NUCLEAR POWER AND NUCLEAR PROLIFERATION

by Milton S. Plesset

The far-reaching benefits of peaceful uses of nuclear power go hand in hand with dangers of its potential misuse.

The materials necessary for producing nuclear bombs are spreading throughout the world. This will, of course, lead to an increase in the number of nations which have nuclear weapons. This is the problem of nuclear proliferation. The problem has three distinct aspects—technical, industrial-economic, and political—and these dissimilar aspects must be kept in simultaneous focus if a successful nonproliferation treaty is to be developed.

The formal source of treaty efforts is the Eighteen Nation Disarmament Committee (ENDC) which consists of the five NATO countries (United States, Canada, Italy, United Kingdom, and France), the five Warsaw Pact countries (Bulgaria, Czechoslovakia, Poland, Rumania, and U.S.S.R.), and eight nonaligned countries (Brazil, Burma, Ethiopia, India, Mexico, Nigeria, Sweden, and United Arab Republic). France, which is nominally a NATO country, has refused to participate. China was not invited to participate, presumably because of the close relationship of ENDC with the United Nations, so that the only members of the five-nation nuclear club which are participating are the United States, the United Kingdom, and the Soviet Union.

A number of technical and economic factors have led to the increased sense of urgency regarding the problem of nuclear proliferation. While it is clear that rapid diffusion of the materials from which nuclear weapons are made could result in a serious threat to world peace and stability, it is also clear that new developments of the peaceful atom have a great potential for large economic benefits on a worldwide scale.

Two kinds of nuclear weapons material play an essential role in the peaceful applications of nuclear energy: enriched uranium and plutonium. The first designs of power reactors were based on the use of natural uranium. In uranium the chain reaction and continuous energy production come from the rare isotope U^{235} which in natural uranium is only 0.7 percent of the whole, with the remaining 99.3 percent being the nonfissioning isotope U^{238}. Reactors using natural uranium are large structures, and, for special devices such as nuclear power reactors, large size generally implies great cost. Also, natural uranium reactors maintain power production in a rather marginal way; the auxiliary components must be made of special, costly materials which do not absorb too many of the fission neutrons—the particles which maintain the chain process.

In 1964 the nuclear power business emerged from a long period of depression in a spectacular manner. General Electric built a nuclear power plant for Jersey Central Power in which the utility was guaranteed a power-generating cost not to exceed 3.8 mills per kilowatt hour. While cost statements in mills per kwhr are an oversimplification, in the U.S. conventional plants fueled with coal or oil have costs ranging from 5 to over 10 mills. Costs in Europe are even higher.

The reaction of the electric utility industry in the United States has been enormous, as can be seen from the table below, which gives the status of the U.S. civilian nuclear electric power program as of September 20, 1967:

		Megawatts
In Operation	14 plants	2,800
Being Built	18 plants	11,600
On Order	36 plants	30,800
Announced	12 plants	9,800
		55,000
Total U.S. Electric Capacity		250,000

There are two striking characteristics of this latest and very successful generation of nuclear power plants. The first is that they have extremely large power capacities, ranging from 500 to 1,000 megawatts. The city of Los Angeles with its 2.8 million population has a total power capacity of 3,500 megawatts; the capacity of Hoover Dam is about 1,200 megawatts.

A world in which several little Nassers have enriched uranium at their disposal would be a most uncomfortable planet.

A second striking feature of the American design is that it uses enriched uranium. In natural uranium the content of the fissionable, energy-producing isotope U^{235} is less than 1 percent. The new U.S. reactors require uranium fuel in which the content of U^{235} has been increased to about 2 percent. This process is performed in enrichment facilities whose original purpose was solely to obtain weapons-grade uranium, which is very highly enriched material. Enrichment facilities have thus far been built in the U.S., the Soviet Union, France, England, and Communist China—those countries which have demonstrated their weapons capabilities.

