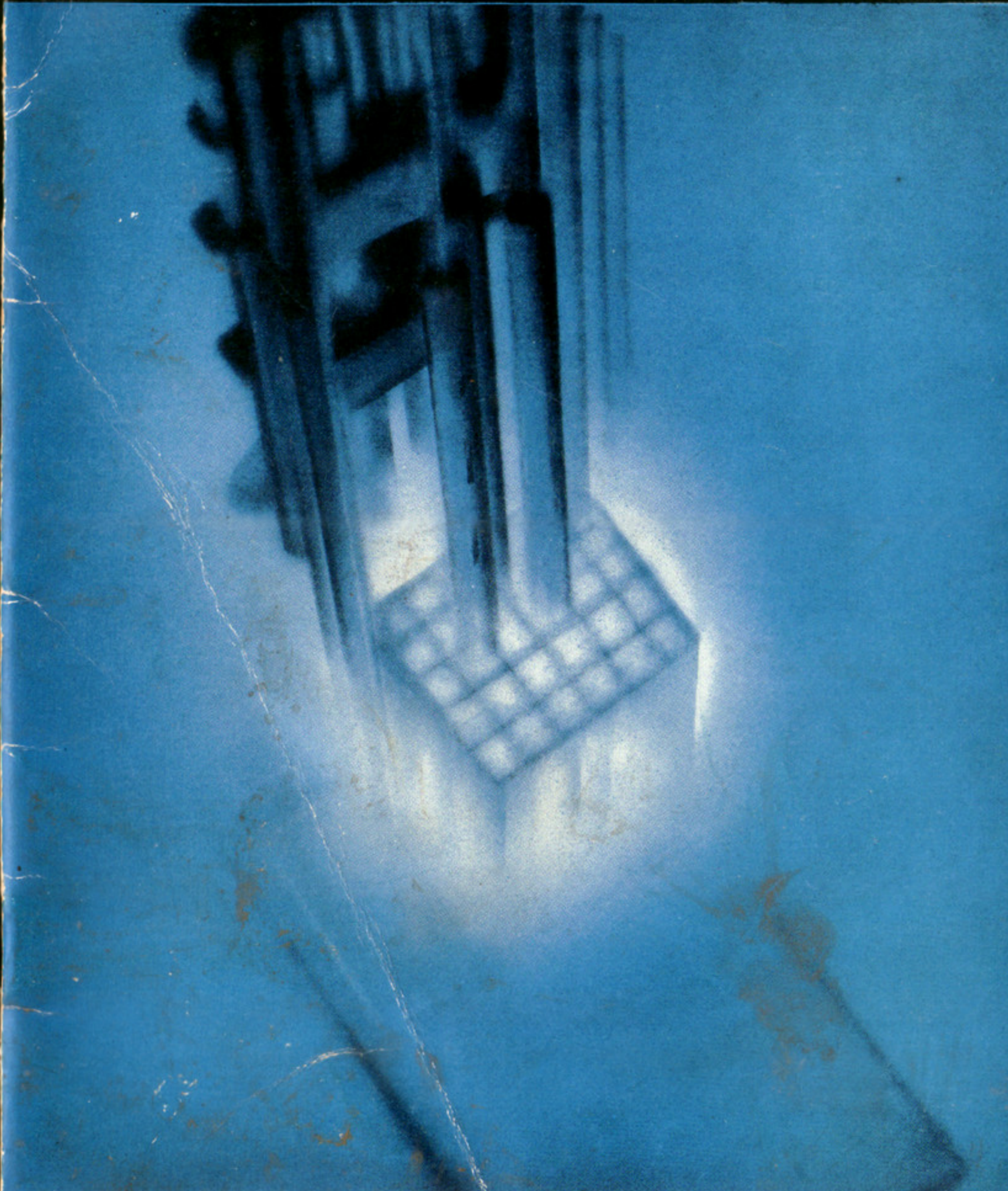
A WORLD TO GAIN The story of the International Conference on the Peaceful Uses of Atomic Energy at Geneva, 1955



published by
THE ASSOCIATION OF SCIENTIFIC WORKERS
and THE LABOUR RESEARCH DEPARTMENT

• *Our cover picture shows the glowing core of the nuclear reactor which was exhibited at the Geneva conference by the United States of America.*

A WORLD TO GAIN

The story of the International Conference on the Peaceful Uses of Atomic Energy at Geneva, 1955

- Prepared by the Atomic Sciences Committee of the Association of Scientific Workers
- Jointly published by the ASSOCIATION OF SCIENTIFIC WORKERS, 15, Half Moon Street, London, W.1, and the LABOUR RESEARCH DEPARTMENT, 2, Soho Square, London, W.1

ONE SHILLING AND SIXPENCE

[1956]

Preface

THE PURPOSE OF *this booklet is to give, in terms intelligible to anyone, a picture of the magnificent prospects for the peaceful applications of nuclear energy which were opened up for the first time by the Geneva Conference of August 1955. For this reason, the figures quoted are, with rare exceptions, to be found in one or other of the documents presented on that occasion.*

Several members of the Atomic Sciences Committee attended the conference, either wholly or in part. The booklet now presented is the outcome of their experiences and impressions coupled with study of the documents presented to the conference.

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Foreword

It was a happy thought of the Association of Scientific Workers to prepare a pamphlet on the peaceful uses of atomic energy in a form which is easily understood by the man in the street.

Up to now, the knowledge of the great majority of the public on atomic energy has been vague and limited to the atomic bomb which was dropped on Hiroshima and to the deadly new weapons which have been developed and tested by the United States of America in the Pacific Ocean and the Nevada desert and by this country in the testing grounds in Australia. Reports by experts have spoken of the annihilation of the populations of large cities by these atomic and hydrogen bombs; mankind shudders at their very names.

Hence it is like a fresh breeze in the desert to read this excellent pamphlet deploring the development of nuclear weapons and pointing out the peace-time usages of atomic energy which would bring benefit to mankind and would raise the standards of living of working populations of every country in the world.

As scientists, the Association of Scientific Workers have given in this pamphlet a clear warning on the continued priority of the production of nuclear weapons. On the other hand, the pamphlet shows some of the ways atomic energy could be used in the development of industry and, indeed, could create another industrial revolution which would give to peoples everywhere a fuller and better life.

I sincerely trust that this pamphlet will be widely read as, in my view, it contains a message for mankind.

