ENERGY

FROM THE

ATOM

BY

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ILLUSTRATIONS.

PREFACE

'Atoms for Peace' this is a phrase we have heard repeated time and time again in recent years. The word "Atoms", however, probably conveys very little to the average layman and Atomic Energy is taken very much for granted. Most people know of the power of the A-bomb and H-bomb but how scientists convert this power for use in a power station is completely beyond them.

This book has been written to give an idea of the relationship between bomb and power station and to explain in simple terms how power is derived from the Atom.

CHAPTER I

The Atom is Split.

Before 1900 everything on this planet was thought by philosophers to be made up of identical atoms. The atom was thought to be an indivisible part of matter and different substances were thought of as just different constructions of the same type of atom.

An English chemist, Dalton, evolved a theory that all matter could be broken down into a number of basic substances, each one with its own special atom. Other matter, said Dalton, was merely composed of combinations of these basic substances, or elements as they are now called. The atom was still indivisible.

In 1898 a student in Paris found that some photographic plates had a network of exposed lines on them. These plates had been in contact with a sample of uranium ore (Uranium was then of no practical use.). These lines were attributed to some mysterious rays which were named 'Becquerel Rays'

Two French scientists, Pierre and Marie Curie, heard of this and experimented to find the nature of these rays. They found that pitchblende emmitted the rays and after working for weeks to concentrate the mysterious substance they eventually produced $\frac{1}{10}$ gram of a white substance.

This substance had a remarkable property, it glowed in the dark, and therefore the Curies called it radium. It was this substance that ruined Dalton's theory. Obviously if radium emmitted light it was giving of some sort of particles.

About the same time a german had discovered that by evacuating a tube and passing an electrical discharge through it a ray could be produced which actually penetrated thin cardboard. These rays, since called X rays, were also attributed to the enmission of some particle from the atom.

In the light of these two experiments the atom was obviously not the smallest part of matter. Subsequent experiments in England and Europe established what is now still thought to be the constsuction of an atom. It was found that there was a central core, or nucleus, around which revolved a negatively charged particle called an electron. The nucleus was made up of protons, which carried a positive charge and neutrons which are apparently neutral. The mass of an atom is almost completely taken up by the nucleus Different elements are made up of atoms having a different number of neutrons, protons, and electrons, the number of protons always being equal to the number of electrons, however, so that the atom is electrically neutral. There is also one neutron for each proton in the nucleus of a stable element.

This theory was evolved in 1911 by Rutherford and proved some time later. It was aslo Rutherford who in 1919 first split the atom. He done this in a cloud chamber filled with nitrogen gas. In this the movement of a proton could be seen as a white streak. The nitrogen gas was bombarded with Alpha particles from an arc lamp and as one of these hit a nitrogen nucleus so the atom was split. The nucleus that had been hit had one proton knocked off it and this proton formed the nucleus of a hydrogen atom. It seem therefore that nitrogen could be changed to hydrogen.

Experiments in 'splitting the atom' continued and in Germany, Proffesor Otto Hahn, in trying to disprove existing theories, found that uranium, when bombarded ~~wth~~ with nuetrons, split into barium and Krypton gas. These two elements had a surplus of neutrons and were found to be unstable (radio-active) and break down very rapidly yielding more neutrons. The new shower of neutrons hit more nuclei and produced even more neutrons.

