Atomic Energy

Two lights shine upon the horizon of civilisation today. One is the fitful glare of the exploding atomic bomb. The other is the rising sun of peacetime progress in the realm of atomic energy. The big question is:

Which light will prevail?

Mankind stands at the crossroads today. One road leads to an ever increasing pace of the atomic armaments race. Its fearful end may be the total destruction of civilisation. The other road leads to the peaceful application of atomic energy for the good of mankind. It promises to usher in the most glorious era in the history of the world, the Era of Atomic Energy.

Which road will mankind take?

Future historians - if there is a future, and if history as we know it continues - will probably call our period mankind's saddest and maddest, and certainly the most dangerous. Human skill and ingenuity have harnessed the basic and most powerful forces of nature, but we are giving priority to their use for destruction; we vote for the statesmen who conduct that policy, and we finance it with our tax money.

For over 2000 years the philosophers had believed that everything on earth consisted of very small, indivisible particles called atoms - indeed, the Greek word atomos means indivisible. John Dalton, the father of Atomic theory, showed that all types of matter are made up of elements which are 92 in number and that each element has its special kind of atom. Atoms combine in clusters to form molecules in an endless series of chemical reactions and in fact this is the process how our Life cycle goes on.

To give an idea about the size of atoms and molecules we can consider an analogy: If a drop of water were magnified to the size of the earth, the molecules would be about the size of oranges. It is calculated that a cubic inch ($16.13cm^3$) of air contains 800, 000, 000, 000, 000, 000 molecules. The atom is still smaller in size. If we could enlarge an atom a million fold it would be about as big as a full stop.

Rutherford gave the portrait of an atom. It was found to consist of a central core known as the 'nucleus' where neutrons and protons are present and the surrounding space is filled with electrons in continuous motion. The nucleus itself is 20,000 times smaller than the size of the atom. Now you can imagine the size of protons, neutrons and electrons in the atom.

Source of Energy

The exploding atomic bomb is the most dramatic and spectacular verification of the Einstein equation, $E = mc^2$, for the release of atomic energy involves the conversion of matter into energy. Einstein will go down in history as the greatest mind of the century about whom Bernard Shaw wrote,"Einstein has made a Universe". To give an idea of the energy released when 1 gram of matter is converted into energy, we get by this simple equation:

Energy $= 1\text{gm}\times(3\times10^{10})^2\ \text{cm}^2/\text{sec}^2 = 9\times10^{20}$ ergs. So energy released is 900 million million millions ergs.

Twenty one days after the detonation of the world's first atomic bomb, the new weapon was used against Japan. Two bombs were dropped from U.S. airplanes (B-29), the first on Hiroshima at 8.15 A.M. on August 6, 1945, the second on Nagasaki at 11.00 A.M. on August 9, 1945. Within the fraction of a second, the U-235 in the bomb changed from a metal sphere into an immense mass of expanding gas, millions of degrees hot. The bomb had the power of 20, 000 tons of T.N.T. and it killed 200,000 people in Hiroshima. Nagasaki bomb was not as effective as the Hiroshima bomb because it failed to explode at the required height of 1000 ft. above the ground.

The loss was so terrible that a moral shock-wave of horror and distress hit every nation on earth. The following lines appeared in an American newspaper:

The atom bomb is here to stay,
Most scientists agree.
Oh, yes, the bomb is here to stay,
The question is, are we?

That question has forced itself with increasing intensity on everybody since 1945. Better and bigger nuclear weapons were invented, built and tested and until an even more ultimate weapon was created, the hydrogen bomb.

Hydrogen Bomb

The H-bomb is not a fission device but works by fusion. H_2 atoms 'fuse' to form helium atoms and everytime some mass is converted into energy. This is known as 'Mass Defect'. The fusion can take place at a temperature of millions of degrees centigrade and an Atom Bomb is used to start the fusion process. Heavy hydrogen or Tritium isotope is used and the extra neutrons are ejected with tremendous energy. The fusion bomb has an immensely greater power of destruction than the fission bomb. The first H_2 bomb was equivalent of 850 Hiroshima bombs. Of late, Russia has developed even 50Megaton H_2 bombs.

The destructive power of bombs can be ascribed to the following four main sources of damage. As the bomb explodes, the fission fragments are heated to a temperature of more than 1,000,000 degrees, and it creates a pressure of thousands of times greater than the atmospheric pressure. At the end of the 1st ten thousandth of a second, the ball of fire is about 45 feet in diameter and a temperature of 300,000 ^{o}C. It seems 100 times brighter than the Sun from a distance of 5 miles. At the end of 1st second the diameter of fire ball becomes 450 ft. and its surface temperature is about that of the surface of the sun, a temperature of 6000 ^{o}C. The rise of the ball of fire is 300 ft. per second.

