

The Atomic Nucleus and its Explosion Creating a World-wide Turmoil

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ABSTRACT: This Research Paper is prepared out of a lecture titled “The ‘Bomb’ and the ‘Turmoil’ delivered to the faculty of an eminent Polytechnic, Shri Bhagubhai Mafatlal Polytechnic, Mumbai-400 056, India by the author on Thursday the 6th August 1998 coinciding with the 53rd anniversary of the bombing of Hiroshima on 6th August 1945. A notice circulated to the staff of the Polytechnic regarding the same is also included. In Fig.1 is shown a copy of a photograph of author taken on the occasion. Just behind the photograph of the author is a pencil sketch of the great scientist Albert Einstein (not very clear) and drawn by the author. The bomb is the brain-child of the scientist and the explosion obeying his famous equation, $E = mc^2$. To avoid making the Abstract lengthier, a vivid summary of the paper can be obtained from the Introduction

KEYWORDS: Atomic Nucleus, Binding Energy, Biological effects of radiation, Chain Reaction, Critical mass, Fission, Fission Bombs, Hiroshima and Nagasaki, Indian Nuclear Explosions, Nuclear Bombs, Nuclear events in ancient India, Pokharan-1 and Pokharan-2, Smiling Buddha, World War II

Preamble: As early as 1924 Winston Churchill speculated about the

Possible military implications “*Might not a bomb no bigger than an orange be found to possess a secret power to destroy a whole block of buildings – nay to concentrate the force of a thousand 24 tons of cordite and a blast a township at a stroke?*”

..... “Winston Churchill’s Imagination”

By Paul Kent, Associated

University Press 2006, p.156

I. INTRODUCTION

Respected Principal and my colleagues: As the title reads: The ‘Bomb’ and the ‘Turmoil’ and as the audience consists of members from various disciplines, I am going to first deal with the Bomb rather more with the Physics of the Bomb, the type of bombs and the mode of their explosion. Physics, among all sciences, is generally taken to be a difficult subject probably because of its language which is Mathematics and I will purposely avoid any mathematical treatment so that none of you will have any problem of understanding the matter I am going to present.

The detonations of the bombs are of two kinds. One, a detonation in order to carry out some test during the peaceful time and the other carried out as a weapon during the war time as done in the case of the bombing of cities of Hiroshima and Nagasaki of Japan in August 1945 during the second World War. In both cases whether you carry out a test bomb or do actual bombing during war, there is a turmoil created by people. In the case of a peaceful test, various countries of the world create a political turmoil and verbally attack the country which carried out the test explosion. In the case when the bomb is used as a weapon in the war, there is a greater turmoil because of loss of life and property.

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Fig.1 Prof. V.C.A. Nair delivering a lecture on "The Bomb and the Turmoil"

Now, coming to the bomb, I will be dealing in detail with the circumstances that led to the making of a bomb by the Manhattan team in the United States during the Second World War, its testing the type of bombs manufactured and the actual process of dropping the bomb on Hiroshima, Japan on 6th August 1945. I will be very brief with the bomb dropped on Nagasaki, Japan. I will also go in details of India's first successful nuclear explosion carried out on 18th May 1974 and two other explosions carried out on 11th and 13th May 1998 at Pokharan, Rajasthan, India.. All these explosions and tests created turmoil in world politics. The subject matter of the paper will be supported by enough number of photographs. In the Conclusion I shall include cost and effects of nuclear radiation. Some information regarding nuclear bombs, although uncertain, of ancient times that probably happened in India. I will be thus dividing my lecture mainly into 4 parts: (A) Physics of the Atomic Nucleus, (B) The Explosive Device and Mode of Explosion, (C) History of World's First Nuclear Bomb tested and exploded by US, and (D) The Indian Bombs and after. The Paper ends with a Conclusion followed by an Appendix and Epilogue.