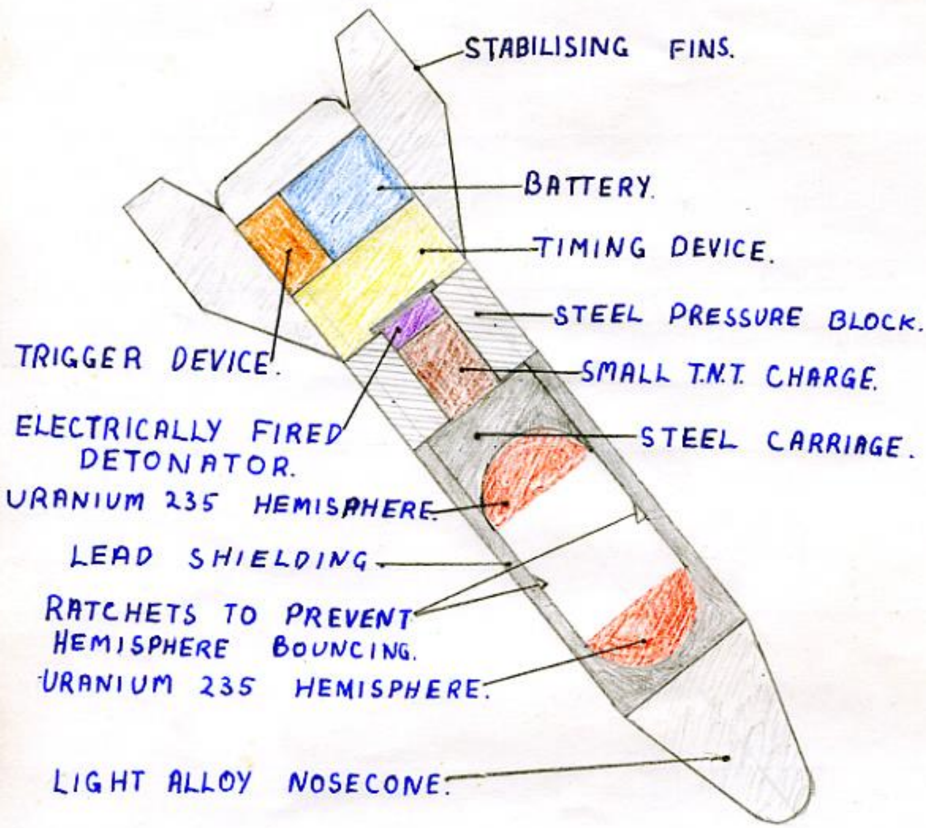
From this discovery it was realised that great amounts of energy could be released by using enough radio-active material to make this process cumulative. At this time however the Second World War started and one of Prof. Hahn's assistants, a Jew, was forced to leave Germany and continue her work in America.

CHAPTER II

The Bomb.

Due to the 1939-45 War both Germany and America knew of this regenerative characteristic of radio-active materials. It did not take either country long to realise that if this action was produced in a piece of radio-active material of more than a critical weight, a chain reaction would turn nearly all its mass into energy. This could be used as a bomb of vast power. Both countries therefore made Atomic Research a military project and security became vital.

The Germans, for their bomb, decided that neutrons liberated by uranium 235 would cause a suitable chain reaction. Uranium 235 however was very expensive to obtain and it was decided to use uranium 238, natural uranium, which is less radio-active, and some material to slow down the neutrons and make them more efficient, inasmuch as they hit more nuclei if going slower. The material for slowing neutrons down was to be heavy water.



THE A-BOMB

AN ARTIST'S IMPRESSION.

Heavy water, water consisting of oxygen and deuterium hydrogen with an extra neutron, was relatively easily obtained and there were stocks of it on the continent. British agents however destroyed Germany's heavy water stocks and plant time and time again so that in 1945 Germany had no more than a theory.

America had during this time gathered a number of scientists together for the Manhatten Project. These scientists had by 1945 produced a workable bomb which was exploded in the New Mexico desert on July 16th. 1945.

Later two of these bombs were dropped on Japan at Hiroshima and Nagasaki.

The American bomb was thought to consist of two pieces of uranium 235 of just over one half critical mass. These were forced together when the bomb was dropped and the resulting chain reaction exploded the bomb. The exact critical mass and mechanics of the bomb are still a very closely guarded military secret

Since Hiroshima improvements have been made to the bomb by using plutonium 239 istead of uranium. This is much easier to obtain as it can be obtained by chemical processes from natural uranium. Both America and Russia were soon in possesion of these new improved bombs and as the arm race continued the hydrogen bomb was evolved.

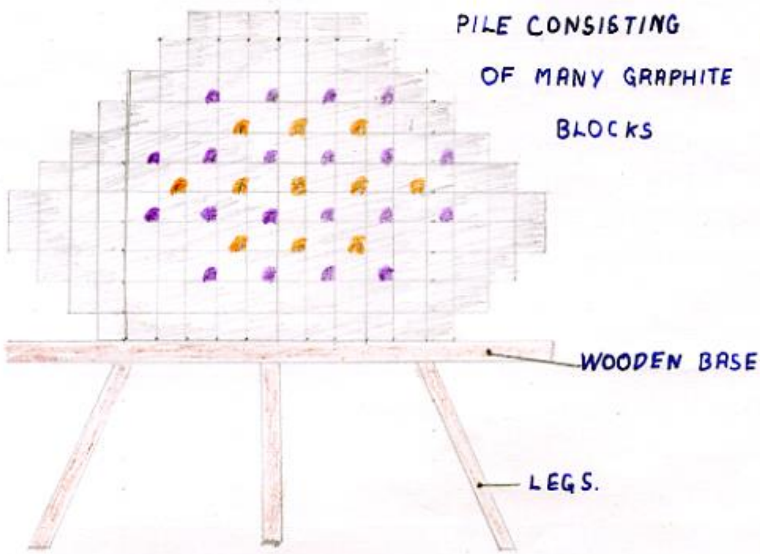
It had been found that, just as large atoms could be broken into smaller ones to release energy, so could small atoms be fused to make large atoms. This process, the fusion process, releases even larger amounts of energy than the fission process. It has however the disadvantage of requiring great temperatures to enable the action to begin.

