canadian General Electric

NUCLEAR FUEL HANDLING

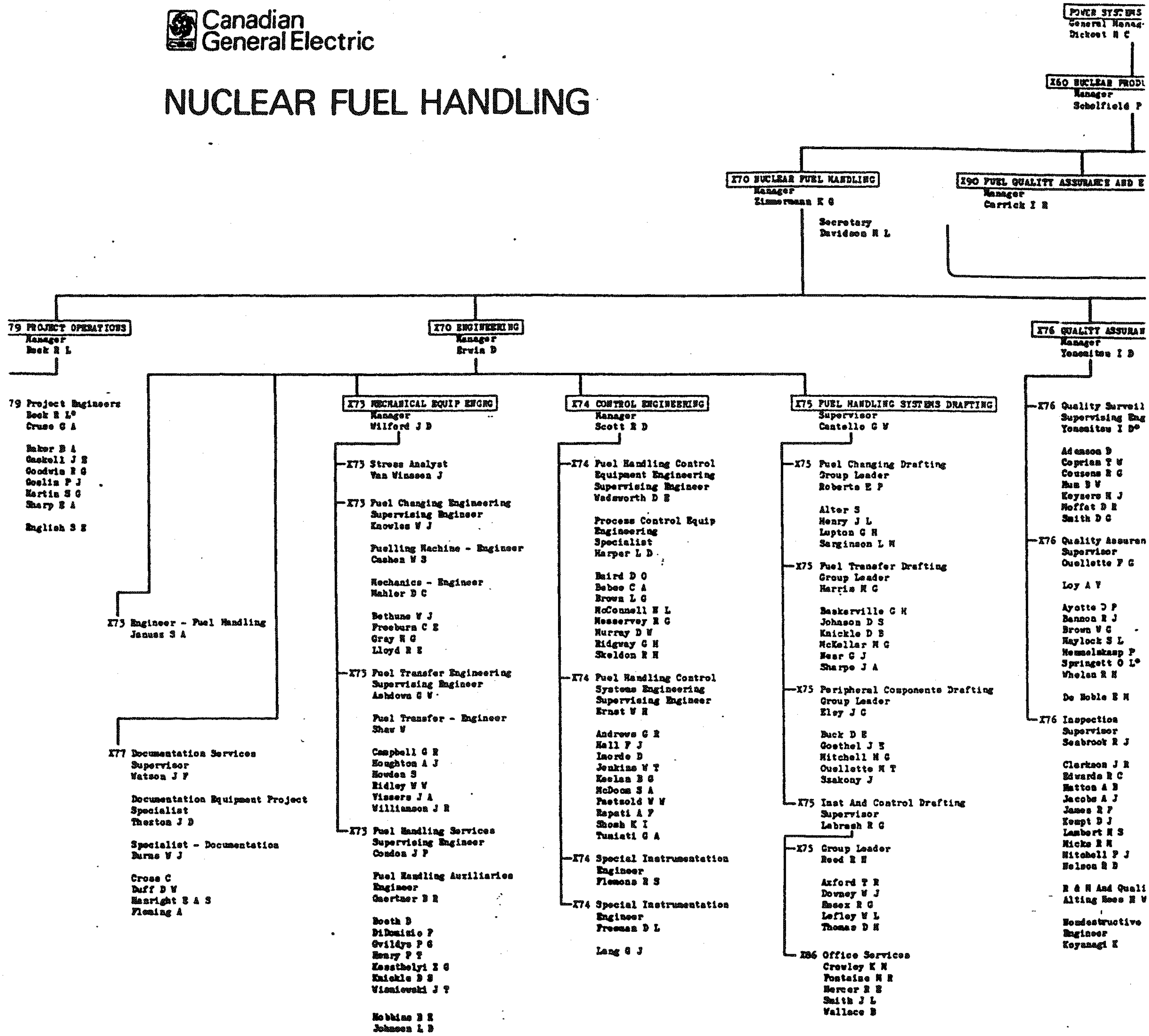


Chart No. 5 (sheet 1 of 2) Nuclear Fuel Handling, 3 February, 1984

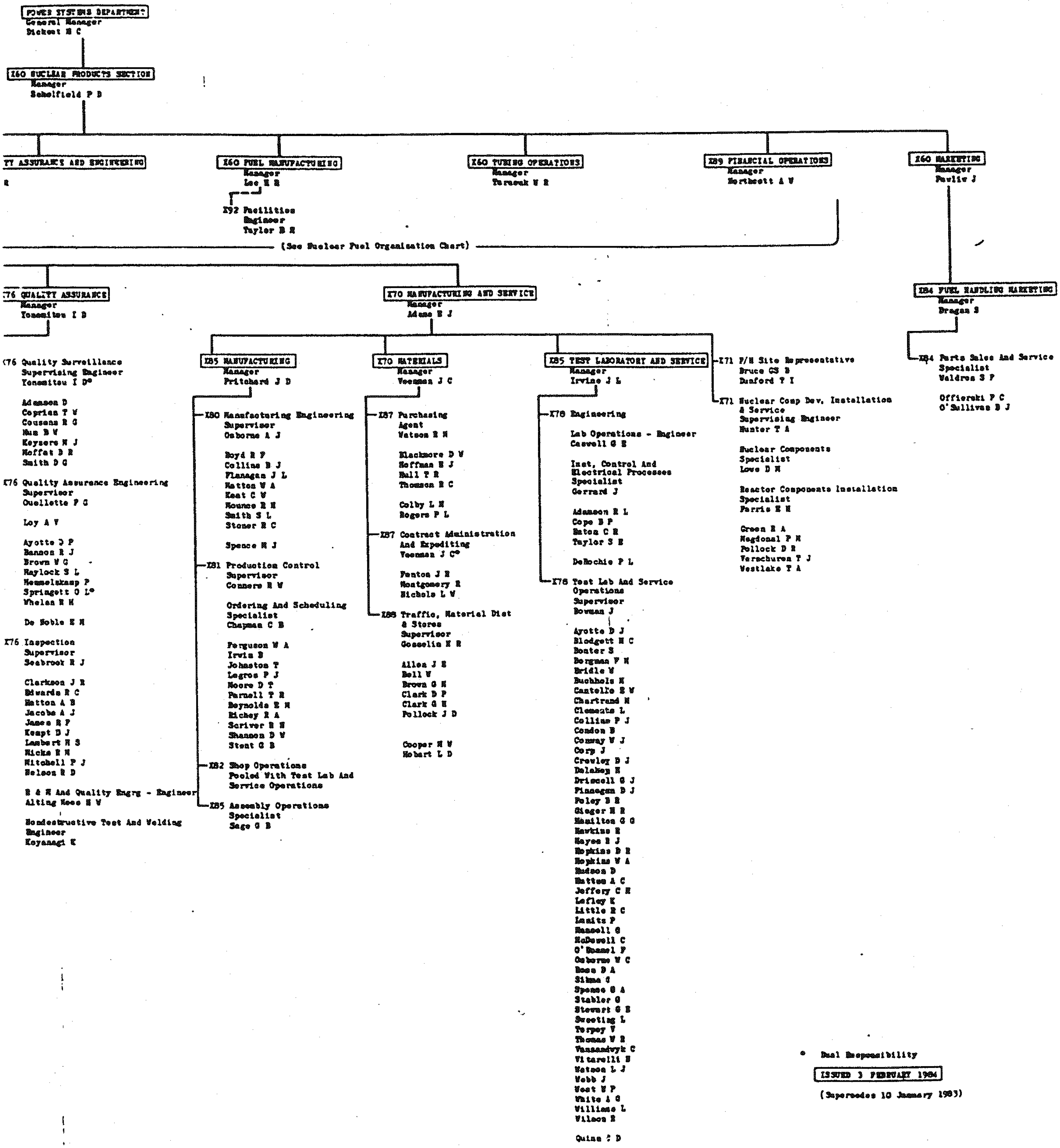


Chart No. 5 (sheet 2 of 2) Nuclear Fuel Handling, 3 February, 1984

Canadian General Electric

NUCLEAR FUEL

POWER SYSTEMS DEPARTMENT
General Manager
Dickout H C

X60 NUCLEAR PRODUCTS SECTION
Manager - Scholfield P D

X60 Secretary
Lansfield

X70 NUCLEAR FUEL HANDLING
Manager
Zimmermann K G

(See Nuclear Fuel Handling Organization Chart)

X60 MARKETING
Manager
Pawliw J

- X91 Flood W T

X60 FUEL MANUFACTURING
Manager
Lee H R

X62 MANUFACTURING ENGINEERING
Manager
Hurrle R F

- X62 Hynes P E
  Hetheral J F
- X62 Beryllium Processes
  Engineer
  Ali H N

  Welding Processes
  Engineer
  Cooper D A

  Electronic Processes
  Specialist
  Tsiang K
- X62 Process Methods
  Supervisor
  Phillips W J

  Berry J G
  Dearing J
  Dingman J
  Fenn G T
  Rowlandson A L
  Sharpe R A

  Hennessey L
- X92 Facilities