Gavin Martin

General Secretary, Confederation of Shipbuilding and Engineering Unions.

Humanity in Crisis

In round figures you have today 2,000 million brothers and sisters, and 100,000 more of them are born each day. By the year 2000 the world population will stand at about 3,000 million.

Into what sort of world are they born? For most their lot is poverty and suffering, most of it preventable. Probably less than 25 per cent of the earth's surface is efficiently used for the raising of food. More than 25 per cent is desert, much of it man-made, and in many places expanding; the Sahara for example advances in places at the rate of thirty-five miles per year. There are also huge areas of white desert, and of green: the frozen tundra of the Arctic and the untamed forests of the Amazon. Humanity might be fed from these areas; to harness them requires power.

But power production is inadequate, and its distribution fantastically unbalanced. North America and Western Europe together consume 55 per cent of all that is produced; the U.S.S.R. 17 per cent; Asia, India and the rest of the world a little under 20 per cent. Amongst the developed areas consumption of power per head is more than ten times that of the under-developed. Moreover, such power as the under-developed world manages to scrape together is often bought at the cost of further aggravating its own crisis; for example, in India 80 per cent of the power consumed per head is produced by the burning of dung, urgently needed for agricultural use. The under-developed part of the world, containing two-thirds of its population, has less than 8 per cent of the total world electric generating capacity. It is not surprising that the world of 1956 is not at peace with itself; there is no reason why it should be.

The rise of Britain in modern times was based on coal. Over 95 per cent of our power still comes from coal, but the situation has long been reached when the output of the British pits ceased to expand. The top annual production was reached as long ago as 1913 with the mining of 287 million tons. More recently, the figure has fluctuated around 200 million tons. In 1954 the total production was just over 220 million tons, the reward of a very intensive effort. In fact, the large programme of capital investment undertaken by the National Coal Board can do little more than stabilize the present level of output, a point which is reflected in the Coal Board's target for last year of 250 million tons.

Even supposing it is achieved, our growing electricity requirements will soon outstrip this slight increase. Our power stations now consume 40 million tons of coal per year; by 1960 they will require 60 million tons, and to cope with a doubling power consumption every decade, 100 million tons will be required annually by 1975. Thus, an extra 70 million tons per year will be necessary for electricity production alone in twenty years' time. It is impossible to imagine this being produced in our pits.

Although our mounting fuel crisis must concern us very greatly it is but a small reflection of what is happening elsewhere. The crisis is, in fact, world-wide; and at our present levels of population growth and expanding production our conventional sources of energy (mainly coal and oil) must become exhausted within a few hundred years. It is true that other sources remain partly or wholly untapped, such as hydro-electricity, which accounts for only 1·4 per cent of world production at present. Tidal energy, and energy obtained from the use of green plant material have also been considered; but even if all these were fully exploited they would not fill the gap which yawns ever wider each year, and which provides the real crisis of our time.

And in this context we must remember that world requirements will be three times what they are now by the turn of the century. These figures pose an alternative which is as simple as it is inescapable; there must either be in the lifetime of most of us a revolutionary change in our methods of power production and, no less important, of distribution; or else humanity will enter into decline.

The Road to Plenty

At the turn of the century Einstein showed that there was a close relationship between matter and energy which might be summarized colloquially by saying that mass is a form of condensed energy.

Also, at about the same time, it was shown that the atom had a two-fold structure, not unlike that of the solar system in miniature. At the centre of each atom there lies a hard core, the *nucleus*. It comprises very nearly all the mass of the atom. It is surrounded by a number of almost mass-less particles called electrons; and it is from the reactions of these electrons that chemical energy is obtained as, for example, from the burning of coal.

Gradually the idea grew that if we could tap the energy which lay condensed in the nucleus itself we would have a source of power many

Geographical distribution of uranium and thorium ores

Diagram from UNESCO'S publication 'Nuclear energy and its uses in peace' by Gerald Wendt

million times greater than that achievable by conventional means. Because its source is indeed the nucleus, we prefer to describe this as 'nuclear' rather than 'atomic' energy.

That energy was first released in the explosion of the atomic bomb in 1945, and since then a race in atomic armaments has dominated the political dissensions of mankind. Few people realised until recently that the same energy which can destroy an entire city so easily can also be harnessed for the benefit of mankind.

The first practical realisation of this came with the announcement, in 1945, that a power station working on atomic energy had been built in the U.S.S.R. The effect of this was to make people realise that nuclear power was not something in the remote future, but was possible here and now, because the technical problems had been essentially solved.

And then in August, 1955, came the Geneva Conference on the Peaceful Applications of Nuclear Power. This was the greatest scientific conference that has taken place so far in history. Originally intended as a more or less select meeting of government delegates, it grew rapidly until it was finally attended by 1,400 official delegates and over 3,000 observers from atomic institutes and industry. Included amongst these were the most distinguished specialists in nuclear energy from the whole world over; there were relatively few who did not contrive somehow or other to be present in Geneva during the two momentous weeks the conference lasted. Eleven hundred papers were presented; they covered every aspect of the field, from generalities concerned with world power needs in the immediate future, to the most recondite problems of atomic physics.

The conference succeeded in making available to the entire world the know-how of nuclear power production which hitherto had been, in practice, the preserve of three nations only – ourselves, the United States and the U.S.S.R. In the course of this, secrecy in fundamental nuclear physics was destroyed. No less great amongst its achievements was its solid contribution towards re-establishing international confidence and goodwill. The achievements of Geneva, and the prospects of nuclear power should be within the knowledge of every man and woman, and most of what follows here will be, in fact, derived from the findings of the conference. But before we go into this in detail, a few words of explanation are necessary concerning the science of nuclear power production.

