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How Canadian industry can win atomic business

(The president of A.E.C.L., J.L. Gray, bases this article on an address given to a recent alumni reunion at the Banff School of Advanced Management, Alberta.)

THERE REALLY is no such thing as a Canadian atomic industry, at least not in the field normally associated with atomic energy—the production of electric power. But there is one specific phase in the utilization of atomic energy that may be singled out, and the industrial organizations handling this phase could perhaps be classed as atomic industry. They are the uranium producers, the uranium refiners and the uranium fuel manufacturers. In Canada, then, in my view the only "atomic industry" per se is the nuclear fuel industry.

There is, of course, atomic business for Canadian industry. While it has been relatively small to date, it could easily grow to quite significant proportions within the next fifteen to twenty years. This work, which will concern mainly the design, fabrication and operation of nuclear power stations, can be easily handled by the existing industrial organizations so far as plant and equipment are concerned. It may tax the design and development capacity of our heavy engineering industry beyond its present capacities, but so long as industry is aware of this it has a chance to strengthen the areas where weaknesses exist.

Nuclear fuel

There is no obvious reason why Canadian industry cannot become a leading world supplier of natural uranium fuel elements for nuclear power plants. We have ample resources of raw materials that should be competitive in the world markets. We have some of the best development and test facilities in our Chalk River reactors to prove fuel element designs and manufactured products.

In the production of uranium oxide pellets Canadian industry has developed what we believe to be the best and most economical process in the world. Although most of this work has been paid for by AECL, some of the most significant advances are due entirely to the ingenuity and efforts of industry. The techniques of fabricating these pellets into zircaloy-clad fuel elements are also outstanding and indicate that Canada can produce quality products at quite acceptable costs, with every indication that costs will steadily fall with increase in production rate.

Although enriched uranium is not available from Canadian sources, it is available from the United States at their domestic prices. There seems no reason why the Canadian fabricators could not compete in this field against U. S. private industrial organizations when there is no assured market for any particular fuel design.

There is no technical reason why private industry in Canada could not build and operate a facility for producing enriched uranium. However, there is no economic justification for such a plant related to the foreseeable civil nuclear power program, even if a good share of the potential world market was assured.

The situation in the uranium mining industry is fairly well known. We are in a period of over-production based on present needs, with the result that many high cost Canadian mines have been closed to allow the lower cost producers a longer period of operation.

A recent study of the future potential markets for natural uranium in the western world by Eldorado Mining and Refining Limited shows the picture is not as bleak as some people have assumed. The study makes various assumptions as to the requirements of the uranium enrichment plants in the U. S., the U. K. and France, along with estimated needs for research reactors, U. S. propulsion reactors and civil power reactors. It indicates a total annual consumption in 1965 of about 32,000 tons of U_3O_8.

The study further estimates that in 1975 the demands might reach 39,000 tons per year. If we assume that the United States will aim for self-sufficiency from sources within their own territory, this will require about 22,000 tons, leaving 17,000 tons per year as a minimum requirement to be supplied from Canada, South Africa and France.

Although the study tends to be conservative, there are one or two unpredictable variables which cannot be used as a basis of calculation. If there should be a drastic reduction or increase in military requirements, the picture could change appreciably. If the nuclear power stations now coming into operation throughout the world prove to be exceptionally good, this could move the estimated requirement for 1970 ahead one or two years.

The critical period for the present uranium producers, then, is still from 1965 to 1968 or 1969. But there are some very good signs that by 1970 we should have a healthy industry.

Radioactive isotopes

For many years the NRX reactor at Chalk River had a neutron flux higher than other reactors. This made Canada more capable of producing substantial quantities of high specific activity radioisotopes than any other country in the world. With this facility, and later the NRU reactor, we undertook to exploit them and formed our Commercial Products Division. Since the research reactors at Chalk River are still the only significant source of radioactive isotopes in Canada, the only Canadian industry of any magnitude in this field has grown around this group.

The Canadian market for radioisotopes is relatively small and a much greater volume is essential for a satisfactory operation. This can be achieved only by creating volume through exports. A vigorous sales program has led to exports which now account for 93% of our total sales.