II. REVIEW OF LITERATURE

As the subject matter of this paper was delivered as a lecture nearly two decades ago and the lecture as a research paper presented as on today, the reader might find some recent additions which are inevitable. Being historical, the material is mainly from internet such as Wikipedia, the free encyclopedia, some material from standard text books and few from local media such as The Times of India, Mumbai and Indian Express, Mumbai. Some of the information gathered are recorded and others not recorded. But, however, a generalized list of references is given at the end.


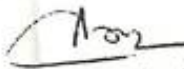
A. PHYSICS OF THE ATOMIC NUCLEUS

Nuclear explosion is a specialized chapter in Nuclear Physics and a great deal of knowledge of the same is necessary for the clear understanding of the subject. The topic on which I intend to present here, I feel, I may not go

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Shri Vile Parle Kelavani Mandal's <u>SHRI BHAGUBHAI MAFATLAL POLYTECHNIC</u>	
S-33/1998-99	3rd August, 98
<u>S T A F F C L U B</u>	
<p>A lecture on "THE BOMB AND THE TURMOIL" by Prof. V.C.A.Nair, in-charge, Physics Section has been organised on Thursday the 6th August, 1998 at 3.30 pm. in the Seminar Hall.</p>	
<p>6th August, coincides with the bombing of Hiroshima (6th August, 1945) and many of the events which will be recalled by Prof. Nair.</p>	
<p>This topic has a significance due to recent nuclear explosions by our country on 11th and 13th May 1998. This is the 14th lecture delivered to the members of staff by Prof. Nair and he has collected lot of information to make the topic interesting, informative and thoughtprovoking.</p>	
<p>All members of staff are requested to attend and make the lecture session a grand success.</p>	
<p>The session will be followed by High Tea</p>	
<p>Classes will be suspended at 3.30 pm. to enable the members to attend the lecture.</p>	
<p>Usual tea at 3.00 pm. will not be served on that day.</p>	
 SECRETARY, STAFF CLUB	 PRESIDENT, STAFF CLUB

Copy of Notice circulated to the faculty of the Polytechnic and signed by Principal, Prof. A.C. Mehta who is also the President of the Staff Club

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into details of it in the mathematical sense, but what is interesting is that the explosion obeys almost all existing laws and techniques of Physics, which is surmised by the single equation of Albert Einstein, $E = mc^2$, where E is the energy given out in the explosion of the atomic nucleus of mass m and c the velocity of light.

To start with some elementary ideas and definitions regarding the structure of atom (Fig.2) will be required. The central core of the atom is called the nucleus around which revolves in more or less circular orbits a certain number of negatively charged particles called electrons. The nucleus consists of protons which are positively charged and an equal number of uncharged particles called neutrons. Both the protons and neutrons which are the nuclear particles and are called as 'nucleons'.

In a normal atom, the number of protons in the nucleus is equal to the number of orbiting electrons and this number, is called the Atomic Number and denoted by 'Z'. The number of nucleons in the atom is known as the 'Mass Number' and is denoted by A. Hence the number of neutrons N present in the nucleus of any atom is given by $N = (A - Z)$. These are standard symbols used in Nuclear Physics.

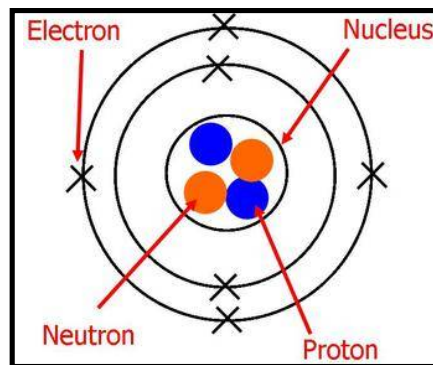


Fig.2 The Structure of Atomits properties.

There are some atoms of the heavier elements such as uranium atom, U_{92}^{234} , having atomic number 92 and mass number 234 but having one or more neutrons in their nucleus making the mass number 235 or 238. Such elements are called as isotopes and represented as U_{92}^{235} or U_{92}^{238} . Thus, electrons, protons and neutrons are the fundamental particles of any atom and their properties are given in Table No.1.