  Engineer
  Taylor B H

  McDougall A R
  Wilson G C
- X64 Development And Support Services
  Supervisor
  Olmstead W J

  Campanaro W V
  Dunning K D
  Foerster H
  Gunia M A
  Hatton S T
  Healey D J
  Hirt E
  Jackson A R
  Nelson D W
- X23 Apers P J
  Black R W
  Eggleton J A
  Hamilton J A
  Rempel R
  Rose J D
  Tully R T

X68 PELLET OPERATIONS
Manager
Quinlan P G

- Mohammed Z
- X61 Material Control
  Specialist
  Smith C A

  Graham J
  Lavigne G
- X68 Shift Operations
  Pellet Operations
  Supervisor
  Bell L W
  Soundy K R

  Brokenshire D
  Edwards V
  Fulton W
  Cal V
  Gales C
  Gallippi G
  Hamilton A
  Holness L
  Hylton V
  Jackson B
  Lutz P
  Nadolski B
  Nicol P
  Noble M
  Ramondino D
  Ramondino G
  Robertson J
  Scroka B
  Sinclair G
  Smith V
  Sooch G
  Soundy J
  Sultana D
- X68 Manufacturing Engineering
  Pellet Op
  Manager
  Jones D J
- X68 Specialist
  McDowall G J

  Ramnauth R
  Rehman Z
- X68 Group Leader
  Lutz L

  Enright D
  Jaeger P
  Lutz P