Deuterium or Tritium, two heavy hydrogen isotopes, were used in the American H-bomb and these fused together to form helium with the release of great amounts of energy.

In reply to the problem of the heat to start the action the H-bomb is detonated by an A-bomb.

The American H-bomb tests at Bikini resulted in a bomb with the equivalent power of 17 million tons of T.N.T. after one of the series had 'run away' and was nearly five times more powerful than expected.

It was because of this 'run away' and subsequent contamination of a fishing vessel about a thousand miles away that such great effort is being made to ban nuclear bombs and use nuclear energy only for peaceful uses.



KEY.

NATURAL URANIUM RODS. METAL CONTROL RODS.

FERMI'S ATOMIC PILE.

CHAPTER III

Power from Reactors.

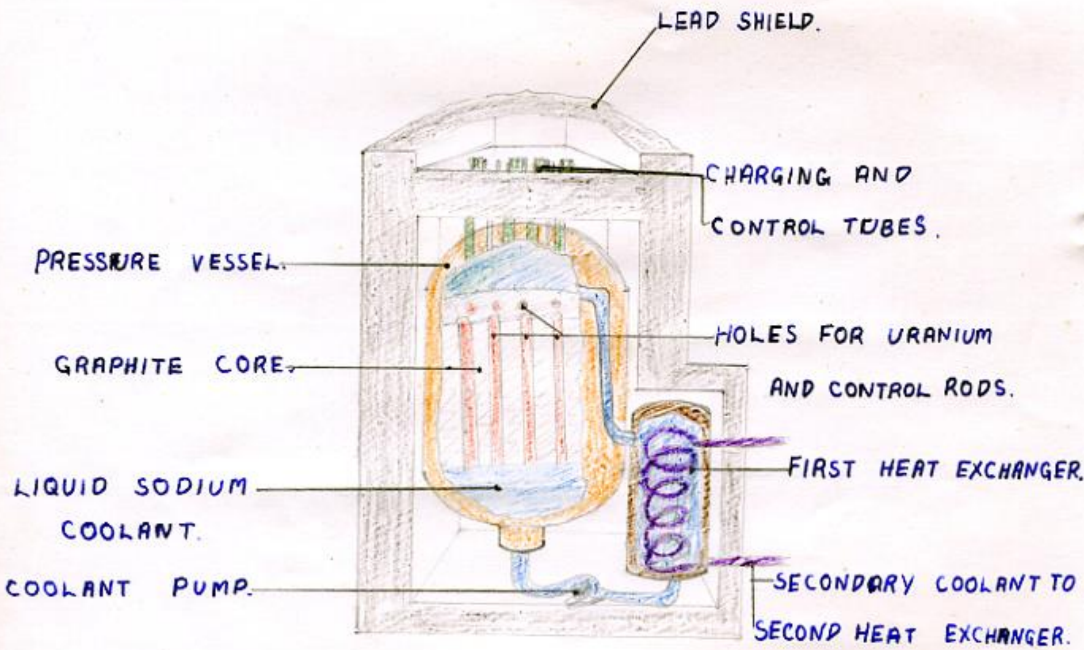
In 1942 while the nuclear arms race was at full swing, Fermi had built a reactor on an American football ground. It was the first reactor to be built and consisted of graphite blocks piled up with natural uranium rods thrust through them. The neutrons of this uranium split nearby nuclei but the action, which was a chain reaction of the same type as in the A-bomb, was prevented from being too violent by a moderator, graphite. The graphite had the effect of making fast moving neutrons bounce and so slow down so that they had longer to strike nuclei. This reactor led the way to the control of chain reactions.

Since Fermi's day refinements have been made to the fuel and to the moderator and numerous systems for the take off of heat have been devised. For fuel anything from natural uranium, a mixture of uranium 238, 140 parts to uranium 235, 1 part, to pure uranium 235 or plutonium can be used. The moderator may consist of graphite, water or heavy water and the coolant can be water, heavy water, sodium or gases at high pressure.