The peaceful and economically significant use of enrichment facilities is a very recent development. There are many highly industrialized countries which do not have their own uranium enriching facilities; but they could build them. Then they would also have the capability of producing weapons-grade uranium. Here we have one kind of proliferation danger.

As an antiproliferation effort the United States has agreed to make enriched uranium available at an attractive price estimated to be about two-thirds of France's enrichment cost. (In the free world France has the largest existing facilities next to the U.S.). Some foreign spokesmen for the industry, such as those in West Germany, have expressed concern about becoming dependent upon the United States for a large segment of their power requirements, indicating some reserve about possible whimsical behavior at a future time by members of the American Congress which might cut off their supply of enriched uranium. Such an action would be a staggering blow to a nation's economy. The U.S. answer to this concern has been to give treaty status to an agreement on an enriched-uranium supply. The American view is that the abrogation of a treaty is a serious step that any country would hesitate to make. A further part of such a treaty would be that the plutonium produced, while belonging to the country owning the reactor, would be under international safeguards.

In spite of the treaty aspect, there are still some reservations on the part of the largest potential users of the U.S. type of reactor—West Germany and Japan. These countries are aware of the enormous world market for power reactors and are keenly interested in extending their foreign trade. They are reluctant to accept a secondary role for their own power needs as well as for their foreign trade. Their position is further weakened since they cannot supply enriched-uranium fuel even if they could compete on plant designs and construction.

The U.S. is thus far effectively the sole source for the supply of enriched fuel. It has established a price for the enrichment of uranium which has a direct effect on the cost of electricity generated from nuclear energy. Of course, the lower the U.S. figure is, the less—so the AEC believes—is the pressure for a foreign country to get its own enrichment facilities. Perhaps this attitude stimulated the AEC to lower the enrichment charge by 10 percent last September. This decrease means a further improvement in the competitive position of the enriched-uranium-fueled power reactor relative to the fossil-fueled power plant.

One point that the AEC has not made clear is the capability of our enrichment facilities for meeting the demand. The AEC has been steadily raising its predictions of the level of nuclear power production. In 1962 the prediction for 1980 was 40,000 megawatts. This is less than the nuclear power ordered or installed by 1967. The present AEC estimate for 1980 is 150,000 megawatts.

In any case, two important questions arise for the foreign operator of an enriched-uranium power reactor abroad: Will the existing U.S. enriching capacity meet the demands of the 1980s and later, and if it does not, will this capacity be increased sufficiently to meet the expected requirements? The AEC has just released information which indicates that our present enrichment capacity will barely meet the U.S. domestic needs. As for the second question, since foreign needs might be expected to have lower priority than domestic needs, foreign concern is entirely reasonable. The pressure for independent enriching facilities will certainly increase. Actually, the most efficient course is for the U.S. to increase its enriching capacity.

In every case so far the development of uranium-enrichment facilities has been motivated by a national drive toward nuclear armament. The economic value of an enrichment capability is of only recent importance. This economic incentive, however, may serve as a convenient excuse toward such a development. The AEC proliferation nightmare is that an enrichment method will be developed which will be so simple and inexpensive that any country would be able to develop it.

Actually, the realities of the enrichment situation are somewhat different. The scientific and technical procedures for enrichment are well understood, and there is no particular need for secrecy. The actual design and construction of an enrichment facility, on the other hand, require an engineering and industrial base of appreciable extent.

The pressure for enrichment facilities is only a part of the concern over nuclear proliferation. A very great concern is with the production and use of plutonium. This element did not exist until the advent of the nuclear age, and it is now produced in large quantities in nuclear reactors. Plutonium has outstanding fissionability, which means that it is an outstanding material for nuclear bombs. Less than 10 kg (22 lbs) of plutonium are sufficient to produce a nuclear weapon. Plutonium is always being produced in a reactor since U^{238} is a fertile material; that is to say, when a U^{238} nucleus captures a neutron, a fissionable nucleus, plutonium, can be produced. In a 1,000-megawatt nuclear plant, sufficient plutonium is produced to make more than 20 nuclear bombs per year. Furthermore, the separation of plutonium from nonfissionable materials is not a difficult physical process, like the one required for uranium enrichment. Rather, it is a simple chemical process, since plutonium is obviously a different chemical element from uranium.