From the table it is seen that protons and neutrons have almost the same mass and are more massive than electrons. In the treatment of our bomb we will be more concerned with neutron and we shall stick to To avoid inconvenience of expressing the masses of atoms in kilogram, a unit of mass known as 'atomic mass unit' (a .m. u) is adopted. One atomic mass unit is equal to $\frac{1}{12}$ th mass of carbon atom or $\frac{1}{16}$ th mass of oxygen atom and that is,
 $1 \text{ a.m.u.} = 1.66 \times 10^{-27} \text{ kg}$.

This is equivalent to 931 MeV (M for million), eV for electron Volt which is the unit for energy in Atomic and Nuclear Physics and $1 \text{ eV} = 1.6 \times 10^{-19} \text{ Joule}$. Thus in terms of atomic mass units, the mass of a neutron is equal to 1.00898 a.m.u which is almost equal to, say 1 a.m.u

Table No.1

Particle	Mass	Charge
Electron	$9.107 \times 10^{-31} \text{ kg}$	$- 1.6 \times 10^{-19} \text{ coulomb}$
Proton	$1.672 \times 10^{-27} \text{ kg}$	$+ 1.6 \times 10^{-19} \text{ coulomb}$
Neutron	$1.675 \times 10^{-27} \text{ kg}$	No charge

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Density of nuclear matter:

As a matter of caution, I would like to point out here that it is not the density of a substance as usually understood, but it is the density of nuclear matter which is something different and surprise you all as will be seen now. Usually substances of high densities are platinum, iridium, gold and osmium. The highest density among these is that of osmium the value of which is 24.5 gram per cc. I am purposely expressing quantities in c.g.s units to bring out a real surprise.

Now, let us see the density of nuclear matter. Taking uranium nucleus containing 238 nucleons, we have

$$\text{Radius, } r \text{ of the nucleus} = 0.93 \times 10^{-12} \text{ cm}$$

$$\therefore \text{Volume, } V = \frac{4}{3}\pi r^3 = 3.4 \times 10^{-36} \text{ cc}$$

$$\text{Mass of 1 nucleon} = 1 \text{ a. m. u} = 1.66 \times 10^{-27} \text{ kg} = 1.66 \times 10^{-24} \text{ gram}$$

$$\therefore \text{Mass of 238 nucleons} = 238 \times 1.66 \times 10^{-24} = 395 \times 10^{-24} \text{ gram}$$

$$\text{Thus, the density of nuclear matter} = \frac{\text{Mass}}{\text{Volume}} = \frac{1.66 \times 10^{-24}}{3.4 \times 10^{-36}} = 1.16 \times 10^{14} \text{ gram per cc}$$

The densities of other nuclei are of the same order. This means if we could pack 1 cc of space tight with atomic nuclei, its total weight would be about 116 000 000 tons which appears to be a paradox for a lay man and the birth of the bomb starts from this paradox.

Mass defect and Binding Energy There is a peculiarity to be noted in the case of atomic nuclei. That is, the mass of the nucleus is less than the sum of the masses of protons and nucleons present in the nucleus. Thus, there is a change in mass and this change in mass is called 'mass defect' and is denoted by Δm . It is found that larger the mass defect, the more stable will the nuclei. As mass and energy are equivalent, in order to break the nucleus or rather to rupture the nucleus, energy equivalent to mass defect should be given to the nucleus of the atom. In other words, the energy equivalent to mass defect is responsible for holding the nucleons together in the nucleus. This energy we call as the Binding Energy of the nucleus and is shown in the graph of Fig.3. We find from the graph that