Size of reactors have been reduced by making the moderator the coolant, so that it actually circulates through the heat exchangers. To improve economy, as uranium is still very expensive, reactors have been surrounded by a blanket of natural uranium, which, when bombarded with neutrons, turns to plutonium. Plutonium can be used as a fuel for certain reactors and so these reactors, called breeder reactors, actually make more fuel than they use.

In Britain the first nuclear research station was built at Harwell. At this establishment no less than seven experimental reactors have been operated since 1947. Apart from their uses as research projects, these reactors have provided radio active isotopes of every discription and supplies of plutonium as fuel for commercial reactors.

With the appearance at Harwell of reactors capable of giving large outputs of



THE CALDER HALL REACTOR.

heat, atomic power stations were found to be more economical in the long run. It was found that even though the initial building and fuelling cost of a nuclear power station were much larger the running costs over a long period were very much smaller than the old coal or oil fired power station.

It was 14 years after Fermi's crude 'atomic pile' that the first nuclear power station was erected in Great Britain, Calder Hall. A reactor at this station consists of a metal cylinder 37 feet in diameter and filled with pure graphite. The graphite has 1760 vertical holes bored in it. The fuel, bars of uranium in magnesium sheaths, is placed in some of these holes while rods of boron steel, used to control the reaction, are hung in others. As the control rods are pulled out a chain reaction starts and the uranium, of which there is 120 tons gets hot. It is allowed to reach a temperature of 400°c. This heat is removed by carbon dioxide gas, at a pressure of ten pounds per square inch, which is pumped through the graphite core, through outlet pipes 4 ½ feet in diameter and then through heat exchangers.

The heat exchangers, four of them, contain several miles of stainless steel pipe through which flows ordinary water. The carbon dioxide heats this water, turns it to steam and the steam drives turbines just as in a conventional power station. The eight turbines of Calder Hall are capable of generating 184,000 kilo-watts of electricity.

By 1961 Britain will have seven nuclear power stations with improved reactors which will be generating over a million kilo-watts of electricity.

Two very important points that must be kept in mind while building and running a nuclear power station is safety from radiation and disposal of waste material and spent fuel.

Radiation is a major difficulty as the human body is only able to stand very limited amounts of radiation without harmful effects. The actual reactor must therefore be shielded by a lead or concrete wall. This may be over 7 ft. thick to give effective shielding. Devices for measuring radiation, geiger countersas they are called, must be placed everywhere there is a likelyhood of escaping radiation and the steam output from the heat exchangers must be constantly monitored.

Radio-active waste products are given out by a reactor in two ways, spent fuel and fumes. The fumes are led away into the atmosphere through high chimney stacks after first passing through filters to extract any solid matter. The spent fuel taken from the reactors is kept for a period in special under-ground storage places until the radiation has dropped to a certain safe level. Disposal is then completed by sinking the waste in the sea at set places where tides and currents cannot wash any radio-activity up on the shore.

It is expected that in the future the disposal of radio-active wastes will be one of the biggest problems of the nuclear age. This problem could be solved however with the coming of space travel.

CHAPTER IV

Isotopes.

One side product of nuclear reactors is the isotope. An isotope is an element that has been bombarded with neutrons and has had its nuclei split. Having once had its nucleus upset the atom continues to break up and due to this emmits various rays.

The radiation is generally of three types, Alpha particles, Beta particles and gamma radiation. Alpha particles are in fact helium nuclei without their electrons, they travel at very high speed and are comparatively heavy yet can be easily stopped by a sheet of paper. Beta particles are electrons travelling at high speed with almost no mass. They can be stopped by a fraction of an inch of steel. Gamma radiation is somewhat different being an electro-magnetic radiation similar to radio waves but of a much higher frequency. It can only be stopped by very thick metal or concrete shields.

These radiations are given off by an isotope for periods ranging from a fraction of a second to millions of years depending on the element and the type of radiation. It is this property that makes isotopes so useful in nearly every industry today.

One of the main demands for isotopes is from hospitals. By the injection of very minute amounts of active salts into the human body, virtually the whole system can be checked. The salts are injected then carefully traced on their way round the body by sensitive geiger counters. In most hospitals nowadays isotopes are gradually replacing X-rays as from a very small piece of an isotope the same penetrating power can be obtained as from a big permanent machine operating with voltages as high as a million volts. Photographic plates are also sensitive to radiation as they are to X-rays

Isotopes are not only used for diagnosis but also for actually curing. Treatment of cancer is now carried out by radiation from cobalt 60 or radium and is quite successful. The radiation may be administered in practically any form depending on the ailment. Cobalt 60 and raduim radiations are normally released from a small hole in a large steel ball that can be placed over the patient. Less active isotopes with shorter half lifes may be injected in suspension in liquids, drunk, eaten or even placed on the head of a needle which is then placed in the appropriate part of the body.

