USSR occupied a very special position. It had very large reserves of natural fuel and therefore had no problem of lack of such fuels. At the same time distribution of natural fuels was unequal, and this made the production of power in certain areas more expensive. The economic efficiency of nuclear plants would be the principal factor affecting decisions to build them, i.e. the power cost and the unit cost of construction in roubles per kilowatt of installed capacity. One of the main factors in reducing the cost per kilowatt was the construction of larger unit blocks, and was much more important in nuclear than in conventional stations.

After discussing the influence on costs of various factors in both thermal and fast reactors, Dr. Morokhov mentioned that they were now planning to reach a fuel burn-up of 30 000 megawatt days per tonne in thermal nuclear reactors and 100 000 for fast reactors. The main ways to do this were to raise the strength of composition of the materials, to employ ceramic fuels and more resistant construction materials. It was also clear that the higher the efficiency the greater would be the power produced and thus the less the fuel component would figure in the overall costs. According to their calculations, the cost of electricity produced could reach 40 kopeks per kilowatt hour, a figure competitive with conventional power which would enable them to use nuclear power very largely in the national economy of the USSR.

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# GIANT MACHINE TO STUDY MINUTE PARTICLES

**"A great human enterprise that stretches the mind in its conception" was one of the phrases used by Ambassador Henry D. Smyth, US Representative to the Agency and US Member of the Board of Governors, in describing to members of the staff a new "atom smashing" machine to be built by the US National Accelerator Laboratory. Its purpose is to enlarge knowledge of the fundamental laws governing the universe.**

Dr. Smyth, who visited the Agency on 28 February to talk about the project, said that he was going to describe a very large machine to study very small objects, a statement more than justified by his supporting statistics. He confessed that he found it very difficult to avoid the purple prose of popular science writers in considering the ways in which atomic particle would be made to travel hundreds of thousand of kilometers in a few seconds or of the effort of synchronising the pulses of nearly a thousand electro-magnets in the operation.

Dr. Henry D. Smyth

The machine, which is intended for use by scientists from all over the world, will be able to accelerate protons to an energy of 200 billion electron volts (200 BeV in US abbreviation, 200 GeV elsewhere). An electron volt is a measure of the energy and thus indirectly of the velocity of a particle; this energy can be increased by electric voltage.

It will cost about 250 million dollars to build the new machine on a site near Chicago. At least six years will be needed to plan, build and put it into operation and annual running expenses will be 50 or 60 million dollars. Planning and the supervision of construction will absorb the time and energy of several hundreds of specialists, and it will be used by about 500 highly trained men and women from many countries.

"The results of their work" said Dr. Smyth "will probably have no immediate direct utility, but are expected to add substantially to our understanding of the universe in which we live".

As an illustration of the techniques and problems of nuclear physics he compared nuclear particles, such as protons, to bullets and placed his briefcase on the lectern to illustrate what could happen if a shot were fired at it. The bullet could go right through the case, could lodge inside, could be deflected or could itself break up. This was the kind of thing that happened when protons were aimed at a target — an atom of an element — and investigations of the results had led to Rutherford's "scattering" propositions and to research on cosmic rays as well as the development of many high-voltage machines. The first such device was made by Cockcroft and Walton, and others, such as cyclotrons, synchrocyclotrons and linear accelerators have followed.

## DISCOVERIES ALREADY MADE

Enlarging the power of such machines made more and more discoveries of the minute particles within atoms, their structure and their behaviour, possible. At present there were very large devices at Serpukhov, USSR (70 billion electron volts), Brookhaven, USA (33), the European Centre for Nuclear Research, or CERN, in Switzerland (30), Argonne, USA (12.5), Australia (10) and Dubna, USSR (10). In each of these, atomic particles were accelerated to a very high speed and then aimed at a target, the results being observed principally by specialized methods which allow tracks of particles to be photographed. Observations made in this way had produced a great deal of knowledge. It has been established that electrons, the outer particles of an atom, and that protons, part of the nucleus, have infinite life, while neutrons when released from the nucleus last for a thousand seconds, or 17 minutes. Other minute fragments have been traced, such as the meson with a life that might be a hundred millionth of a second and others which might last for as little as a hundred million million millionths of a second, written by scientists as $10^{-20}$ seconds. It has also been established that if the mass of an electron is taken as 1, that of protons and neutrons is 1800 and that there are heavier particles with masses of up to about 2600.