  Moffatt G
  Nemet J

X67 ASSEMBLY SHOP OPERATIONS
Manager
Warr H V

- X67 Shop Operations
  Supervisors
  Baptie A W
  Leeper R W
  Low T J
  Stewart J T

  Dispatcher
  Stephenson P S

  Adams S
  Argent R
  Bagshaw J
  Brooks J
  Buott A
  Burnett A
  Butler E
  Caddigan E
  Campanaro J
  Caravaggio J
  Chambers H D
  Condon J
  Cox D
  Creighton D
  Crowe K
  Crowhurst D
  Day J
  Druce L
  Drummond J
  Dufresne J
  Dunford B
  Fornaro V
  Galvin G
  Gooley L
  Goudy R
  Graham G
  Hayes F
  Hickey M
  Hoar W
  Hockaday F
  Hueston P
  Kasaboski W
  Keating T
  Lane A
  Lavallee W
  Linklater C
  Marfleet R
  Markwick D
  McGillen P
  Menzies D
  Menzies M
  Mills I
  Minnie R
  Monck A
  O'Reilly P
  Parke C
  Partridge R
  Paudash E
  Pearson R
  Peel G
  Peters R
  Puffer S
  Ridley P
  Robbins D
  Scarlett R
  Scriver A
  Smale W
  Smith R
  Terry G
  Towns H
  Troy M
  Twomey E
  Vanwart A
  Wakelin D
  Weddele R
  Whatley R
  Williams R
  Williamson C
  Willis R
  Wilson L
  Wilson M