A Plain Man's Guide to the Atom

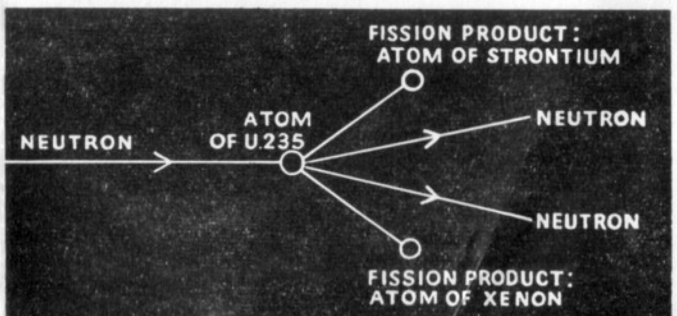
ALL THINGS which make up our familiar surroundings such as air and water, coal and wood, animals, plants and earth, are made up of about ninety different types of matter, which are called elements. Thus, for example, coal is largely made up of the elements carbon and hydrogen; and water of hydrogen and oxygen. These elements, if they could be sub-divided continually, would ultimately be found to consist of atoms. Sub-divide further: 'split the atom' – and its chemical characteristics are changed: it is no longer an atom of the same element. All the atoms of a given element are in most respects alike; and although they differ in important details from the atoms of every other element they all have in common the sun-and-planet structure which has already been outlined; a central nucleus wherein lies the greatest reserve of energy of the atom, and the almost mass-less orbital electrons which revolve around it, and upon which most of the familiar properties of matter are based.

It happens that certain of the heaviest metals, such as uranium and radium, have unstable nuclei. They are unstable precisely because they are so large and heavy, and they break down spontaneously, emitting large quantities of energy of various sorts. The process is known as radio-activity. Now atoms are so tiny that millions of them are required to bridge a penny. Yet, under the right circumstances, the radioactive decomposition of a single atomic nucleus is big enough to be seen by the naked eye. Clearly the energy released is of an order of magnitude which is enormous by all conventional standards.

Can we do this 'to order'? Obviously it is not enough to explode these nuclei one by one; we must envisage a process, a chain-reaction, in which the first nucleus, as it releases its energy, produces not only enough for us to use, but also enough to 'touch off' surrounding atoms and thus get the nuclear fire alight.

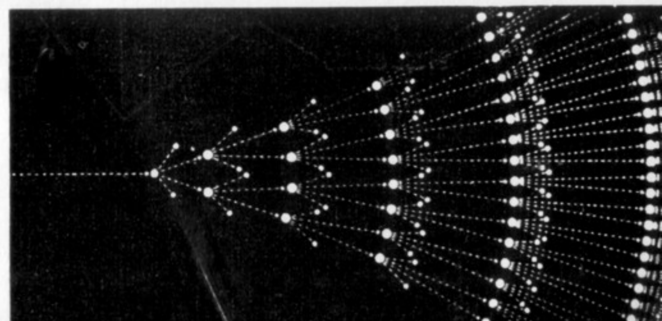
One of the ways in which this can be done is by using certain of the heaviest metals, notably uranium and thorium. If certain of their nuclei are bombarded with sub-atomic, high-energy particles called neutrons, the nuclei explode violently in a process known as nuclear fission. Enormous quantities of energy including much heat are released from the fission of even one uranium nucleus; and amongst that energy are between two and three further neutrons which, properly husbanded, can be used to promote fission in surrounding nuclei. In this way from the disintegration of one atom a chain-reaction can rapidly be made to grow until the energy released is on a sufficiently large scale to be used by man.

All nuclear power programmes are based on fission at present, but there is another possibility, the thermonuclear reaction, which uses not the very heaviest but the very lightest elements, such as hydrogen and lithium. It is known that it is possible to 'knock together' certain of these very light nuclei to make nuclei of elements which are somewhat



● *On being hit by a slow neutron, an atom of uranium 235 splits into two fission products. In addition, two or three neutrons are ejected at high speed as the uranium atom splits up.*

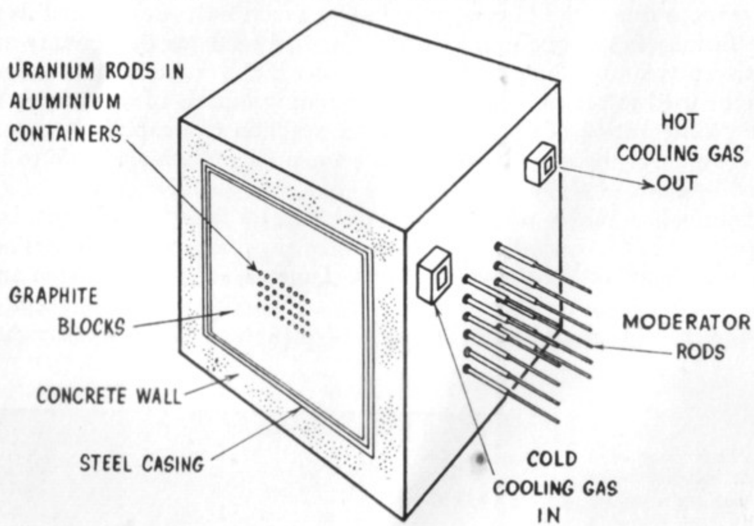
● *The build-up of a chain reaction with uranium 235. From the first fission, the two neutrons ejected produce two further fissions, and so on. In practice, some of the neutrons may escape or be captured (or absorbed) by other substances present.*



heavier. When this happens some of the mass is lost and appears as energy. Thus, for example, the sun derives its energy by a complex cyclic process involving the build-up of four hydrogen nuclei into one of helium; the helium nucleus weighs a little less than it ought to, and the 'missing' mass has been converted into energy. It is probable that within our lifetime this source of energy, which forms the basis of the hydrogen bomb, will also be harnessed to the advantage of mankind. Indeed, at Geneva it was stated that this development may be not more than ten to twenty years ahead. But at the moment it is not a practical proposition.

What a Nuclear Power Station Will Be Like

It is generally known that we are already building nuclear power stations in this country. They will be very similar to conventional power stations except in one respect; that instead of a coal burning furnace they will have a nuclear furnace – i.e. the heat will be raised by nuclear fission in an instrument known as a nuclear pile or reactor. The reactors being built at the moment consist essentially of uranium bars which lie in a number of channels drilled through blocks of



graphite. The purpose of the graphite can be explained if we imagine the fission process starting in a bar of uranium somewhere at the centre of the pile. The first fission releases enough neutrons to carry on the process and establish the chain-reaction, but they are going so fast that they escape out of the bar of uranium in which they were born without giving rise to any further fission. Outside the bar they find themselves surrounded on all sides by graphite. Graphite, like heavy water, is what is known as a 'moderator', that is to say, it possesses the power of making the neutrons lose energy without absorbing them; so that by the time the neutrons have reached the other side of the graphite and have come into contact with another bar of uranium, they are of just the right energy to promote fission within that bar. The graphite is made exactly the right thickness for this purpose.

