tained 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 make-up 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