During the past thirty years the use of accelerators of gradually increasing power to bombard atoms with higher and higher energy had led to the discovery of increasing numbers of so-called fundamental particles, a few of which had been predicted by theory though most had not. It had also been seen that most particles had very short lifetimes. There were some moderately satisfactory methods of classifying these particles into families whose behaviour was more or less described by empirical rules. However, nobody yet knew what particles were really fundamental and what basic laws governed their existence or behaviour. Thus the reason for working with higher energy lay in the hope of finding some fundamental rules to replace this statement.

Dr. Smyth outlined the operations to be carried out by the accelerator and the mechanism for its operation. Protons have to be formed and then accelerated in relatively small steps. In order to repeat these steps many times they are carried out in a circle from which, after reaching the desired energy, they must be released to impigne on a target. At this stage ways of observing the results of their impact must be provided.

The protons are obtained by an electrical arc in hydrogen, and are given their first acceleration by a Cockcroft-Walton machine. Then a linear accelerator increases the energy to 200 million electron volts. At this stage they enter a "booster" synchotron, a circular arrangement of electro-magnets 150 metres in diameter, where the energy is raised to ten billion electron volts. This synchroton, although but a part of the whole system, is itself as big as similar machines existing in only three or four places.

## THREE CROWDED SECONDS

All these operations are only the beginning. The protons come out of the "booster" into the main machine. This is essentially a 2 km diameter ring of electro-magnets together with other equipment designed to impose electric fields to give further energy. Now the protons travel round in a ring-shaped tube of stainless steel about 5 × 10 cm in cross-section. Each time round the full circle (more than 6 kilometers) the protons pass through a phased electric field that increases the energy by 2.66 million electron volts. To reach the full energy the therefore have to go round about 75 000 times, or a distance of approximately 500 000 km. All this occurs in about 3 seconds.

The mechanism around the ring serves two purposes, one being to bend the beam of particles to keep them in the circle and the other to focus the particles so that they would not diverge and hit the walls. Separate magnets or groups of magnets, will be used for each purpose. There will be 768 magnets for bending the beams, each one 20 ft long (approximately 6 meters) and each weighing 10 tons, as well as 180 similar focussing magnets.

At the end of their circular travels the protons have to be laid into a straight tube to bring them to the target. This tube is 2 km long and leads to buildings occupying 75 000 sq. ft. (nearly 7 000 sq. m.) and used for experiments. From the tube would come a beam of 15 thousand billion protons per second.

"When we started studying this scheme" said Mr. Smyth "200 GeV looked like a very difficult and important energy to reach. Now feel that we could, and may want to, go to higher energies, and at CERN there has been talk of a 300 GeV machine. One of the features of the accelerator I have been describing is that it could fairly easily be converted to give 400 GeV and possibly go as high as 500 GeV".

The machine, sited 30 miles (48 km) west of Chicago, would be operating by about 1975.

"We hope" concluded Mr. Smyth "that scientists not only from USA and Canada, but from any of the countries represented in the Agency, will make use of it. The only requirement for admission will be brains and training. It is intended for scientists all over the world."

Students at a training course held in Ankara on the application of isotope techniques in hydrology carry out a practical test connected with water flow. The course was organized by the Agency in co-operation with the Government of Turkey on an interregional basis. Costs were met from funds of the United Nations Development Programme.

Members of the staff of the Dacca Atomic Energy Centre in East Pakistan in front of the main entrance. Research in nuclear physics has been carried out with assistance from the Agency in 1965 and subsequently under the UN Development Programme, using a Van de Graaff accelerator (UN Photo).