The pile of uranium and graphite is very large (2,000 tons of graphite are required for each pile as we are building them at present). The pile can be cooled by many means; by gas or water or liquid metal for example. Our present practice is to use carbon dioxide. The heat so extracted is used to raise steam which in turn is used to generate electricity. The pile is controlled by a 'moderator'; rods of cadmium or boron steel which absorb neutrons readily and so stop the chain reaction when they are inserted into the pile.

In Britain and other countries it is the practice to enclose any large-

The Windscale piles. Photo from 'Britain's Atomic Factories', HMSO 1954.

scale reactor in a steel shell in order that if an accident should occur to the pile there is no possibility of radioactive leakage. This is one illustration of the great care which is being taken in the matter of protection, for no possibility of such an accident is envisaged, and the reactor designs which have been released for routine industrial use are absolutely safe and stable in operation.

Outside the steel shell lies a further shell of concrete, the so-called 'biological shield'. Its function is to absorb stray radiation escaping from the pile in order that no-one may be harmed merely by approaching the pile. The amount of time which one may spend in the vicinity of the pile is, of course, limited, and all essential pile-controls are remotely-operated.

Although except for the furnace there is no great difference between the new power station and the old, yet that one difference will introduce great changes in the labour structure of the power industry. Coal will no longer be burnt, ashes will no longer be raked; the nuclear furnace will be controlled by one or perhaps two technicians sitting at a desk. A large part of the personnel of the old type of power station will not be required in the new.

A Long Term Answer to the Fuel Crisis

In this type of pile one ton of uranium will do the work of 10,000 tons of coal. But it so happens that only a small part of natural uranium is fissile – i.e. can be burnt in this way. This is the material known as U-235. More than 99 per cent of uranium consists of U-238 in which it is hard to promote fission. Once the U-235 in a ton of uranium has been burnt in the pile that uranium would, therefore, be useless, but for one thing: that some of the U-238 atoms whilst in the pile absorb neutrons without producing fission, but forming instead a new element called plutonium whose properties are similar to those of U-235.

In the operation of the power station, therefore, the U-235 is partially replaced by plutonium; but the pile does not produce as much plutonium as it burns U-235 and thus must ultimately come to a standstill unless some means can be found of producing further fissile material from somewhere or other.

Fortunately, a means has been discovered of doing this and it was one of the great surprises at Geneva to find out how rapid progress had been in this field. The process is known as 'breeding'; it is done by building a pile in such a way that it will actually produce more fissile material than it burns. Such a pile has to be designed with breeding in view and is very different from the one already described. Typically it will contain a core of pure or nearly pure fissile material

in which the fission reaction is proceeding at a very fast rate, yielding fast neutrons. The core is very small, a matter of inches across. There is no moderator. A 'blanket' of suitable material, such as natural uranium, surrounds the core and absorbs these neutrons, forming plutonium. Matters are arranged so that a given neutron has the highest possible chance of reaching the 'blanket'.

We in Britain have produced experimentally a small pile whose breeding-rate is so rapid that for every atom of fissile material that it destroys, two more make their appearance in the 'blanket'. By the use of breeder piles it is therefore possible to build up stocks of fissile material comparatively rapidly. Thus, when the uranium in the power-reactor is spent it is possible to reactivate it by putting back into it such fissile material as is required, which has been prepared artificially. It is also possible to put in more fissile material than is found naturally. In this case one has what is called an 'enriched' reactor in which the fission process is going on much more rapidly than in a reactor powered with the more dilute natural uranium. It also means that an enriched pile can be made very much smaller than a natural one.

It is clear that as long as nuclear power was wholly dependent on the natural supply of fissile material it could provide no long-term answer to the world fuel crisis. The successful development of breeding has altered all this; where one ton of uranium now replaces 10,000 tons of coal, it will be possible in future to make it do the work of one million tons of coal by reactivating it with fissile material once stocks of this have been built up by breeding.

Nor is this all; for there exists in nature another element known as thorium, which is three times as plentiful as uranium and which is quite as suitable for use in a nuclear power reactor, except that it does not contain that vital one per cent of fissile material. If we want to use thorium we must mix fissile material with it; and we can only do this if we can prepare such material in quantity. Once established, thorium can also be used to prepare fissile material, in this case another form of uranium, U-233.

In addition to this, it was shown at Geneva that world resources of uranium are much greater than was suspected even a few years ago. Seven countries have reserves of more than one million tons. This is not all high-grade ore and a lot of it is uneconomic to work at present. But great strides have been made in the technicalities of uranium production from low grade ore by many countries, such as Sweden and Yugoslavia. It can thus be seen that we shall be able to obtain power from fission for as far ahead into the future as we can see; and when one adds to this the fact, mentioned earlier, that thermonuclear power will almost certainly be tamed, the prospect does indeed become limitless.

Much interesting information was given at Geneva concerning the cost of nuclear power. Stations such as we are building at present cost £15–£20 million and will consist of two nuclear reactors and generating plant producing 50–100,000 kilowatts. The stations that the C.E.A. expect to build in two years' time will have a capital cost of about £150 per kilowatt, allowing for the cost of fuel. This is about twice the capital cost per kilowatt of a conventional coal or oil burning station, but the fuel costs are less.

The present cost of conventionally-generated power in this country is 0·6d. per kilowatt. The figure for nuclear power, as it is to be produced in the immediate future, is 0·76d., which might be reduced eventually to 0·42d. But the figure of 0·76 allows no credit for the plutonium produced. If this is sold or recycled through the pile the cost of the power is reduced to 0·65d. per kilowatt.

At this point we cannot avoid a critical note. It was stated at Geneva that the British industrial piles of the Calder type were not designed solely for power, but also for plutonium production, required for military purposes. To satisfy the latter requirement it was admitted that 30 per cent of the maximum power output which they could have had was deliberately sacrificed. The point is so important to us as a nation that it is as well to quote from the text of the paper presented by J. A. Jukes: '*A power station. . . designed to produce fissile material for military purposes as well as electricity is already under construction at Calder Hall in England. . . As Calder Hall was not designed purely as a power producer it was not given the maximum power output which it could have had. Known modifications to the design, which would not add significantly to the capital cost, would increase the electrical output by 50 per cent.*' Our gratification at British progress must therefore be tempered by knowledge of the enormous and continuing drag which military stockpiling is exercising on these developments, and by the realisation that until this utterly unproductive wastage is stopped there can be no real hope of nuclear power paying its way.

