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. ■