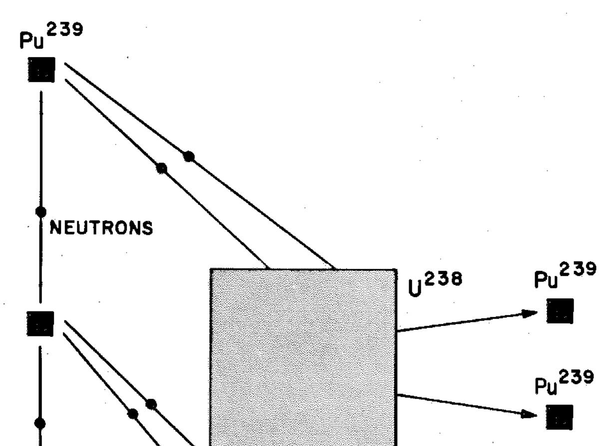
The U.S. and the U.S.S.R. have proposed that inspection and verification of the fissionable materials uranium and plutonium be made by the International Atomic Energy Agency (IAEA). The European Community group, for which West Germany has been the active spokesman, has strongly objected to this inspection proposal. It points out that Euratom, the atomic energy division of the European Economic Community, already has an extensive and capable inspection system of its own. Further, it is clear that France, which accepts Euratom inspection of its civilian nuclear installations, would refuse to accept inspection by IAEA. West Germany and Japan also would probably be unwilling to accept IAEA. They already feel they have lost out to the United States in the first great stage of economic development of nuclear reactors—those based on slightly enriched uranium. As great industrial powers, they feel it is essential for them to have an independent role in the next stage of nuclear power development. West Germany is already making an important investment in this next stage and genuinely fears that its developments will be stolen by Russian or other inspectors from IAEA.

The rapid growth of nuclear power production in the world means that the output of plutonium from the conversion of enriched uranium will be huge. By 1980 the world supply will be over 100,000 kg. This figure translated into an equivalent number of nuclear bombs (over 10,000) is truly awesome. Yet, in spite of this enormous production there is universal agreement that the shortage of plutonium will be acute until at least the year 2000. This shortage will result from the increased need for plutonium for nuclear power production in the new type of reactor to come.

The implications for the proliferation problem of large amounts of plutonium in several places throughout the world are almost too obvious, and the existence of an acute shortage at the same time may seem paradoxical. To understand this situation it is necessary to consider the next stage in the production of electric power by means of the plutonium fast-breeder reactor. Here we are talking about developments which will take place by the early 1980s and will rapidly become large scale. The physical and engineering principles which are the basis for the plutonium fast-breeder reactor are already well known. What remains is only a technological and manufacturing development that requires experience with various prototypes already operating or now being built in the United States, in the U.S.S.R., in England, and in West Germany.

The plutonium fast-breeder reactor is a compact structure which will have a power density of the order of a megawatt per liter—1,000 times greater than the power density in the gas-cooled natural-uranium reactor and more than ten times greater than in the enriched-uranium reactor. The fission energy comes from the plutonium; natural uranium will be included in the reactor to be converted to

THE PLUTONIUM FAST BREEDER



The plutonium fast breeder, the electrical power producer of the future, uses a costly fission energy fuel (Pu^{239} at \$40 a gram), but it will actually produce more Pu^{239} than it uses. Neutrons given off from the fission of one unit of Pu^{239} will not only keep the energy-producing chain reaction going, but, when combined with uranium 238, will produce two new units of Pu^{239}.

plutonium. So, while plutonium is consumed in the reactor, it is also being produced by the conversion of uranium. Actually, more plutonium will be produced than is consumed.