The first is the shock-wave, a huge wave of pressure which travels outwards sweeping buildings over a radius of 10 miles.

The second source of damage is the heat wave. This sets everything to fire on its way and causes skin burns.

The third source consists of radioactive rays or nuclear radiations of gamma rays and neutrons.

The fourth source is the residuel radioactivity left behind by the fission fragments of the bomb explosion.

But what is the maximum radiation which may still be regarded as harmless? You need 600 r to kill a man within a short time, and there is an international agreement stating that 0.3r per week can be tolerated by humans without any danger to their health. The intensity of radiation is measured in units of 'roentgen' 'r' which is the amount of x-or gamma rays which will produce one unit of electricity in one cm^3 of air by ionisation.

Plutonium & Thorium

One of the major improvements in atom bombs since Hiroshima has been the use of plutonium instead of U - 235. It is very costly and difficult process to separote U-235 from U-238, whereas plutonium can be separated in a chemical separation plant. The reactors are used to get plutonium from Uranium-238 by bombarding it with slow neutrons. Capture of the neutron takes place with the simultaneous emission of two electrons and we get the new element of Pu which yields more neutrons as compared with U - 235 and is hence more effective fissionable material. The reaction can be represented as:

$$_{92}U^{238} + _{0}n^{1} \rightarrow _{92}U^{239}$$

$$_{92}U^{239} \rightarrow _{93}Np^{239} + e + \nu_e$$

$$_{93}Np^{239} \rightarrow _{94}Pu^{239} + e + \nu_e$$

Thorium, like plutonium, is an excellent reactor fuel and India has plenty of Thorium sands on sea coasts. It is mildly radioactive but when converted into Uranium U-233 by neutron capture, it becomes highly effective fissionable material.

Peace Time Uses of Atomic Power

(a) Atomic Reactors

One consequence would be to retard the rate at which the nation consumed its dwindling resources of coal, petroleum and natural gas. Our reserves are growing less and the demand for industrial power is increasing. By 1975, the consumption of electricity would triple and as the present resources could hardly cope with the demand, it would mean rising costs of production. Atomic energy not only holds the promise of meeting this situation but of eventually putting a far greater store of industrial power at the command of mankind. It should free the world from the burdens of hunger and poverty.

The atom bomb and atomic reactor are essentially both fission devices and the chain reaction is common to both. In the bomb it 'goes mad'; in the reactor we can control it.

The fission product in which we are most interested if we want to generate power is heat. As the two parts of the split nucleus fly apart with high velocity, the energy of movement of these fission fragments is converted into heat by braking collisions with neighbouring atoms; or, simply, matter is converted into heat. In order to produce the warmth of a one-kilowatt electric fire, more than 30 million million fissions per second are necessary. The energy released from one atom of fissile material is 50 million times as great as that produced by an atom in the combustion of hydrogon when petrol vapour burns in cylinder of motor-car. So the difference in chemical change and atomic annihilation is enormous.

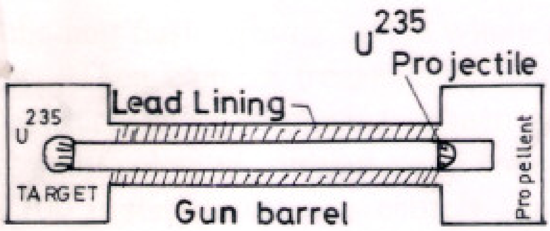
Man can release incredible forces locked up in the atoms of matter. If one ounce of matter could be completely destroyed and changed into energy it would yield as much power as we derive from burning 100,000 tons of coal in a conventional power station.

The first proof of the Einstein equation was given by Rutherford's experiment in 1919, in which he split the Nitrogen atom by α-particle bombardment. The transmutation of elements became possible and the dream of Alchemists came true. The discovery of neutron in 1932 by Chadwick accelerated the work of atom-splitting in laboratories.

A kilogram of matter, if completely converted into energy, would release 25 billion kilowatt-hours of energy, the equal of the entire U.S. production of electricity for two average months.

The atomic bomb and the peaceful employment of atomic energy both became possible because of the discovery of a phenomenon known as nuclear fission. It was discovered by Enrico Fermi in Italy and Joliot - Curie team in Paris. In Germany, the pioneering work was done by Otto Hahn and Lise Meitner. They all found that the Uranium atom when struck by a neutron breaks up into two fragments, one of Barium and the other of Krypton, with the release of one to three neutrons in a trillionth of a second. These neutrons further collide with other Uranium atoms and release more of the neutrons. Thus the chain reaction starts and the whole process is completed within a fraction of a second. The nuclear fission takes place with both fast as well as slow neutrons and accordingly we get either the atomic bomb, in which the reaction is uncontrolled, or the nuclear reactor, for which the chain reaction is controlled.