- X63 Health Physics And Safety
  Supervisor
  Mann H C
- X63 MacInnes A E

  Freeman D
  Hobbins M
  Leahy J

  Radiation Safety And Quality Control
  Supervisor
  Millier L R*

  Bruce D J
  Citter R
  Quinlan S C
  Wilson S

  Jelovica I
  McMillan B S
  Nerad J
  Taipe L
  Varjas Z

X61 MATE
Mana
Boss

- X61 Purc
  Alle

  York
  Olve

  Inve
  Spec
  McCa

  Basc
  Perk
  Wese
- X61 Prod
  Supe
  Smit

  Augu
  Lest
  Shee

  Conn
  Leah

Chart No. 6 (sheet 1 of 2) Nuclear Fuel, 10 February, 1984

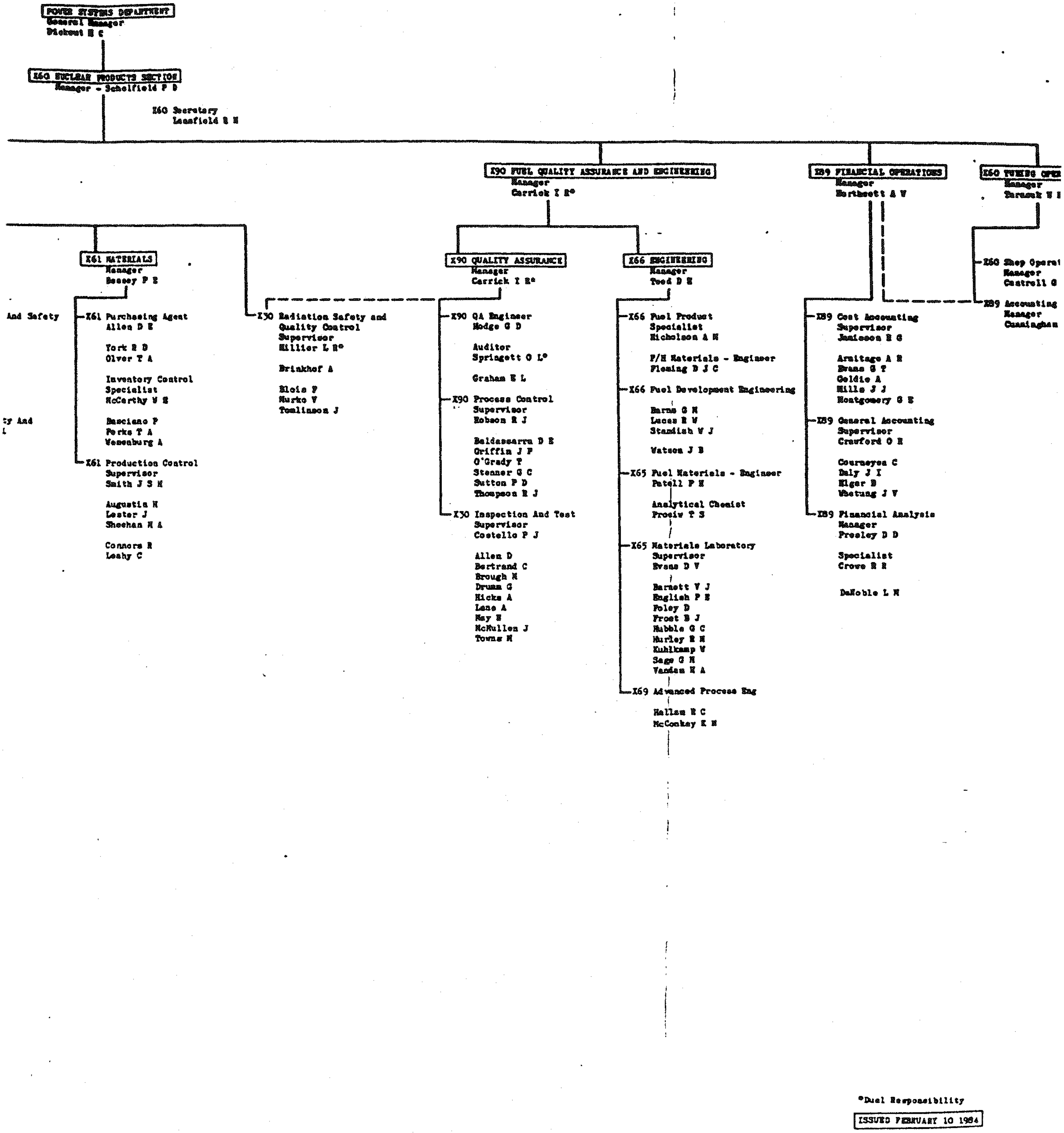


Chart No. 6 (sheet 2 of 2) Nuclear Fuel, 10 February, 1984

POWER SYSTEMS CANADA

Executive Vice-President
P D Scholfield 8213
Secretary * F I Spence 8085

NUCLEAR FUEL HANDLING OPERATIONS

D Erwin 7072 | Administrator * J A Foster 7236

PROJECT OPERATIONS
J D Wilford 7071

R F Boyd
W Watton

Engrg Systems
J Booveriwala
D T Nash
S L Wood

MECHANICAL EQUIP ENGRG
D C Mahler 7104

Supervising Engineers
W J Knowles

Techn. Counsellors
B R Gaertner
M G Gray
P G Gvildys
E G Keszthelyi

Engineers
W J Bethune
B DeRochie
P T Henry
C W Hill
M W Ip
A K Koyanagi
LJ Lancaster
T G Onderwater
J W Pilgrim
W W Ridley
M S Simnicki

Engrg. Assist.-Spec.
J Houghton
J W Spenceley
J T Wisniewski

Clerical
P L Prest

CONTROL ENGINEERING
B P Cope 7216