It has been found that isotopes radiation in minute quantities will kill bacteria. Foodstuffs have had their storage life extended up to four times by irradiation from Gamma rays. Radiation has been used to kill destructive insects in grain and even stop potatoes sprouting in warm climates.

Experiments with plants and small animals have proved that radiation plays a part in evolution. Mutational improvements to crops have been brought about by irradiation of seeds and strains of crops have been produced which are resistant to diseases, insects and frost. The Americans are also experimenting on human volunteers but there is no way of predicting what will happen in this line.

Industry is the other major user of isotopes. The cable industry having found a new insulator, polythene, can now by irradiation cause it to withstand temperatures forty degrees ~~#~~ higher without melting. Rubber can be vulcanised by radiation instead of with sulphur and then has higher temperature resistance and better wearing properties.

Apart from the effect of giving additional strength radiation is used in nearly every mass production industry as a means of checking. Beta particles, from isotopes with short half lifes, are used in checking the filling of packets, cigarettes for example. Each cigarette has a small quantity of an isotope included in its manufacture and then the packets are passed under a sensitive geiger counter. The reading gives immediate warning if the packet is not full. It is only a matter of hours later that the radiation from each packet is negligible

Isotopes with long half lifes are used for continuous monitoring of solid materials. A source of radiation is placed one side of the thing to be monitored, say a sheet of rubber, and a detector the other. Any variation in the size of the sheet are immediately detected as a variation of radiation strength and feed-back circuits correct the error.

Today geiger counters tracking isotope radiation can trace the movements of everything from oil in pipelines to pebbles in the sea. Even archaeologists today establish the age of bones and fossils up to millions of years old simply by measuring the amount of Carbon 14 in them. It seems, in fact, that now one can do almost anything with an isotope.

CHAPTER V

The Future.

Today as isotopes are becoming more and more useful work is still going on at full speed to improve the present sources of power. America has already sailed a nuclear submarine under the North Pole while Russia has claimed to have flown a nuclear aeroplane.

For marine power the nuclear power plant has very obvious advantages as the weight of the shield is not essentially important. Aircraft however have to be very light and the shielding here presents a problem which will probably not be solved effectively for some considerable time.

On the ground, Britain hopes to be generating a quarter of her total electrical power by 1965. This will be done by nuclear fission reactors of the types already operating in various parts of the country.

Research at Harwell has now turned to the harnessing of the power of the H-bomb, nuclear fusion. A certain amount of success was achieved with Zeta, (Zero Energy Thermo-nuclear Apparatus), but as the title suggests it gave noo power output. The way has now been opened however to the taming of the H-bomb.

It now seems possible that inside the next century when nuclear fission and fusion processes are being used effectively to give power and plenty, this world may become a paradise for man.

GLOSSARY

Alpha Particle

Nucleus of a helium atom without its electrons, therefore positively charged. Streams of alpha rays are given off by many radio-active substances.

Atom.

The smallest particle of an element which retains the characteristics of the element

Atomic Energy.

The energy released when the nucleus of a heavy atom is chipped or split by colliding with a neutron or another particle. A minute part of the nucleus changes completely into energy.

Atomic Pile

A nuclear reactor having a graphite moderator.

Beta Particle

An electron when emitted as radiation

Breeder Reactor.
A nuclear reactor producing more nuclear fuel than its consumes.

Core.
The inner part of a nuclear reactor containing the atomic fuel and the moderator.

Critical Mass.
The smallest mass of a fissile material in which a chain reaction can be maintained.

Electron
The smallest atomic particle and the lightest component of matter.

Fission.
The disintegration of atomic nuclei in a chain reaction when hit by neutrons, a process by which neutrons and energy are released.

Fusion
The 'melting together' of two atoms of low atomic weight.

Gamma Radiation

Electro-magnetic radiation similar to X-rays, produced when certain nuclei disintergrate.

Geiger Counter

Instrument for detecting and counting alpha, beta and gamma radiation.

Half Life

Time taken by a radio active substance to decay to half its original activity.

Neutron

An atomic particle which has no electric charge, found in the nucleus.

Nucleus

The central part of the atom containing most of its mass and a positive charge.

Proton

The basic particle of the atomic nucleus carrying a positive charge.

Radio-Activity.

The spontaneous disintergrations of atoms.

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