Other figures were given by the U.S.A. and U.S.S.R. They all show the same picture of increased capital costs, but of running costs which make it possible to generate electricity by nuclear means at a price which makes economic sense.

Despite the possibility of building small-sized enriched piles of high capacity, nuclear power for propulsion, except perhaps for ships, is not looked upon as an economic proposition until such time as the cost of plutonium falls as a consequence of breeding.

In what fields, then, will nuclear power find its greatest application? Not, it appears, in underdeveloped areas purely because they are such. To India, for example, with its large reserves of coal and water power, nuclear power by itself cannot be the means to economic salvation. It has of course a great role in India, and indeed throughout the Far East

in providing power to populations who live at great distances from conventional sources. To produce an equitable distribution of power-potential in India involves as alternatives either an intensive programme of rail-building, in order that coal may be brought to stations remote from the pithead, or else the development of nuclear power-stations for which the transport-problem is virtually non-existent. Many other parallels exist throughout Asia, and there can be no doubt that the welcome awakening of that vast continent will be greatly speeded by the new power source.

But over and above that, there are many areas of the world the development of which is hindered not merely because they possess no power resources but because natural conditions prevent access by man. Deserts are an obvious example; in areas totally devoid of communications a nuclear power-station may be a feasible proposition where the conventional type is not, because of the far larger demands which the latter makes on manpower and transport. The Amazon valley presents another interesting probability. Few who have not seen it can imagine the virility with which tropical vegetation grows and the effortless ease with which it hampers or even prohibits normal means of access by land or river. It is significant to note here that Brazil has the world's second largest reserves of thorium.

The distant prospect which most fires the imagination is surely that of the opening-up of Antarctica. If that mighty land is ever tamed and its priceless reserves of minerals harnessed to the needs of Man, it will be through nuclear power, and nuclear power alone. Access can never be guaranteed, and its difficulties are never less than formidable. No scheme of exploitation which is dependent on regular access for large numbers of men and things can ever succeed, in the initial stages at least. But a nuclear power-station can remain isolated for years together, provided that it can be reached at intervals for maintenance purposes by relatively small numbers of men.

At the present time about 900 types of nuclear reactor could be built of which perhaps twenty are seriously worthy of investigation. Some details will make clear how broad the field is.

It has already been mentioned that if the fuel is enriched then the reactor can be built very small; the U.S.A. at Geneva showed a working nuclear reactor in the exhibition which had a core of uranium enriched with U-235 of only about 2 feet across and 6 feet deep. In fact, the U.S.A. submitted more reactor designs than any other nation.

The moderator may also vary. Heavy water is for many purposes more efficient than graphite and a design was submitted at Geneva known as a water boiler reactor. In this conditions are such that the water not only acts as moderator, but is allowed to boil in the reactor core itself; the steam formed can be used to generate electricity.

Another design used liquid fuel elements; in this case a liquid alloy of uranium and bismuth. This was allowed to circulate through the graphite moderator and was claimed to work with an efficiency of 42 per cent in power generation.

Other reactors are what is known as homogeneous, that is to say, instead of having fuel elements and moderator kept apart, they are mixed together in one solution. Reactors are, in fact, enormously versatile; they can be 'tailor-made' to fit all manner of requirements.

The U.S.S.R. power reactor was the only nuclear power station to be described which was actually in operation. The fuel is uranium enriched five per cent with U-235. The pile is graphite-moderated and water-cooled. It generates 5,000 kilowatts. Its operation is not economic, its neutron economy is poor and it forms very little plutonium. But to the U.S.S.R. must go the credit for making the ordinary man and woman realise that useful quantities of power can be obtained from nuclear reactors. Also, its operation has given Russian technicians working experience in design and operation which will shortly bear fruit in the 100,000 kilowatt power stations which are now nearing completion.

Ourselves at Geneva

In spite of Russian achievements, however, it was the British who took to Geneva the only proposal for a nuclear power station which is not only in course of construction, but which will also operate economically. This is the 50,000 kilowatt graphite moderated unenriched uranium station of the Calder Hall type. It was fully described by Sir Christopher Hinton, and one of the most outstanding features of his paper were his illustrations of the many great advances in technique which were necessary in order to build these piles. For example, each pile is encased in a steel shell 40 feet across, 60 feet high and 2 inches thick. This, because of its size, had to be piece-welded on site. After welding it was annealed by heating to a temperature of 550 degrees C. and being kept there for eight hours before being allowed to cool slowly and uniformly. This was achieved by radiant heating with a peak load of 1½ megawatts and constituted, in Hinton's own words: '. . . the biggest electrical oven in the world'. This remarkable achievement is matched by many others, especially in the chemical field; for example, the incredibly high degree of purity which is required of the materials that go into pile production.

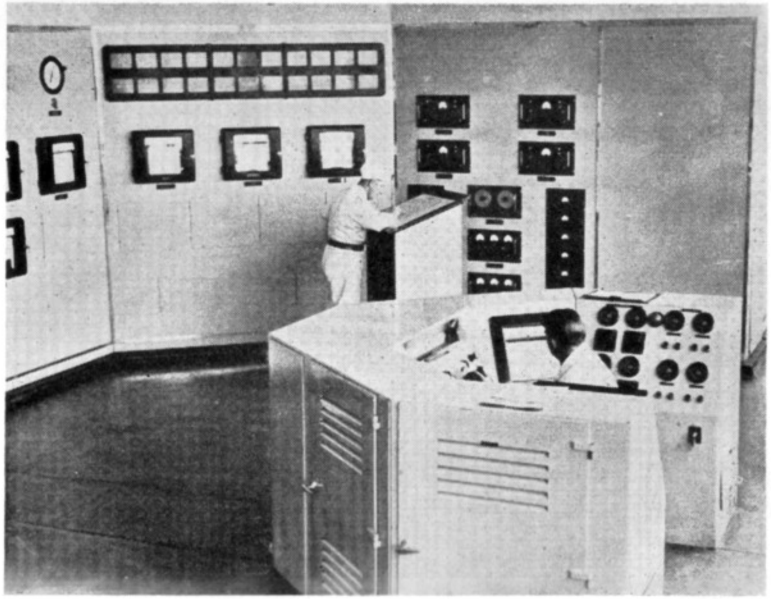
There is nothing experimental or tentative about Calder Hall. It is the intention of the Atomic Energy Authority to offer this type for export; and so real are the possibilities in this field that private industry has already deployed its forces to exploit them to the full. A group of firms including C. A. Parsons, Sir Robert McAlpine, General Electric Company, Simon Carves, Associated Electric Company, John Thompson, English Electric Company and Babcock and Wilcox, have come together with the expressed intention of equipping themselves to build nuclear power stations in any part of the world. Their engineers are being trained by the Atomic Energy Authority with whom they keep in close touch. There are altogether 182 companies engaged in one way or another in the manufacture of equipment and materials.