An important characteristic of the breeder is the so-called doubling time—the time required to replace the initial charge of plutonium and to produce an additional amount equal to the initial charge. The design objective is a doubling time for plutonium which is shorter than the doubling time for installed electric power; that is, the breeder doubling time should be less than 10 years. We must understand that uranium is consumed, but it is of the utmost significance that the U^{238} which is converted is 99.3 percent of the total. We are then freed of the need to buy 140 pounds of uranium to get a pound of the fissionable U^{235}.

The direct economic result is that the cost of the natural uranium being consumed becomes an entirely secondary matter. One can go to quite poor sources of uranium and still have an economic fuel. The kind of poor source that is pertinent here is, for example, the low concentration of uranium dissolved in the oceans. The total amount of dissolved uranium is in excess of a billion tons.

The plutonium breeder reactor means that the electric power needs of the world can be met for thousands of years at a fraction of the present cost. A greater and growing share of the electric power production will certainly be nuclear. It is projected that between 2020 and 2040 essentially all of the electric power in the United States will be produced by plutonium fast breeder reactors. We can therefore be certain that the great expansion in the world's energy needs will be met without the world suffocating itself by the combustion of fossil fuels.

Evidently a kind of millenium is near in which the world's electric power can be generated at extremely low cost. We have at hand unlimited resources for power with negligible fuel costs. The efforts of Project Sherwood, the AEC project to attain low cost energy from the controlled fusion of hydrogen, so far unsuccessful, is no longer justifiable as necessary to meet the world's energy requirements now that these requirements will be met by the plutonium fast breeder.

One cannot anticipate all the benefits that will come from the availability of cheap electrical energy in large packages. One such use, however, is the desalination of sea water. We can surely expect others. The development of the plutonium fast-breeder is proceeding even more rapidly than was anticipated two or three years ago. The next generation of mankind, we hope, will adjust calmly to the fact that there will be hundreds of plutonium power reactors scattered around the world.

But the following questions will surely be raised. In view of the danger from nuclear power, why bother with it? Why not continue with fossil fuels as sources of energy? We must appreciate the tremendous growth in power demands not only in the highly industrialized countries but in the less developed countries as well. Fossil fuels will continue to be used for power generation for some time, but their share of the total will be a decreasing one and should be decreasing because of the air pollution problem, if for no other reason. Further, the nuclear power plant has an important flexibility in that it does not need to be located in a way which is convenient for receipt of fossil fuels in bulk.

In view of the economic benefits on the one hand and the threat of a spread of nuclear weapons on the other, we might expect that it would not be too difficult to draft a treaty which would receive ready acceptance by most of the nations of the world. Actually, there have been many difficulties and delays in the development of a treaty.

One source of difficulty comes from the basic feature of the proposed treaty. The nuclear powers who sign the treaty promise that they will not assist any non-nuclear power to acquire nuclear weapons. Since none of the nuclear powers had any intention of doing this in any case, it should be easy for them to accept such a treaty. On the other hand, the non-nuclear powers who sign the treaty *do* give up something quite concrete since they are asked to renounce any attempt to acquire nuclear weapons. Many countries that do not now have nuclear weapons could acquire them with no help from the present nuclear powers. Non-nuclear powers such as Sweden, West Germany, Canada, or Japan are well aware that they could, without outside help, have a more efficient nuclear weapons program than has France or China. There is an even longer list of countries which could develop nuclear weapons—less efficiently perhaps, but still effectively.

Nontechnical people frequently believe that there are scientific facts which may be held secret and which will thereby effectively inhibit the development of nuclear weapons in a country which does not have them. The actual situation is that the scientific, physical principles at the basis of nuclear weapons are very widely known and available. What are not generally available are the engineering and technical procedures which facilitate the manufacture of nuclear material and devices. To secure these techniques takes time and effort. The necessary techniques are, of course, made easier to develop when there is a sophisticated engineering base in industry, but many countries *do* have this base already.