Techn. Counsellors
W E Ernst
D E Wadsworth

Engineers
D Campbell ◊
W K Cook
R J Dungan
A Kalinowski
D W Murray
W W Paetzold
D J Rayment
G H Ridgway
M Riposan
D Riposan
R H Skeldon
L Stephens
P C Tai
M I Townsend
T P VanderVeen
S Verscay ◊
D S Winlow

Engrg. Assist.-Spec.
D O Baird
C A Bebee
A Caple
T D Cosh
P H Graham
W T Jenkins
K Lefley
R G Messervey
M J Sokolowski
H P Ujc

Clerical
D J Lewis

DRAFTING
R G LeBrash *

S Alter
B M Crichton
J G Eley
R G Essex
K L Irwin
W L Lefley
M T Ouellette
L M Sarginson
J A Sharpe
J Szakony

Office Services
E W McCarthy
P Rogers
B Wallace

DOCUMENTATION SVCS
R G LeBrash * 7277

Technical Writers
D P Ayotte
P J Roberts

Techn. Illustrators
C Cross
R May

Word Processing
A R Armitage
M A Fleming

MANUFACTURING OPERATIONS
J A MacDonald 7066

Techn. Counsellor-Mfg.
J A Vissers

Engrg. Assist.-Spec.-Mfg.
S Bonter
J Gerrard
C M Jeffery
G B Stent

Planner
A J Robinson

Technician & Fabrication
W W Suggitt 7238

Lab Assistants
D J Ayotte
F M Borgman
W J Conway
J T Corp
D J Crowley
D Dunn
R C Edwards
D Finnegan
D R Foley
R L Hardy
S T Hatton
J R Hayes
D F Hudson
R C Little
S E May
C G McDowell
D R Nelson
E Nicholas
W C Osborne
B L Payne
R Rempel
C Sikma
R Smith
G A Spence
V L Sweeting
W R Thomas
C Vanzandwyk
J L Webb
A G White
L C J Williams