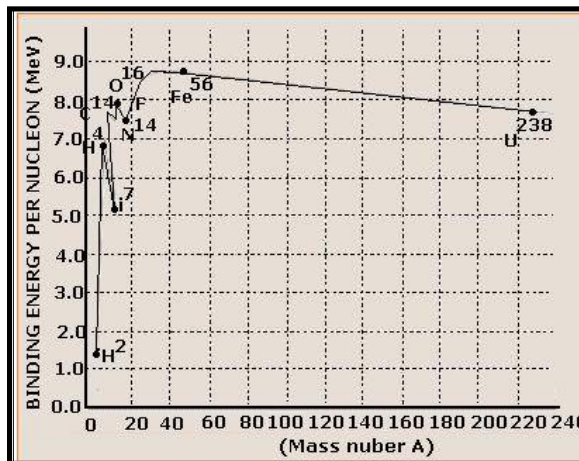


Fig.3 Graph of Binding Energy per Nucleon

the Binding Energy per nucleon steadily increases for lower nuclei and decreases for nuclei of large mass numbers. Due to the extremely high density, if we can burn 1 kg of uranium we can get energy equivalent to 20 million kWh real burning of 2000 tons of high grade coal. The word, 'burning' is not used in the conventional sense. To derive energy from the nucleus, we must bombard it with a fast moving massive particle. The possibility of bombarding the nucleus was taken up by two German Chemists, Otto Hahn and his assistant, Fritz Strassman. They wanted a massive and uncharged particle with which they can bombard the nucleus and such a particle is none other than neutron present in the nucleus which at their time was not freely

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Fig.4 Otto Han (1879-1968)



Fig.5 Sir James Chadwick (1891-1974)

detected. But, however, Sir James Chadwick (Fig.5) a British physicist in the year 1932 discovered Neutron and with this discovery and its independent existence, Otto Hahn and his assistant Fritz Strassmann with the theoretical explanation given in 1939 by Lise Meitner and her nephew Otto Robert Frisch succeeded in bombarding and break the nucleus on 17 December 1938. The experiments performed by them and the arrangement is shown in Fig.6. This is an important stage in the formation of a nuclear bomb.

Nuclear Fission

The process of breaking the nucleus by bombardment is called nuclear fission. As we notice from the graph of Fig.3, the binding energy per nucleon being less for nuclei of large mass numbers, let us try to bombard the nucleus of uranium-235 atom with an energy of 1 eV and see the state of affairs. For bombarding, there exists powerful particle accelerators. The nucleus of an atom is considered to be a drop of water or mercury having the property of surface tension. The forces of surface tension maintain spherical shape as the surface area of a sphere is minimum for a certain volume. The surface tension of water is just $0.075 \frac{N}{m}$ whereas the surface tension of nuclear fluid is $93 \times 10^{15} \frac{N}{m}$. Here is another surprise for you. This force of surface tension of nuclear fluid can support a weight of 1 billion tons. In the nucleus of a normal atom, the surface tension forces exactly balance the forces of repulsion exerted by the protons of the nucleus. Whenever a nucleus is bombarded with a neutron, depending upon the variation in speed of the neutron, there are possibilities that the neutron can bounce back (reflection) or get scattered (scattering). The speed is so chosen that the neutron is made to enter the target nucleus of the atom. We call this 'Neutron Capture'. The atom so chosen should have sufficiently high neutron capture cross section expressed in

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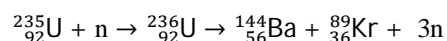
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Fig.6 The experimental set-up of Hahn and Strassman for nuclear fission in 1938

'Barn'. (1 Barn = $10^{-28}m^2$). This value for uranium-235 atom under consideration is 107 Barn whereas for uranium-238, it is just 3.5 Barn. But, it is 315 Barn for Plutonium-239 which is much higher. The neutron entering the nucleus or rather captured by the nucleus is something like an unwanted guest entering to create chaos. The nucleus is in a state of unstable equilibrium. The electrostatic forces of repulsion among the protons predominate the surface tension forces and the nucleus is in a state of rupture. The surface of the nucleus oscillates and we get two separate particles along with the release of large amount of energy as shown Fig.7. The phenomenon is similar to cell division in Biology and the name 'Fission' is given to it. The two separate particles are called as fission fragments. In the subject of Nuclear Physics the process of fission can be detected in the case of Cloud Chamber experiments and photographic plate method. The question now is, what do the fragments of fission correspond to? Hahn and Strassmann showed that in the case of Uranium-235 atom. The two fragments correspond to Barium and Krypton as shown in Fig.7. That is,



'n' standing for neutron. In addition to the two fragments Barium and Krypton, the fission process is accompanied by 3 fast moving neutrons with large amount of energy.