The non-nuclear powers can reasonably feel that they are making a positive contribution to world stability by signing a nonproliferation treaty. A similar positive contribution from the nuclear powers seems lacking in the eyes of these have-not countries. The reluctance of the non-nuclear powers is understandable as is their demand for some kind of *quid pro quo*.

It is necessary to have most of the countries of the world not only accept a nonproliferation treaty but to do so with real enthusiasm.

The United States and the Soviet Union are in agreement on most points of the proposed treaty, and any agreement between the superpowers is an item of the greatest importance. Yet, I believe that it is necessary to have most of the countries of the world not only accept the treaty but to do so with real enthusiasm. I should like to make the following proposals which I believe would greatly improve the response to the nonproliferation treaty.

First, the United States should not insist that the inspection and monitoring of fissionable material be done *solely* by the IAEA. The IAEA inspection capability is appropriate to the pre-industrial era and is adapted to a relatively low-level stage in nuclear power. The IAEA cannot claim to have a higher level of inspection competence than Euratom. The nations in Euratom announced last November that they are united in their rejection of IAEA inspection as provided in the draft treaty. They will allow inspection only of fissionable materials, enriched uranium and plutonium, but not of power reactors and related plants. Further, they demand that IAEA and Euratom negotiate on a free and equal basis on inspection procedures. The U.S.S.R. will not be enthusiastic about this possibility, but it is worth pressure from the United States in its favor. For purely technical reasons no inspection procedure is going to be entirely adequate to guarantee that *no* diversion of fissionable material takes place. The essential inaccuracies in control will always be equivalent to enough material for quite a few nuclear weapons. The success of a nonproliferation effort must be based ultimately not on elaborate surveillance or inspection but rather on the development of some kind of responsibility of nations. Technical developments have made *certainties* in the world impossible to obtain.

Second, the United States should terminate completely, and make a strong effort to get the U.S.S.R. to terminate, its program for the development of peaceful applications for nuclear explosions. Peaceful nuclear explosions, if we may use such a term, for making canals or for underground mining, differ only in intent from military nuclear explosions. The loophole provided by such programs is too large, and the potential economic gain from these applications is too small to justify acceptance.

Third, the United States and the Soviet Union should extend the test-ban treaty to include underground tests. This step will make their test ban complete. Actually, the gap between the United States and the Soviet Union on this point during the original treaty discussions was not so large as might be supposed. Underground explosions were not included because the Soviet Union would not accept the number of on-site inspections of suspicious seismic events within its borders which the United States felt would be necessary. Since the execution of the original treaty there has been some improvement in the Soviet attitude regarding foreign surveys, and there has been a significant improvement in the techniques of seismic measurements which would aid in the discrimination between earthquakes and underground nuclear explosions. A nominal inspection privilege would be an entirely adequate safeguard against the possibility of cheating. Again, we must realize that we cannot demand *certainties* in a technically complex and politically involved situation.

While all three of these steps would increase the acceptability of a nonproliferation treaty to the non-nuclear powers, the completion of the test-ban treaty would be the most significant contribution to their enthusiastic acceptance and support of the treaty. The international moral pressure on France and mainland China would be correspondingly increased. These two countries could very well discover that their second-rate nuclear arsenals represent a net loss in national prestige.

The world needs a good nonproliferation treaty, but the moment is gone when it would have been easy to get a good one. We have been technically inventive; now we need to be politically and organizationally inventive. In spite of the potential dangers of the widespread diffusion of nuclear materials, perhaps the great economic benefits will confine the use of nuclear materials to economic applications. The revolution in energy supply will be just as available in an underdeveloped part of the world as it is in a highly industrialized country. It is inevitable, perhaps, that it will come more slowly in the areas of the world which need it most. But it will come.