Promote, then, as an object of primary importance, institutions for the general diffusion of knowledge.

General Washington in *Farewell Address.*

By Professor Messel*

Nuclear Power For Australian Industry

Before discussing the economics of nuclear power for industry, it is perhaps worthwhile to see why, in a general way, so many countries of the world are interested in nuclear energy as a source of power.

Mr. Palmer Putnam has recently made a survey of world fuel reserves for the Materials Policy Commission of the U.S.A. The results of this survey contain the answer to the above question. Putnam reported that the complete world coal reserves will probably dwindle to a negligible amount within 100 years and that the oil and gas reserves will disappear in about one half of that time. The question now arises—what then?

There is little or no hope that power from wind, tides and waterfalls will take over any large fraction of our power requirements. The utilization of solar energy is not as easy as many people have been lead to believe and is not likely to play a major rôle in supplying power for many hundreds of years. This source of power will probably be tapped after the world's mineable uranium resources have been depleted. Thus, in spite of the fact that nuclear energy has a number of disadvantages, such as the inherent danger of radioactivity, the difficulty of disposing of radioactive wastes, it seems that the world will—whether it likes it or not—be forced to turn more and more to nuclear energy as its major source of power.

It is amply obvious from the above that uranium—the fuel required for the generation of nuclear energy—will rapidly become one of the world's most precious commodities. Those countries which are blessed with rich mineral deposits of this metal will be in a unique position, and will have a decided advantage over their less fortunate neighbours. Australia it appears is one of the fortunate countries and is likely to be among the top three uranium ore producers in the Western world.

Unfortunately, Australians have not realised what nuclear

* Professor Messel is Professor of Physics, University of Sydney.

power can mean to this country and are rapidly falling in with the deplorable view that in uranium we have a handy exportable mineral for which there exists a very ready dollar market overseas. Australians have yet to realize that in their uranium resources—in nuclear energy—they may have the means at their disposal for making their nation another Canada or America of the southern hemisphere.

Uranium is not just another mineral to be exported. The return, whether it be in pounds or dollars, will be negligible compared to the national budget and will probably do little to build Australia into a great nation. Let us make sure that our children's children will not be left with just holes in the ground—where Rum Jungle and Radium Hill once stood—and nothing to show for it.

Now, who is it that settles these issues? In a democratic nation like ours they are usually settled in the traditional democratic way—out in the open, in a national forum where the views and interests of all sides can be fairly presented. Unfortunately we are living in a world where the threat of war is constantly with us and extraordinary security precautions have had to be taken in certain fields —especially in nuclear energy. Secrecy has become the password in this field. Decisions and answers which would normally come down from the market place where the people most affected conduct their business, now come down from the Olympus. This unfortunate circumstance is one which we must accept as long as world tension remains as high as it is. On the other hand, we must make sure that secrecy is not carried beyond the bounds dictated by security; it must never be used as a cloak for mistakes and blunders.

Not only has Australia the uranium required to generate electricity from nuclear power, but it has the great need for electrical power as well. This country has potential wealth and natural resources but does not have cheap conventional electrical power—where and when it wants it—required to develop this potentiality. The extent to which Australian industries develop depends upon the availability of cheap sources of power.

Uranium has one further particular advantage for Australia, on account of the comparatively small quantity needed to meet the country's power needs, there should be no serious difficulties of transport in making uranium available to various portions of the country. It would be much easier to transport a few tons of uranium to Yampi Sound than transport a million tons of coal!

Because of the peculiar set of circumstances in Australia where

not only have you the need for power, the natural resources to be developed, large distances and costs to be faced in transporting conventional fuels, the lack of conventional sources of power and the availability of uranium required to generate nuclear power, this country will benefit as much as any nation in the world from successful utilization of nuclear energy for power purposes. Obviously, then, nuclear power merits some attention in Australia.

A casual examination of the American Atomic Energy Commission's yearly budget staggers one. Likewise, the hundreds of millions of pounds spent yearly by England in atomic energy developments does little to encourage one to examine the economic feasibility of nuclear energy for industrial power purposes. It is therefore entirely excusable if many people assume outright that nuclear power can never be an economic proposition in Australia and leave it at that.

It is true that a country of Australia's size cannot afford to invest thousands of millions of pounds in nuclear energy; however, it is equally true that there is no need to do so. Building nuclear-powered aircraft, aircraft-carriers, submarines, hydrogen and atom bombs by the score is one matter—and a very costly one—and building nuclear power stations for industry is another. What are the true costs of an industrial nuclear power station and are such stations technically feasible?

The technical feasibility of power derived from atomic energy has already been proved and will be demonstrated in an apt way when the first nuclear-powered submarine, the *Nautilus* in the U.S.A., takes to the water in January, 1954. However, what is technically and economically feasible for defence purposes may bear little relation to what is a sound business investment in an industrial undertaking. The economic problem is one of considerable magnitude, complicated by the fact that as yet no nuclear reactor has been built for the sole purpose of generating power for industrial purposes. There are well over 30 nuclear reactors in the world today but not one of these has been built for this purpose alone.

Though no industrial nuclear-powered, electricity generating station has yet been built, a good deal of study has gone into the various cost factors involved. During the past year, four large American industrial teams carried out an independent analysis of industrial nuclear power. These teams had complete access to all the classified data of the American Atomic Energy Commission. Their analyses were made according to certain conditions, one being

that the teams should consider the possibilities for dual-purpose reactors; that is, nuclear power stations which would not only generate substantial amounts of power, but would breed plutonium (needed for atom bombs and defence purposes) as well. The designs and cost data arrived at by these groups was, therefore, not necessarily the same as that which would be obtained if nuclear reactors were considered for power purposes only. The conclusions arrived at by these groups are most interesting. They found that:—

(a) dual-purpose reactors generating electricity and breeding plutonium could be a paying proposition in America today providing the government guaranteed to buy the plutonium produced;

(b) no nuclear reactor for generating power only could be built *in America* immediately which would be competitive with power from conventional steam plant;

(c) given several years for further technological advances, power from nuclear reactors will probably be as cheap as that from conventional steam plant;

(d) the capital costs of nuclear power plants will be high, about two to three times as great as that of steam plant, and hence the first power stations to be built should be as large as possible, around the 500,000 kilowatt level.