These markets are created and maintained by designing and developing new equipment to use radioisotopes like iodine-131, phosphorus-32 and carbon-14. To support these programs, we spend about 15% of earned revenue on research and development, a very large sum for a normal commercial operation. These programs have proved quite successful.

Canada was first in the world in the development of cobalt-60 beam therapy units for cancer treatment. By 1961, 250 Canadian cobalt-60 beam therapy units had been sold to hospitals and clinics in 39 countries. There are now 30 companies producing such units throughout the world and their equipment has created an annual market for more than 500,000 curies of cobalt-60 at an average price of about $3.70 per curie. Our Commercial Products Division supplies about 70% of this world market.

Several gammacells and special irradiators designed by Commercial Products Division, using cobalt-60 gamma rays for the irradiation of materials, have been installed in universities and research institutes in Canada. Fifty such units have been exported. The gammacell is mainly a research tool to measure and test the effects of gamma rays on materials. If some of these experiments are successful, new production processes or better products could result.

Co-operative programs with Canadian research institutes and other government laboratories have given valuable data on the gamma irradiation of food and food products to increase shelf life, inhibit sprouting, and to pasteurize and sterilize some items. A mobile demonstration irradiator has been designed to operate on a standard commercial trailer, to process potatoes at the warehouses of Canadian producers. If the final results indicate economic feasibility, the next step will be full-scale production facilities using large amounts of cobalt-60.

Many important Canadian industries use radioisotopes for research and process control. They are used in thickness and density gauging, particularly of paper products, metal foils and similar thin materials. The cigarette industry uses radioisotope density gauges to control the packing of the tobacco, providing a better product and less wastage. Nondestructive testing of welds in all fields is accomplished using radiographic techniques, with major savings in time and materials.

Estimates have been made as to the savings resulting from such use of isotopes. Although figures are not available for Canada, U. S. estimates in 1957 suggested annual savings of $500 million to U. S. agriculture and $200 million to U. S. industry. A recent National Industrial Conference Board report (No. 87) estimates an annual saving of $5 billion by 1965.

These figures are very large but not unreasonable when one thinks of increasing grain production in the U. S. by a few bushels to the acre, through improved use of fertilizers developed by use of radioactively-tagged phosphorus and other elements. The numbers indicate the order of magnitude of savings from the use of radioactive materials. When we add the benefits of their application in medicine it is not difficult to argue that **if atomic energy had produced nothing but isotopes the effort and expense have been worthwhile.**

Our Commercial Products Division has grown in ten years from a small group to a total staff of 260. Annual revenues have climbed from $500 thousand to $4 million. A loss operation has turned into a profit operation. Isotope sales have increased from a few curies to 500,000 curies per year. We have worked hard to gain and to hold a major portion of the world market. The future looks good provided the research reactors at Chalk River remain available for production of radioactive material, and we keep up with the competition on design of equipment and continue to give high quality service.

Heavy water production

One aspect of atomic energy that may easily result in a new industry for Canada is the production of heavy water. If the heavy water reactor systems work as well as expected, they will not only find application in Canada but elsewhere in the world. If we have a source of energy — part fairly low grade steam and part electric — that is as cheap as other world sources, then we could become a world supplier of heavy water.

A heavy water moderated and cooled nuclear power reactor needs nearly 1 ton of heavy water per megawatt of electric output. This means that, for every 200 MWe plant installed, 200 tons D_2O must be supplied. The annual makeup requirements should be quite low—2 to 3% — and will be disregarded in this discussion.

The present price of $28 per pound for heavy water should come down to $20 or below in a modern plant of reasonable size — 200 tons per year—using a low cost energy source. Using $20 per pound and assuming that one 200 MWe plant per year is being installed (this could easily be the condition in Ontario alone by 1970) the volume of business from one production plant, 200 tons, is $8 million per year.