The British also showed at Geneva the designs for the first industrial-sized power-producing breeder pile, to be built anywhere in the world. It is now being erected at Dounreay in Caithness. We submitted also many papers dealing with nuclear power costs, reactor types and reactor safety, all of which showed that British practice in the bread-and-butter job of nuclear power production is ahead of that in the U.S. and abreast of that in the Soviet Union. This very considerable achievement has been dictated to us by economic necessity and our own fuel crisis. It is an achievement of which we have every reason to be proud and it would be pleasing to hope that our plan for the production of not less than 45 per cent of our power by nuclear means in 1975 can be fulfilled. It would also be pleasing to hope that we could, in fact, sell reactors in the export market. Both of these ends are threatened by our acute scientific and technical manpower shortage. The design centre of atomic energy production at Risley at the moment can find only one in ten of the personnel that it needs; and this shortage applies without distinction to all technical grades. The situation is aggravated by competition for staff from the Atomic Weapons Establishment at Aldermaston.

Unless very drastic steps are taken in the immediate future to increase the supply of trained scientific manpower we shall in all probability fail to achieve our target. Sir Christopher Hinton himself stated, in November 1955, that progress to that date would in all probability have been faster had sufficient technical manpower been available. Successive governments bear a heavy responsibility for their outright failure to tackle this problem.

Nuclear Secrecy after Geneva

It is probably true to say that the quantity of secret data actually released at Geneva was small, though highly important. The main secrets which were disposed of were in the field of fission-physics, upon



The desk in the pile control room at Windscale. Photo from 'Britain's Atomic Factories', HMSO 1954.

such topics as the number of neutrons released in the fission of uranium and plutonium isotopes. But a great number of facts were also made available which, though not actually secret, were at least very difficult of access. The result of these exchanges, in which all the leading nations gave as well as received, is that no nation that wishes to have a nuclear power enterprise need feel debarred because of lack of essential technical information. This is in itself a valuable contribution to international goodwill which will persist notwithstanding the fact that certain non-essential design data of nuclear reactors are being kept secret by various countries, including our own, which expect to compete in the reactor-market and hope that these details will give them a selling advantage.

It must not be supposed that the leading nuclear powers learnt anything fundamentally new from these disclosures; it was the smaller powers that benefited. The others merely registered the futility of their policy of nuclear secrecy. It is indeed seldom that any policy is so thoroughly discredited by events as was this policy by the events of Geneva. For years past nuclear scientists everywhere have had to submit to the imposition, often at the hands of men most ignorant of

the nature and methods of science, of security restrictions which have hampered their work, damaged the international basis of science, contributed in no small way to international tension and have been the means of hounding from public service many a distinguished man of science on the score of political unreliability. The ludicrous results of this costly policy were seen when the curtain was finally lifted at Geneva. It was found that the nuclear constants which have been such closely-guarded secrets for a decade were in fact no secrets at all; they have been obtained in every leading country, and usually with such close agreement that all the figures might have come from the same laboratory and been plotted on the same piece of graph-paper – a demonstration which, in one sensational case, was actually made at the conference.

There were other examples. Many ingenious ideas for reactor-designs were not only found to have originated more or less simultaneously in different places, but often showed almost uncanny similarity of detail. Again, despite all the efforts of security, no fewer than five countries independently developed precisely the same technique for the extraction of uranium from certain ores.

By a superhuman effort of will it is perhaps possible to believe that all this was achieved by the mutual operation of espionage systems of diabolical efficiency, a belief which has the interesting consequence of exalting the intellectual capacity of the spy above that of the scientist. But most scientists will see in this only the vindication of what they have always maintained: that insight and technical ability are what count in science and that ideas cannot be shut up in boxes. Those who strive for the re-establishment of freedom of scientific intercourse may well draw encouragement from the example of Geneva.

That they may encounter further opposition is well illustrated by the peculiar way in which the subject of thermonuclear power was handled at the conference. It is not known who first ordained that the subject was not to be discussed, but it is a reasonable guess that none of the leading powers was anxious that a subject which might possibly throw a little incidental light on the working of the hydrogen bomb should appear on the agenda.

The fact that the matter was discussed even unofficially was due to the initiative of the president of the conference, H. J. Bhabha of India, himself a distinguished nuclear physicist. Bhabha, in his opening address, took occasion to remark that thermonuclear power might be developed within a decade or so. Not content with this indiscretion, he elaborated the theme at a subsequent press conference, with the result that, at further press conferences, reluctant admissions were made by the spokesmen of Britain and the United States that their countries were indeed working actively on the subject – in secret.

One would surely have imagined that this theme, so obviously important and relevant to the purpose of this outstanding international meeting, might have been permitted to arise unhindered in the natural course of events. But, had the chair been occupied by a less forceful character, the conference might well have concluded with the world still ignorant even of the possibility of taming the H-reaction. The incident illustrates the great and dangerous gap which still exists between scientific and political thinking on all questions connected with nuclear energy. Nuclear secrecy, though damaged and seriously discredited by the Geneva proceedings, still exists as a drag on the wheels of progress.

Almost a Side Issue: Radioisotopes and Their Uses

ONE OF the most outstanding features of radioactivity is the fact that it is extremely easy to detect. Under the right circumstances the radioactivity of even one atom can be detected. For this reason, radioactivity has received widespread application in research. The way it works can be best illustrated by an example.

There is a gland in the neck known as the thyroid. Its purpose is to make a secretion which, circulated in the body, controls the rate at which many body-processes work. If the gland produces too much secretion the person concerned becomes nervous, irritable, loses weight and, in general, is living at much too fast a pace. A person with too little secretion is sluggish, stupid and prone to become fat. Whilst not fatal, thyroid disorders of this sort can cause a great deal of unhappiness throughout life.