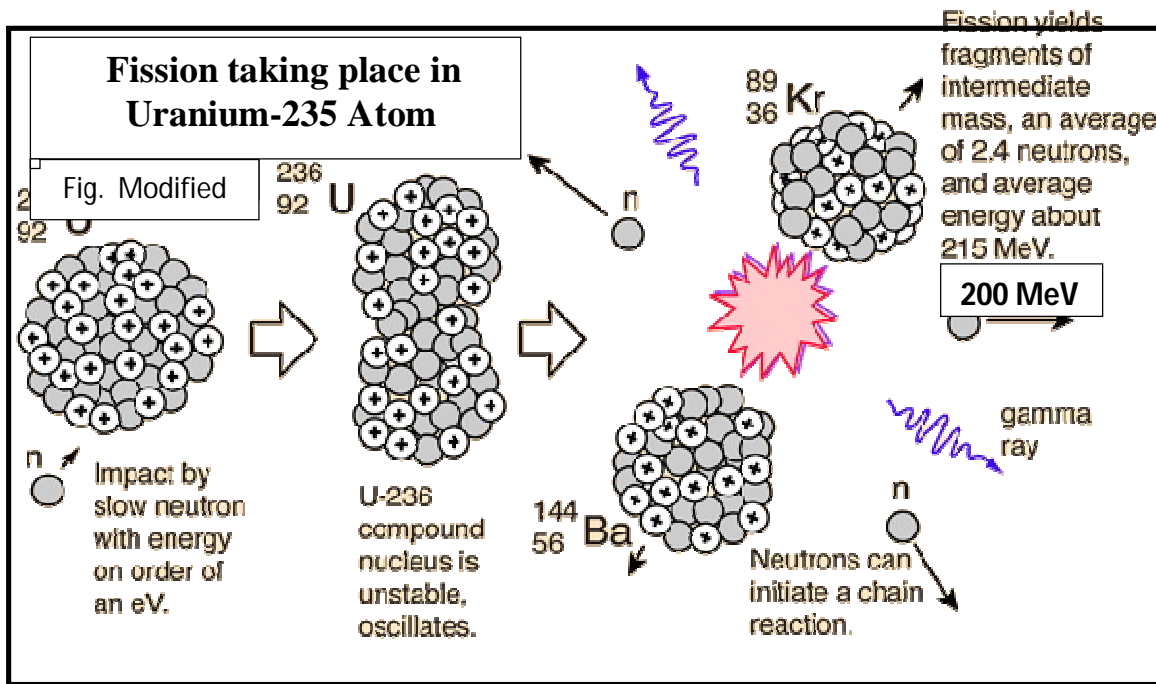


Fig.7 Formation of Fission in Uranium-235 atom

It is known that all heavy nuclei starting approximately with Thorium-232 are fissionable under proper excitation conditions. The fission fragments do not interact with the uranium atoms as they are expelled.

It is of interest to know as to what happens to the orbiting electrons of the atom when the speeding heavy neutron strikes the nucleus of the atom. As the mass of an electron is negligibly less than that of the neutron, the situation is something like a speeding truck simply ignores few rats running amuck on the road.

From the experiments it is worked out that the total energy released from the fission of one Uranium-235 nucleus is about 200 MeV. Subtracting from this the amount of energy released by Gamma-rays, neutrino and others, we get the net energy as 184 MeV.

Let us now work out the amount of energy released from the fission of 1 kg of uranium-235 atom. We proceed as follows:

One gram atom of uranium contains 6.02×10^{23} atoms which is the Avogadro's number.