Fabricators
G H Boyd
L J DeNoble
G Field
R G Hawkins
R D Inward
E Outwater

Clerical
S Hall

Quality Program
K Koyanagi

Procurement/QS
R J Bannon
T W Coprian
J R Fenton
T R Hull
B W Hun
H J Keyzers
S F Loft
L W Nichols +
R C Thomson

Materials Control
R W Conners 7135

B Carew
B G Johnston
P J Legros
J H Lester

Receiving & Stores
J W Hobart
P Laton

Engineering Assis.-
H Boyd
S E Hepburn
P J Mitchell

Inspection-NDT
W A Ferguson
D G Gilpin
M A Jones
I D Kemp

* Dual Responsibility
\+ JD Edwards Project
◊ Contract

Chart No. 7 (sheet 1 of 2) Power Systems Canada, September, 1994

POWER SYSTEMS CANADA

Executive Vice-President
P D Scholfield 8213
Secretary - F I Spence 8085

NUCLEAR FUEL HANDLING OPERATIONS

D Erwin 7072 | Administrator - J A Foster 7236

DRAFTING
R G LaBrash *

S Alter
B N Crichton
J G Eley
R G Essex
K L Irwin
W L Lefley
W T Ouellette
L M Sarginson
J A Sharpe
J Szakony

Office Services
E W McCarthy
P Rogers
B Wallace

DOCUMENTATION SVCS
R G LaBrash * 7277

Technical Writers
D P Ayotte
P J Roberts

Techn. Illustrators
C Cross
R May

Word Processing
A R Armitage
M A Fleming

MANUFACTURING OPERATIONS
J A MacDonald 7046

Techn. Counsellor-Mfg.
J A Vissers

Engrg. Assist.-Spec.-Mfg.
S Bonter
J Gerrard
C M Jeffery
G B Stent

Planner
A J Robinson

Technician & Fabrication
W W Suggitt 7238

Lab Assistants
D J Ayotte
F M Borgman
W J Conway
J T Corp
D J Crowley
D Dunn
R C Edwards
D Finnegan
D R Foley
R L Hardy
S T Hatton
J R Hayes
D F Hudson
R C Little
S E May
C G McDowell
D R Nelson
E Nicholas
W C Osborne
B L Payne
R Rempel
C Sikma
R Smith
G A Spence
V L Sweeting
W R Thomas
C Vanzandwyk
J L Webb
A G White
L C J Williams

Fabricators
G S Boyd
L J DeNoble
G Field
R G Hawkins
R D Inward
E Outwater

Clerical
S Hall

Quality Program
K Koyanagi

Procurement/QS
R J Bannon
T W Coprian
J R Fenton
T R Hall
B W Hum
M J Keyzers
S F Loft
L W Nichols +
R C Thomson

Materials Control
R W Conners 7135

B Carew
B G Johnston
P J Legros
J H Lester

Receiving & Stores
J W Hobart
P Laton

Engineering Assis.-QA
B Boyd
S E Hepburn
P J Mitchell

Inspection-NDT
W A Ferguson
D G Gilpin
M A Jones
I D Kemp

F/C SERVICES
T A Hunter 7332

P Brennan

D R Pollock
E Schartinger
T A Westlake

FINANCIAL OPER.
B M Kelly 7093

R R Crowe
L M DeNoble
W B Dunfield
G T Evans
A Goldie
G E Montgomery
A K Saunders
J D Seifried
S Vangalis