It is quite probable that by the mid-1970's modification and improvements to the heavy water reactor system we are now building will be in the form of other coolants — perhaps organics, more probably light water steam. Such improvements will lower the net cost of power but they will also lower the annual requirement for heavy water. There seems little doubt, however, that there is a very good potential long-term market for the output of a 200 ton per year plant in Canada if the price is $20 per pound or lower. This could easily rise to 500 tons or 1,000 tons per year in the next fifteen to twenty years.

To me, this should be a straight private industry, private investor venture. There are no security restrictions. The technical information is available from the United States and there are several small plants operating in countries outside the United States. The probable market—though not too clear today—should be quite assessable within a year or two. The operating experience with Canada's first nuclear power station, NPD, should supply some of the answers needed.

Canadian commercial companies are now looking at the possibility of entering the heavy water production field. The benefits to our economy could be substantial.

Nuclear power

For Canadian industry the most important aspect of atomic energy is undoubtedly nuclear power.

. Nuclear power plants are in many ways very similar to conventional coal- or oil-fired electric generating stations. The generating end — that is, the turbines, generators, condensers, transformers, water intake and outfall structures, etc. — are the same as those of any thermal plant. The boiler, however, is quite different since this is the heart of the nuclear plant where uranium is "burned" in place of coal or oil.

This similarity between nuclear power plants and conventional thermal power plants can be emphasized with reference to a specific case. We have analyzed the cost of Canada's first nuclear station, the 20,000 kw NPD (Nuclear Power Demonstration) and have expressed the various items of cost as percent of total cost. Table 1 summarizes this analysis with a breakdown of costs into direct, indirect and heavy water. The direct costs have been further broken down to "nuclear", "special conventional" and "standard conventional".

Table 1
Cost breakdown of NPD as percent total plant cost

	Nuclear	Conventional Special	Conventional Standard	Total
Direct costs	17%	13%	23%	53%
Indirect costs				32%
Heavy water				15%
Total				100%

A number of interesting points stand out in this breakdown. The indirect costs (administration and overheads, engineering and development, and commissioning), at 32% of total cost of the plant, are much higher than normal. This is largely because of the very high cost of engineering and development, which stands at 21% of total cost. This same cost would be only about 8% in a large conventional plant where there is very little development expense.

The "nuclear" items of direct cost make up 17% of the total plant cost and the "special conventional" items an additional 13%. Taken together, the items needing special consideration make up 30% of the total plant costs. The special nature of these plants may be emphasized even more by looking only at the direct cost figures: a simple calculation shows that the nuclear and special items make up over half the direct costs. With such a high proportion of the direct costs associated with non-conventional items, the engineering costs are bound to be high. In this case they are at least twice normal.

The items classified as "nuclear" are mainly in the reactor and steam boiler areas of the plant. The major pieces are the calandria and its various fittings, coupled with the moderator dump facilities, the primary cooling circuit with its special pumps and heat exchangers, and the fuel handling equipment with the fuelling machines as the main item.

The work in the "special conventional" category is concerned mainly with ensuring that the equipment or material that would normally be used in a conventional plant, will function under the very demanding conditions found in some areas of the nuclear plant. Pumps may be required to operate with virtually no leaks. They may be in an area where maintenance is very difficult, owing to radiation fields. Normal seal material may have a very short life under irradiation and special materials may have to be developed for valves and glands.

The civil structures around a nuclear boiler must have very special treatment. Concrete may have to be "heavy concrete" — one employing a special aggregate to supply the required mass for shielding with minimum thickness. Concrete surfaces may require cooling, owing to heat from radiation. Concrete may have to be not only water-proof but vapor-proof, to contain heavy water as liquid and vapor. All these are special problems. Materials and equipment are conventional but employed in a special manner or given some special treatment to meet the uncommon requirements of the nuclear system.

Another important distinction between modern thermal plants is the nuclear plant's relative intolerance of equipment shortcomings. The very high value of some of the contained material requires first-class performance from equipment. Radioactivity may prevent access to and maintenance of some equipment during plant operation, further emphasizing the necessity for reliability. Reliability is also necessary because the reactor continues to produce heat even after shut-down. It also rapidly increases to considerable excess power, so that when it is required to shut down it must do so promptly.