Hence, the energy released in the fission of all the nuclei contained in 1 kg of U^{235} is:

$$\frac{1000}{235} \times 6.02 \times 10^{23} \times 184 = 4.75 \times 10^{26} \text{ MeV}$$

This is equivalent to 1.8×10^{10} k cal or 20,000,000 kWh of energy. It should be noted that the energy released in the explosion of Trinitrotoluene (TNT) is only few eV per molecule.

So far we have only realized that an explosion is possible, but there are other factors such as the type of target nuclei and requirement of an unlimited number of secondary neutrons produced in fission

Production of Secondary neutrons in Fission

It is observed that a fission event is accompanied by a stream of secondary neutrons having less energy. The number of such neutrons per fission depends upon the target nuclei. The time required for a fission event is just a microsecond or even less. In order to determine the number of neutrons produced per fission, we define a quantity k known as the 'Reproduction Factor', given by

$$k = \frac{\text{Rate of neutron production}}{\text{Rate of neutron disappearance}}$$

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A relation between k and the number of neutrons in various generations is given by the graph of Fig.8..An expected value of k is 1, but for slightly greater than 1, say 1.1, we get for 5 generations, $(1.1)^5 = 1.61$ neutrons. In 1000 generations, say in $(\frac{1}{1000})^{\text{th}}$ of a second, this will go to 1×10^{41} neutrons. See what a great number. It is 1 followed by 41 zeroes.

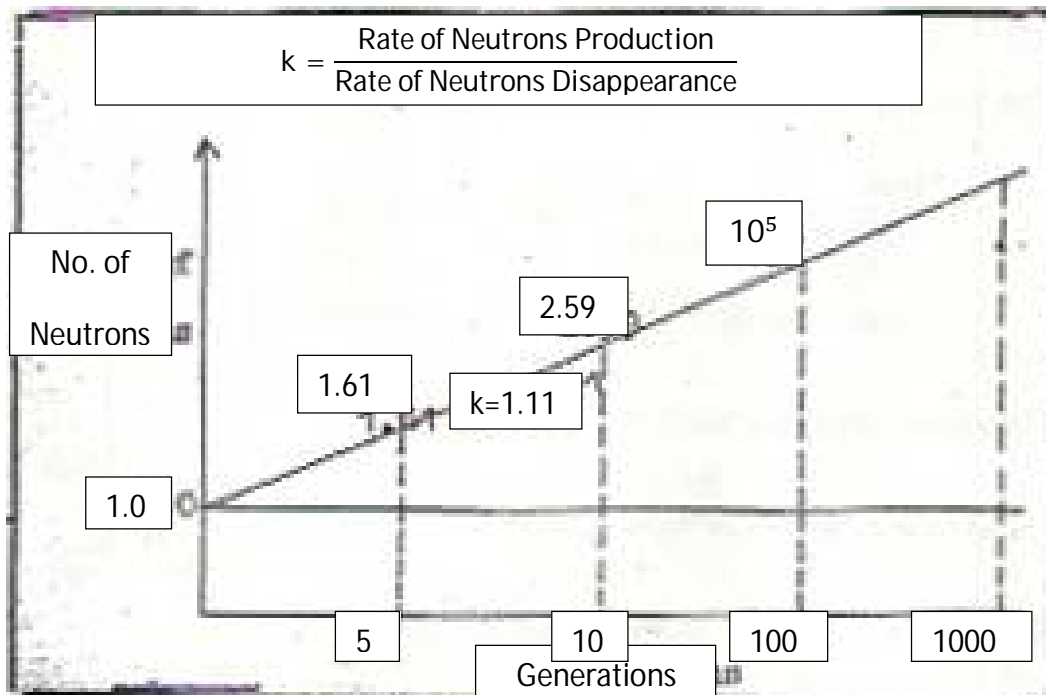


Fig.8. Multiplication of generations for values slightly greater than k

Critical Mass and Chain Reaction

The discovery of the emission of secondary neutrons in fission process is a crucial fact, for it renders immediately obvious that a self-sustaining chain reaction is possible, since the neutrons so produced in the fission of a nucleus can in principle cause fission, in their turn, in other neighboring nuclei producing more secondary neutrons and more fission resulting thereby in a rapid geometric increase of fission until the whole of the fissionable material is disintegrated. On account of the emission of particles of the same kind as those started the fission, a self-propagating chain reaction is obtained involving so many nuclei that the entire mass will explode, thus producing enormous energy.