The thyroid secretion contains about 60 per cent by weight of iodine. It is possible to add to the body a slight trace of radioactive iodine, a quantity not sufficient in itself to upset the iodine-balance of the body but nevertheless containing quite sufficient radioactivity for its course throughout the body to be followed. As this radioactive iodine behaves chemically like ordinary iodine the thyroid gland will presently become radioactive. We can find out by experience how radioactive the gland should become in a given time. A gland that is working too fast will become more active than this; one that is acting too slowly will become less active. The radioactivity of the living gland is quite easy to detect. This simple and speedy method of diagnosis is only one example of several that might be given.

The importance of all this for our theme lies in the fact that radioactive iodine is a by-product of the operation of nuclear energy plants;

• *Treatment of a patient with radioactivity from Cobalt 60.*

and not only it but many other common elements such as phosphorus, sodium, carbon and potassium can be made artificially radioactive by the use of a pile. These radioactive sub-varieties (or isotopes as they are called), have proved of the greatest use in medical, agricultural and industrial research.

Tiny traces are all that are needed for diagnosis; but in large quantities they are also used for curative purposes in a certain limited number of cases. Here the action is rather different since one is using the radiation emitted by the radioactivity to kill certain tissues of the body whose presence is causing disease. Thus, for example, radioiodine may be given in large quantities to a person whose thyroid gland is too overactive with the intention of killing part of it. The same effect may be achieved by surgery, but this is not always possible to carry out.

• *Food preservation by exposure to radioactivity.*

Radioactive isotopes have also been used in the treatment of certain forms of cancer and, here again, the principle remains the same. The cancer cells selectively take up a large quantity of the radioactivity and are killed by the radiation with which they are bombarded in consequence. This method of treatment is so far effective in a very limited number of cases, and the idea which has somehow grown that radioactive isotopes are the answer to cancer has, unfortunately, no foundation in fact.

In industry the wear in bearing materials has been measured by making the bearing surface radioactive and then measuring the radioactivity worn off into the lubricant after a period of use. Leaks in pipes can be similarly detected by looking for the radioactivity escaping from the leak. The movement of river beds and mud banks, for example in the Thames Estuary, has been studied by following the movement of radioactivity added to the mud. The quantities of radioactivity involved are so slight that they represent no hazard to anything.

Another by-product of nuclear reactors has been the development of a new field of chemistry which has become known as 'radiation chemistry'. In this radioactivity from the pile or fission products is made to change the nature of substances; thus the properties of polythene can be changed in this way. Before irradiation it softens at about 80 degrees C, and at that temperature is soluble in a number of liquids. After irradiation its softening point is raised and it becomes insoluble in any liquid. Such modifications of properties may prove very useful, in many other cases as well.

The Dark Side of the Moon

From what has been said about the medical uses of radioactive materials it will have already been guessed that running a nuclear furnace, because it produces radioactivity by-products, is potentially dangerous. This is true; and it is the price that we have to pay for our development of this new power source.

Radiation of the sort that arises in this enterprise is dangerous to every form of life. The human body is made up of thousands of millions of cells, every one of which is liable to be damaged when it comes into contact with radiation. From this process the germ cells (ova and spermatozoa) are not exempt; in fact, they are amongst the most easily damaged. The damage so acquired may not kill the germ cell and may, therefore, be transmitted to a future generation.

For man, the question of radiation hazard is thus a dual one, both aspects of which must be borne in mind: there is the prospect of

damage to the individual who is alive now, and there is the further chance that damage to his remote descendants may take place even though he himself has survived apparently unscathed his contact with radiation.

About the first of these processes we know probably enough for safe working, though there are important gaps in our knowledge. We know that there are certain levels of exposure of the body which are so slight that the body tissues, which are always naturally in a rapid state of turn-over, can repair the damage done. This experience has come down to us as the result of 50 years of working with radium and with X-rays, where the hazards are substantially the same as those we are discussing. If one exceeds the safe level various forms of damage may result, such as damage to the blood system or the skin. Radiation may also give rise to various forms of cancer; this seems to be due to local overdose caused, for example, by radioactive substances which enter the body in the form of dust, spray or vapour and settle in the lungs or in the bones. It is not known whether there is a safe level of working which applies in the case of radiation cancer, and its onset is usually delayed many years; but it is known that most individuals who have worked with radioactivity all their lives have not contracted it.

All this sounds alarming. But we must remember that mankind has always been exposed to a certain level of radiation from cosmic rays, from radioactive materials in the rocks and from certain materials in his own body which are naturally radioactive. Our species has endured this for a quarter of a million years; it must have produced some fatalities, but we continue to survive. We believe, upon fairly good evidence, that we can safely increase this exposure 50–100 times. We do not yet know precisely how far we may travel upon that path; and, it must of necessity be many years, indeed generations, before our knowledge of the deleterious effect of radiation can be as precise as we would wish it to be now.

It is within that context that we are proposing to develop nuclear power, the inevitable effect of which will be to expose part of the population to a greater degree of radiation than ever before, and to present the same risk to humanity as a whole in the event of accidents, or even of carelessness.

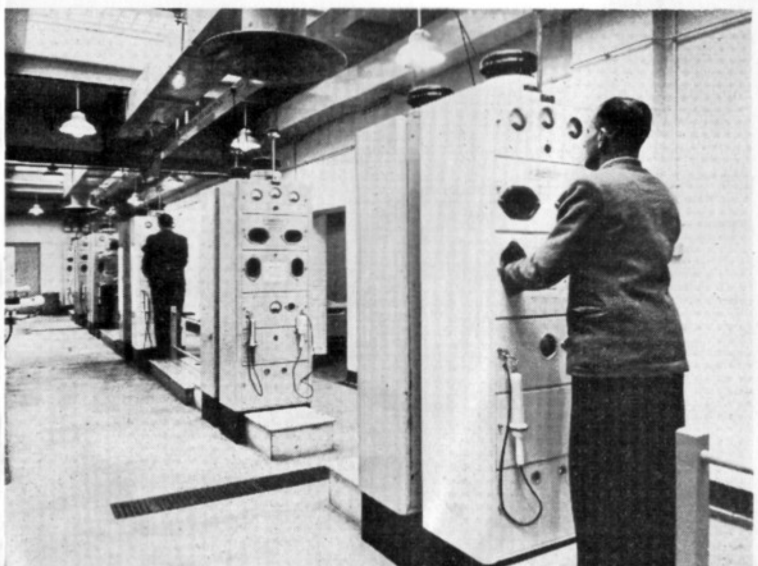
The hazard is not slight. For every atom of uranium that is destroyed in the manufacture of nuclear power, two others make their appearance and these are nearly always radioactive. The quantity of radioactivity which thus accumulates inside a working nuclear reactor is colossal. Some idea of the size of this problem may be gauged by the fact that the Dounreay pile will contain 100 million Curies of radioactivity; one Curie is the quantity of radiation emitted from one gramme of radium. This means that a working nuclear reactor will normally contain more radioactivity than that which would arise from the entire world supply of radium, if it could be gathered together.