Points (b) and (d) are of particular interest. For instance, even though the capital costs are much higher for nuclear power plant, the final cost per kilowatt hour of electricity delivered is very close to that for conventional steam power plant, being approximately 1.2 and 0.6 penny per kilowatt hour respectively. The reason for this apparent anomaly will become obvious later on. The point is of some importance because so many of the reports appearing at the present day endeavour to condemn power plants by simply pointing to the high capital costs. This is really a red-herring because it is not the capital costs which matter in the long run—it is the cost per kilowatt hour which the consumer will be asked to pay.

Though nuclear power is not a paying proposition in America yet, this does not say that it would not be a paying proposition in many remote parts of Australia today. Conditions are very different in Australia from those existing in America. We have an urgent need for more power, whereas this is not the case in America. One thing is certain—before any further large-scale expenditure on electrical power generation is made in Australia, a close study should

be made of the feasibility of achieving the same end by using nuclear power at an equal or even smaller cost.

As pointed out in (c), there is hope that within a few years nuclear power will be on a competitive basis with coal, even in America. It is true that a large number of large technical hurdles have still to be crossed; however, these are being overcome at a greater rate today than new ones are appearing. The American teams feel confident that, given further time for development, nuclear power will compete with steam power.

It should be stressed at this stage that nuclear power will *supplement* and not replace coal and oil. There will be plenty of scope for both. Whereas one would not consider building a nuclear reactor at Newcastle, one at Yampi Sound would be an entirely different matter. The reason for this will perhaps be more evident after the relative fuel values of uranium and coal are compared.

Let us now examine briefly the question of the amount of uranium required to meet all of Australia's power needs. The calculation is straightforward and is reproduced below.

(1) The experimentally established fact is that in the fission of one nucleus of uranium-235 there is approximately 8.9×10^{-18} kilowatt hours of energy released;

(2) 1 gram of uranium-235 contains 2.56×10^{21} nuclei;

(3) hence the complete fission of 1 gram of uranium will yield $2.56 \times 10^{21} \times 8.9 \times 10^{-18} = 22{,}784$ kilowatt hours of energy;

(4) and hence the fission of 1 ton of uranium per year (365×24 hours) will yield $(2000 \times 454, \times 22{,}784)/365 \times 24) = 2{,}365{,}000$ kilowatts of power or 2365 megawatts;

(5) assuming a thermodynamic efficiency of 25 per cent., we get from the complete utilization of 1 ton of uranium per year $2365/4 = 591$ megawatts of power;

(6) Assuming that the burning of 1 lb. of medium grade coal yields about 2 kilowatt hours of energy, we see that the complete utilization of 1 ton of uranium is equivalent to burning $(22{,}784 \times 454)/2 = 5{,}171{,}968$ tons of coal.

From (5) we see that the complete utilization of one ton of uranium per year will yield 591 megawatts of power providing a thermodynamic efficiency of 25 per cent. is used. The installed capacity in Australia at the present time is 2361 megawatts, thus

the complete utilization of only 4 tons of uranium per year with the above thermodynamic efficiency would give us the same amount of power. *It is now most important to point out that we cannot hope to get 100 per cent. utilization of our uranium.* There are numerous reasons for this which cannot be discussed in this article. At the present time, utilization factors of 1 per cent. are reasonable, and we can hope in the near future for a figure ranging from 5 to 20 per cent. For instance, in the latter case Australia's power needs would be met with a consumption of 20 tons per annum, or in the case of 5 per cent. utilization, 80 tons of uranium per annum. For the equivalence of coal in these cases one has to multiply by the same factors. For instance, in the case of 20 per cent. utilization, one ton of uranium is equivalent to 1,000,000 tons of coal.

This now explains the statement why nuclear power stations might play such an important rôle in various parts of Australia—the question of transportation simply becomes negligible. It also explains the anomaly, wherein, even though the capital costs of nuclear plant is two to three times as great as that of conventional steam plant, the difference in cost per kilowatt of electricity delivered may still be negligible.

So far, nuclear reactors for power purposes only have been discussed. The radioactive fission by-products from nuclear reactors are proving to be of great value in the fields of medical, biological, industrial and agricultural research. In fact, radioactive isotopes are revolutionizing these fields. Australia would benefit a great deal from the by-products of a nuclear reactor and can look forward to a new era in these fields. It is perhaps fair to mention that not all nuclear reactors cost great sums of money. Many of the smaller ones used for experimental purposes cost less than half a million pounds to build. Australia is looking forward to an experimental nuclear reactor being built in this country shortly.

In bringing this article to a close, it is perhaps worth venturing a guess as to how long it will be before Australia gets its *first* nuclear power plant. The most optimistic answers to this question are usually given by people who have never built a nuclear reactor. I am one of these people, hence I will be optimistic and state that if Australia puts its shoulder to the problem and pushes it, then we will have nuclear power station number one in Australia within ten years, and a nuclear-powered industry within 30 to 40 years.

Can Australia afford a nuclear-powered industry? I will put the question another way—can Australia afford not to have a nuclear-powered industry? The answer is obviously "no".