The escape of electrons is a surface effect dependent on the surface area and hence on the square of the radius, whereas fission is a volume effect dependent on the volume and hence on the cube of the radius. Thus, the ratio of the rate of escape of neutrons from the system to the rate of their production varies inversely as the radius, decreasing with increasing size. As the radius is increased from a small value, a critical size is reached beyond which more neutrons are produced than are lost, so that a chain reaction can progress rapidly. In terms of the multiplication factor k , its value must be at least 1 for critical size and is of great importance. For values less than 1, the material is completely stable and perfectly safe, but above which, the system becomes unstable and explodes spontaneously. In Nuclear Engineering dealing with the construction and operation of reactors, the multiplication factor k is expressed as a 4-factor and a 6-factor formula the details of which I am deliberately avoiding to make matters very simple. Thus, to sum up,

If $k = 1$, the chain reaction attains critical and the neutron production will remain constant.

If $k < 1$, the chain reaction is sub-critical and the neutron production will decay exponentially.

If $k > 1$, the chain reaction is super-critical and the neutron production will grow exponentially

A chain reaction was first obtained successfully by the Italian-American Physicist, Enrico Fermi on 2nd December 1942, the details of which we shall deal with later. Fermi realized that if a sample of fissionable material exceeds the

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critical size, the number of fission neutrons and the rate of energy production will increase exponentially with time and the process will acquire an explosive nature. In order to control this chain reaction and avoid explosion, it was Fermi who introduced ‘moderators’ in nuclear reactors. Elements of low atomic weight such as carbon in the form of graphite, Deuterium in heavy water (D₂O), helium, beryllium, etc. are used as moderators. In Fig.9 is shown an un-controlled situation of chain reaction and a chain reaction controlled by means of a moderator.

By the introduction of a moderator, the high energy neutrons experience elastic scattering with the atoms of the moderator i.e. they bounce and jump each other) and there is a transfer of where most of the energy of the high energy neutrons are absorbed by the atoms of the moderator. The neutrons lose their speed and thus become slow neutrons or we call them as thermal neutrons. The energy of a thermal neutron is 0.025 eV whereas the energy of a high energy neutron is of the order of 1 MeV or more. Thus, the function of the moderator is to slow down neutrons