For starting the nuclear fission, Uranium-235 was selected as Uranium-238 which occurs in nature does not yield chain reaction when hit by neutrons but absrobs them by neutron capture. The Uranium-235 was separated from the Uranium-238 as for every 140 Uranium-238 atoms there is only one atom of Uranium-235.



Atom Bomb

It is a sad thought that so many of mankind's greatest inventions have been used first as weapons. Second World War started in 1939 and the fear that Germany would make great efforts to produce an atom bomb spurred the Allies to combine their efforts towards the same goal. Hitler wanted to win the war with the help of atomic bomb. He placed the German scientists under Military order. Lise Meitner, as she was an Austrian Jewess, fled to America. Fermi left his country (Italy) afraid of Fascisim and settled in America. Einstein was already there and later on when Hitler captured Denmark, Niels Bohr too fled to America with all the secrets of nuclear programme of Hitler. So all these refugee scientists worked out the plan for making an Atom Bomb in America with President Roosevelt. The project was to cost 2 billion dollars. On the other hand, all the German efforts to make the bomb were destroyed by the Allies and so Hitler left the idea.

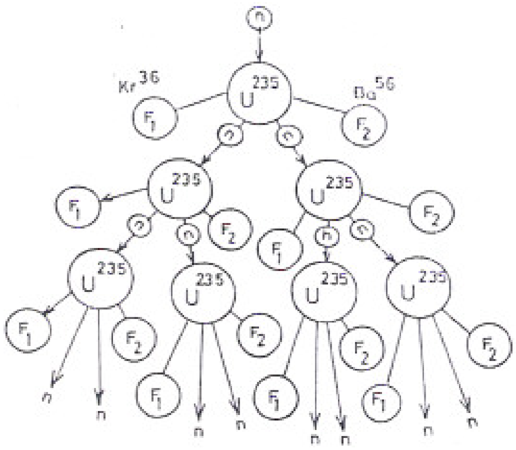
We may well wonder what the course of history could have been if Germany had been the first country to possess - and use- the atom bomb. After all, Uranium fission was discovered in Germany. Prof. Hahn and Heisenberg succeeded in operating a small pilot plant, a pile running on Uranium and Heavy water. But they were thinking more on the lines of peaceful industrial uses and Prof. Hahn had told some of his colleagues early in the war ,"If Hitler gets an atomic bomb, I shall kill myself." German scientists always discouraged the idea of possession of the atomic bomb.

The first atomic reactor was built on the football ground of the university of Chicago by Enrico Fermi and his team. Uranium rods were placed in graphite blocks which acted as a moderator, in place of heavy water, to slow down the fission neutrons. Cadmium rods were used to control the chain reaction as it absorbs fast neutrons. For two years, the best nuclear physicists of the world, under the leadership of Prof. Oppenheimer (who died recently), worked for the Manhattan Project, in the desert of New Mexico. It was here, on 16th July, 1945, the first atomic bomb was tested successfully. The description of the explosion was given as below:

" There was blinding flash lighting up the whole area brighter than the brightest daylight. Then came a tremendous, sustained roar and a heavy pressure wave which knocked down two men outside the control center. Then a huge, multi coloured, surging cloud boiled to an altitude of over 40,000 ft. The 100 ft steel tower was entirely vaporised. Where it had stood was a huge crater ".

What were the mechanics of the atom bomb? Professor Joliot-Curie has given a simple recipe of 'How to make an Atom Bomb'. Take 60 lb. of Uranium-235, he said, and shape it into a hemisphere. Take the same amount again and shape it into a second hemisphere. Fix one half sphere at the end of a cylindrical tube , and place the mobile second half at the other. Spray some neutrons on the flat surface of the stationary hemisphere. Then shoot the second half against the latter so that you have a complete sphere of 120 lb; and drop the bomb quickly, because it is now about to explode.

But the maximum size to start the chain reaction, known as 'critical size', is 20 lb. of Uranium-235.



Chain Reaction

The shape of the bomb is like a huge aerial torpedo weighing 9000 lb. and with an overall length of 25 feet. The long cylinder of the bomb is lined with lead to protect the crew from radiations.

If we want to use atomic energy for the production of power, we have to convert the heat which is created in the reactor into some other form of energy which can be used in homes and factories-that is , into electricity. For this purpose, steam turbine is used in between the reactor and the electricity generator, to generate electricity. The essential elements of the power producing reactor are: The 'fuel' (uranium rods); the 'moderator' (graphite); the 'control rods' (cadmium or boron); and the 'coolant' (water, gas or liquid metal).