This activity comes from a mixture of elements, 34 in all, and none of them radioactive for as long a period as radium is. After a relatively short time a good deal of the radioactivity disappears; after 20 years 99 per cent of the radioactivity is due to two radioactive species only.

These fission-products (as they are called) have to be removed from the pile at intervals and end up as a solution in dilute nitric acid, which can be evaporated down to small bulk and stored, until the radioactivity has decayed away. This process takes about 1,000 years.

Some of the fission-products are gases (notably radioactive xenon and krypton), a certain quantity of which is permitted to escape into the atmosphere. It is clear that a point will arise when this practice is no longer safe; and there are those who question whether it is safe at present. It cannot always be depended on that gases discharged by a chimney will dilute themselves into the air. Sometimes they bear down upon the ground; at other times they may hang in the form of a pall over the surrounding neighbourhood. If the fumes were offensive this would be noticed at once, but there is nothing outwardly offensive about radioactive gas; it is not to be distinguished from any other and, like all other forms of radioactivity, it produces no immediate evil consequences.

There are other ways in which radioactive hazards can arise, and some very sobering papers on these were presented at Geneva. The huge piles at Hanford, Washington State, which make plutonium are cooled by water which is taken from the Columbia River. The water contains mineral salts and, as these are passed through the pile, they are bombarded with neutrons and become radioactive. The effluent therefore contains certain short-lived species of radioactivity of types



Hand and foot radiation monitors in use in a British AE establishment. These instruments will detect extremely small quantities of radioactivity. Photo from 'Britain's Atomic Factories' HMSO 1954.

not commonly held to be very dangerous, such as radiophosphorus and radiosodium.

The authorities at Hanford have always ensured that from the drinking point of view the effluent did not contain more radioactivity than was safe, but on the contrary a great deal less; only then was it allowed to be discharged back into the river. This means to say that if we drank a litre or two of it we would get no harmful quantity of radiation. However, in a study of the accumulation of this radioactivity by various creatures living in the river below the works, it was found that certain of them picked up very considerable levels of activity, especially of radiophosphorus. Some of them had 150,000–350,000 times the activity of the surrounding water. This was still not enough to do them any harm except perhaps genetically, but the authorities who presented the paper in question concluded that, if the effluent had been discharged at tolerance instead of well below it, the organisms would have acquired sufficient radioactivity to have damaged them and would have been unfit for human food.

All this means that it is not enough for man in his use of radioactivity to consider and guard against its effects on those who are working with radioactive materials; nor even is it sufficient for him to take into account the effects on the population as a whole, or upon posterity; he must also define its effect upon the entire plant and animal community of which he is but one part, the balance of which may be irreversibly disturbed in manners which we cannot even foresee at present. Our knowledge in this field is, in fact, fragmentary and stands in the most grotesque contrast to our proposals for the large-scale use of nuclear power.

It is, in fact, a cruel dilemma with which we are confronted; either to forego our development of nuclear power indefinitely, or else to proceed cautiously into the dark. There is no doubt as to the course of action which we shall take. Sufficient is known for us to be able by the use of unremitting care to develop nuclear power without meeting disaster on the way. There is widespread agreement throughout the world on safe working levels of exposure for the radiation worker, which make it possible for work to be done in a safe fashion. This should give us courage to face the genetic danger, of which we are aware, but know nothing from direct human experience.

To the whole problem the answer is *prevention*. The hazard, though enormous, is controllable and, in point of fact, very few radiation accidents have occurred in any nuclear energy enterprise anywhere in the world, whilst in Great Britain the Atomic Energy Authority has a health record which is second to none in all respects, including radiation protection.

The Authority has achieved this position because it has been able to enforce codes of working practice upon its employees, and because everybody working within it is in the last analysis concerned with radiation and, therefore, with the avoidance of radiation damage. This position does not apply to those who work outside the Authority, for example, with radioisotopes. With few exceptions throughout the world these more casual users of radioactivity (and we must remember that their number increases every day) work to no agreed standards of practice and are not protected by any legislation.

Britain is amongst the countries which have as yet no legislation designed to ensure safe working with radioactive materials, although provision to enact such legislation exists already under the Radioactive Substances Act, 1948.

At Geneva the World Health Organisation drew attention to the very serious gap that existed between our proposals for the development of nuclear power and our proposals for safe working. Dr. Dorolle, who was spokesman for the W.H.O., maintained that radiation protection must now be considered as an aspect of public health both nationally and internationally, and he stated the urgency of international collaboration as something which is now forced upon us as we enter into the nuclear age.

The Parting of the Ways

THE ACHIEVEMENTS of the Geneva conference may be summarized as follows:

- It showed that nuclear development was pursuing a very similar pattern the whole world over.
- That the resources of nuclear raw materials were greater and more workable than had been believed.
- That the advances in breeding techniques had been so rapid as to place beyond question the fact that nuclear power presents a long-term answer to our fuel crisis.
- It was further the achievement of the conference to destroy irreversibly such secrecy as stood in the way of the development of nuclear power, and to make a great contribution to international goodwill by so doing.

It must be a matter of pride to us that our country should have played such a leading part in these developments, the more so since it was achieved at the very nadir of our economic fortunes, and without any help from countries outside the Commonwealth. Hand-in-hand with that achievement there goes a great responsibility which we cannot escape. We must ensure that nuclear power is used only for

the welfare of mankind. At present the emphasis still remains on nuclear weapons; nuclear power prospects are still threatened and stunted by the insatiable demands of military stockpiling; co-annihilation still overshadows every inhabitant of the planet irrespective of nationality or colour, religion or political belief.

We must now choose between the alternatives of nuclear annihilation and nuclear prosperity, for there is no middle course. Each one of us must realise that there is now no scientific reason whatever why any country or any person need go short of the power needed to achieve a full and happy life. We must accept that, although this goal cannot be fulfilled overnight, there is no political excuse which will justify failure to achieve it. For in its fulfilment lies not only the happiness and well-being of the individual, but also the only hope of lasting peace.

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