MARKETING
H Stremler 7509

F DiDomizio
W T Flood
T A McLaughlin
P VanBeerschoten

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A. Interviews and Discussions:

Great assistance to the author was provided by former colleagues at APD, some retired, others still active employees of the company. Discussions and recorded interviews were conducted with many of these individuals, too many to list here in fear of unintentionally omitting some of their names. However, it would be inappropriate not to list the names of those persons who suffered through recorded interview sessions, permitted the loan of treasured personal memorabilia of the early days of APD, unearthed illustrations and data, and provided information on current work in the department.

Following, in alphabetical order, are their names:

Dick Beck, P. Eng., Manager, Project Operations (retired)

Personal Interview, February 13, 2001.

Dave Erwin, P. Eng., Manager, Engineering (retired)

Personal Interview, February 11, 1997.

Alex Hoyle, P. Eng., Manager, Project Operations (retired)

Personal Interview, February 14, 1997.

Ralph Flemons, P. Eng., Instrumentation Engineer (retired)

Personal Interview, October 18, 2000, followed by several discussions.

Michael Gray, P. Eng., Fuelling Machine Engineer,

Telephone Interview, July 19, 2000.

Ralph Lloyd, P. Eng., Technical Counsellor (retired)

Personal Interview, February 11, 1997, followed by several discussions re thesis topics.

Rick Lucas, P. Eng., Fuel Development Engineer,

Telephone Interview, January 8, 2001.

Doug Mahler, P. Eng., Manager, Engineering

Personal Interview, February 27, 1997.

Terry Rogers, PhD., Professor, Mechanical and Aerospace Engineering Department, Carleton University (retired)

Personal and Email Discussions, 2001 - 2002.

Paul Scholfield, P. Eng., CGE Vice-President and General Manager Nuclear Products (retired) Personal Interview, February 6, 2001.

Mel Townsend, P. Eng., Instrumentation Specialist

Telephone Interview, March 14, 1997.

Dean Wasson, CGA, Manager, Nuclear Products (retired)

Telephone Interview, March 18, 1997.

Konrad Zimmermann, P. Eng., Manager, Fuel Handling (retired)

Telephone Interview, February 11, 2000, followed by Personal Interview, February 17, 2001.

In addition, the above interviews were augmented with discussions while researching material for this thesis with the following APD co-workers:

Eric Cantello, Supervisor, Fuel Assembly Shop Operations (retired)

John Condon, P. Eng., Manager, Engineering (retired)

Barrie Cope, P. Eng., Manager, Nuclear Products

Gord Davis, P.Eng., Manager, Instrumentation and Control Engineering (retired)

Ron Essex, Drafting Specialist

Judy Foster, Managerial Secretary

Ben Gaertner, P. Eng., Technical Counsellor

Peter Gvildys, P. Eng., Equipment Engineering

Colin Jeffery, Test Laboratory

Zolt Keszthelyi, P. Eng., Equipment Engineering

Bill Knowles, P. Eng., Supervisor, Fuel Transfer Engineering

Rennie May, Technical Illustrator

B. Manuscripts:

Company Files: (Located in APD Offices and Archives, GE Peterborough)

i) Miscellaneous correspondence, AECL/CGE, Ontario Hydro/ CGE, and CGE departmental and inter-departmental.

ii) Technical Reports

iii) Technical Illustrations

iv) Organizational Charts

Note: Some of this material is confidential. As a former APD employee I was granted access to it, but only under conditions of confidentiality.

Personal Files:

Use was made of my personal files acquired over thirty-one years in APD.

Other personal correspondence and material was kindly donated or loaned by interviewees Dick Beck, Eric Cantello, Dave Erwin, Ralph Flemons, Alex Hoyle, Ralph Lloyd, Doug Mahler,Terry Rogers, and Konrad Zimmermann.

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