In short, equipment must do what it is supposed to do. This sounds rather simple but other types of plant have been able to get by with something less than this because equipment is always accessible, there is a limit to possible energy release that is not far above full power, and energy release increases relatively sluggishly.

This distinction is not going to last very long, in my opinion. As automation and remote operation become more prevalent in conventional plants, all types are going to require the same reliability in equipment that the nature of reactors now demands for nuclear plants. For this reason, the experience of acquiring equipment for a nuclear station gives a sort of preview of industry's ability to supply the kind of equipment that will be a routine requirement of tomorrow's society.

The important lesson to be learned is the necessity of a fully co-ordinated design and development team intimately concerned with the details of the job, from conceptual design through development to manufacturing drawings and finally through the shop and into operation. The design group required is not normally found in industry and requires an extraordinary combination of skills and experience, including physicists, engineers and specialists in heat transfer, stress analysis and metallurgy. This class of personnel is available in Canada and the basic shop facilities necessary to manufacture to the final design can be found in our industry. However the development shop and development experience is lacking and delays are inevitable while these are being acquired.

Nuclear items make up 17% of the total cost of the plant. But what of all the other parts of the plant? What has Canadian industry been able to do for us?

It is my impression that Canadian industrial management is willing — even eager—to supply equipment in the quality of materials and with the quality of workmanship we have asked for.

In general, though, with a few notable exceptions, the Canadian engineering industry is not well equipped to meet this demand. This is not intended as a criticism. It would be surprising if they were properly equipped. They are supplying a relatively small market and the large users of equipment in this country have generally shopped in the world at large. Competition has been very keen.

In this situation, presumably to stay competitive, Canadian industry has skimped on overhead. Very few have research and development departments or even first-class control laboratories and adequate quality control staffs. Even fewer have metallurgical staffs and many do not have good receiving inspection. Difficulties with materials and bought-in components are not realized until late stages of manufacture or early operation.

Despite these inadequacies, the firms generally — after many headaches for them and for us — produce the quality of article that is needed. I should point out here that nuclear plant customers in England and the U. S., where the situation is much more favorable for the industries involved, encounter the same kind of difficulties that we do. So I feel that Canadian industry does quite a creditable job from a comparatively weak position.

Future market

The future market can only be a guess. There are too many variables over which we have no control and very little valid information. If, however, we make some assumptions, we can come up with a low and a high estimate of the volume of Canadian business to 1980.

The low estimate assumes nuclear plants built only in Ontario by Canadian firms, with no export sales, to a total capacity of 6,000 MWe. On the high side, we could assume 10,000 MWe which would involve export sales and nuclear plants in some other areas of Canada.

Assuming an average capital cost of $300 per KWe and natural uranium oxide fuel clad in zircaloy at $25 per pound of uranium with an initial fuel inventory of 450 pounds per MWe and a consumption of 250 pounds per MWe per year, we find the following volume of business to 1980:

	Low Estimate	*High Estimate*
Capital cost	1,800 millions	3,000 millions
Initial fuel	70 "	100 "
Operating fuel	300 "	500 "
	2,170 millions	3,600 millions

About 10% of the total value might have to be imported from foreign sources, but a vigorous Canadian nuclear industry could easily balance out this foreign exchange debit by supplying fabricated fuel and heavy water to foreign-built nuclear plants.

My best guess is that nuclear power will continue to improve its economic position, as it has been doing. If it can be assumed that power costs from conventional sources will stay at about their present level, total sales available to Canadian industry from 1965 to 1980 will be around $3 billion. The annual volume at the end of this period could be very large, in the range of $300 - $1,500 million, depending upon how much of the world market is captured. The market is not only for uranium and heavy water but finished fuel, pressure tubes, pumps, auxiliaries, and complete power systems. The opportunity is ours.

This is not all new business. A large proportion is really alternative business. If nuclear power were not available the same kilowatt capacity would be installed using conventional thermal plants or more remote hydraulic sites. If it is assumed that nuclear at $300 per kWe is replacing conventional thermal at $150 per kWe, the "new" business associated with nuclear power is about half the total capital cost plus the nuclear fuel business. In Ontario, this "new" business is replacing imported coal. ■