The economics of nuclear power are somewhat different from those of other forms of energy. It is just the opposite with nuclear power. In this case the initial investment is considerable and after some time nuclear - power costs reach parity with coal-power costs. Then the costs go down considerably as our fuel lasts for many years while coal-generated power is mainly dependent on fuel. So atomic power will be cheaper in the long-run. India has embarked on an ambitious programme for nuclear power and three nuclear reactors are to be set up. The one at Tarapur will go into operation during this year and the other two (one at Rana Partap Sagar, second in Madras) later in 1970, made by Indian scientists fully. So drought will be no more in India when nuclear power is available.

But then there is the problem of safety. Two main types of radiation from the reactor, the neutrons and the gamma rays which are given off during the fission process, must be kept in mind from the very beginning of power-station design. The first principle is that of 'biological shielding': it may be a concrete wall 7 ft. thick or a lead enclosure around the reactor. The other alternative is to operate the reactor either automatically or by remote control. The tendency has been to site nuclear-power stations near the coast where there are unlimited supplies of water. The dangerous waste products must be either buried deep in lead containers or let into sea water after radio active matter has been removed.

Radio-Isotopes

One of the most important by-products of power reactors is the large number of isotopes which we get for a variety of uses- so much so, that a full lecture can be devoted to discuss them. We shall briefly survey all the uses.

Radio- isotopes have taken over from X-rays in almost all the fields of medicine. They can be used in three ways: by radiation from an external source just like X-rays; by implanting a radiation source 'seed' in the patient's body; and by using a solution of radio active salt. They can be carried in a pocket while X-rays require a cumbersome plant. Cobalt-60 is the most effective instrument in the fight against cancer. Radio-iodine is used in tracing the activities of the thyroid gland. Gold - 198 is an effective cure for the lung caner. Similarly, Strontium-90, Phosphorus-32 and Sulphur-35, all radio isotopes, find numerous uses in medical cures. They are applied in diagnosis, treatment and research. In diagnosis, tracer technique can tell the doctor a great deal about the working of his patients body. Water containing radio-iodine when drunk by a patient, and a Geiger counter held close to his neck records the rate at which the iodine is being absorbed by the thyroid gland. X-rays used for this purpose are not reliable and moreover dangerous for health.

Radiation can kill bacteria and can be used for sterilisation in hospitals. Radiation doses of Cesium-137 are used for food-preservation. When potatoes are irradiated with Cobalt-60, they become sweet in taste and their shelf life is enhanced. Evolution can be made to order. Radiation disturbs the genes, the units of heredity, and the chromosomes which results in the modified characteristics of the species. Isotopes have revolutionised agriculture. Seeds when treated by mild doses of radiation yield improved varieties. Japan improved the growth of rice and America that of wheat and soybean by irradiation. Beyond that there is the rather frightening aspect of selective breading of humans by guided irradiation.

Isotopes also find various uses in Industry. Strength of building materials can be increased by radiation treatment. Rubber and Plastics industry promise potential use of isotopes. Package monitoring can be controlled, leaks can be detected in oil-pipes and safety of air-craft can be checked by small amounts of radioactive material.

C-14 is an important radio-isotope of carbon. Radio-carbon dating is used to determine the life of fossils and gives an idea about the life of earth also. Bio-chemists study photo-synthesis with the help of C-14.If we knew the answer we could perhaps produce all our food directly in chemical factories as plants produce their food from CO_2 in air.

Nuclear Transport

America and Russia have used atomic reactors for the propulsion of submarines and air-craft carriers. 'Nautilus' was the first American submarine with a reactor engine. Russia built nuclear Ice breaker 'Lenin' and cleared Siberian lands of ice.

Prospectus for nuclear motor-cars and aeroplanes are dim in the near future because of the considerations of the size of atomic reactor and its huge mass. Moreover, it is not reliable for aeroplanes. It may explode like an atomic bomb and spread dangerous radiation.

As far as Thought can Reach

Scientists want to control the thermo-nuclear fusion as they have done in the case of nuclear fission. The problem of very high temperatures in fusion has been solved by the large magnetic fields known as 'Pinch Effect'. ZETA in U.K. produced a temperature of 5 million ^{o}C for ten-thousandth of a second while 'Stellarator' in America is designed to give a temperature of 100 million ^{o}C for one tenth of a second. At this temperature fusion of atoms can take place. So man will ultimately control the fusion too. Space travel will be easier and cheaper by Ion Rocket and it is thought that Photon Rocket will attain the speed of light and save much time. We cannot foretell how people will live in that distant future.

We do not even know if mankind will outlast our own century. Let us hope for the best.