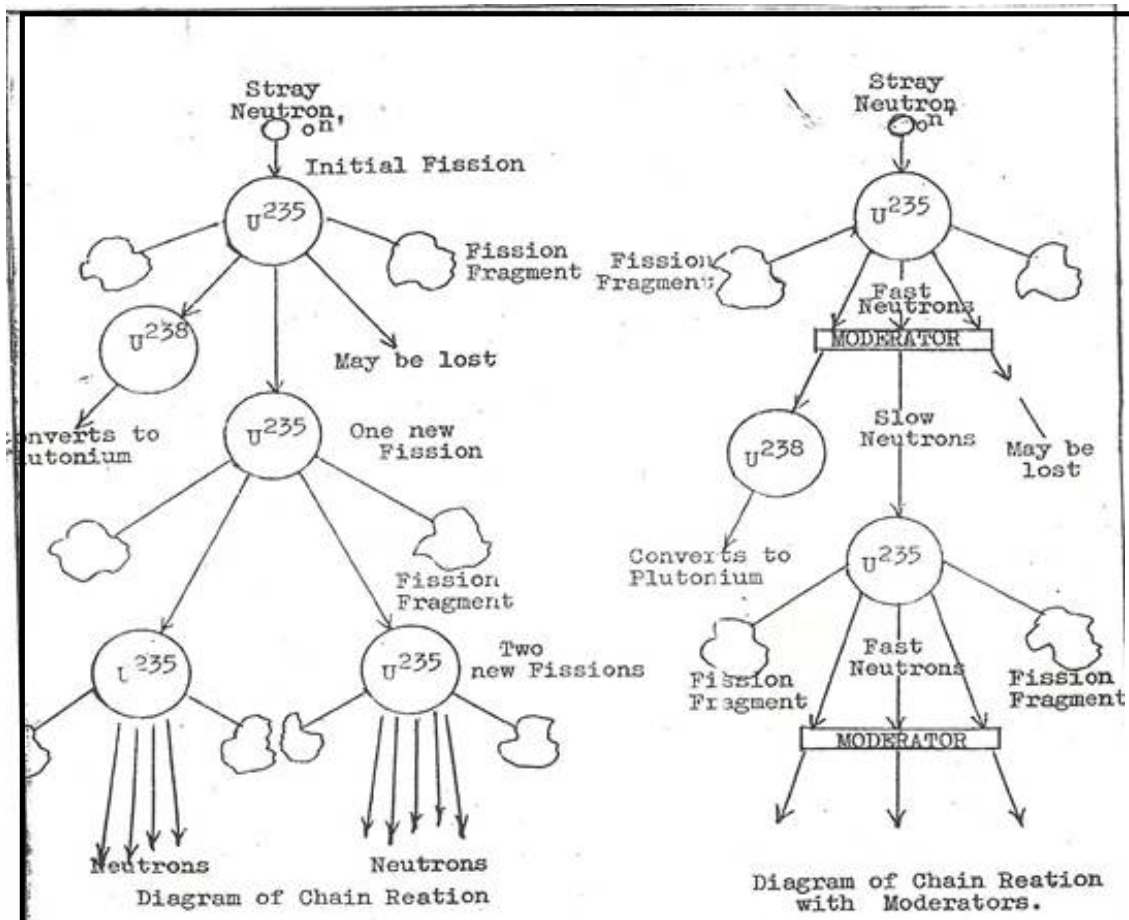


Fig.9. Nuclear chain reaction un-controlled (Bomb) and controlled chain reaction (Reactor)

and hence control the chain reaction. In the case of nuclear explosion device, there is no moderator and hence no control of chain reaction and the fissionable material is allowed to explode spontaneously. Selection of target nuclei is very important in the fission process and hence for the manufacture of a bomb. Among the naturally occurring ores of uranium, the relative abundance of uranium-234 is only 0.006%, uranium-235 is 0.714% and uranium-238 is 99.28%. We also have to see the fission cross section of the material. The fission cross section of uranium-238 is almost zero and hence it is not an ideal target nuclei whereas the fission cross section for uranium-235 is 580 barn but its abundance being much less, it is to be purified from large quantities of ore by a process known as ‘enrichment of uranium’ which

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is a complicated process known only to experts and each nuclear country keeps it as a guarded secret. Usually Plutonium-239 obtained as a by-product in the uranium-235 fission process and having very high fission cross section of 750 barn is used in the manufacture of bombs. Further, it is a stable nucleus having a half-life of 25,000 years.

The physics of the atomic nucleus so far given by me is just sufficient for the understanding of the making of the bomb and its explosion. We have at present only the knowhow of an explosion without making a bomb. We are still to make a bomb and hence much far away from the Turmoil.

B. THE EXPLOSIVE DEVICE AND MODE OF EXPLOSION (FISSION BOMBS)

In order to achieve an explosion, it is necessary to release a large amount of energy in a very short time. An explosive fission reaction must, therefore, be propagated by fast neutrons. The critical mass for plutonium is 10 kg and that for 90% pure uranium-235 is 20 kg. The critical mass is judged by the factor, 'nkp', where 'n' is the total number of neutrons produced in the fission process, 'p' the fraction of neutrons that are lost and 'k' the reproduction factor. The quantity 'nkp' is called the "Neutron Multiplication Factor". These quantities are theoretically worked out and it is seen that $nkp > 1$ or at least equal to 1 for an explosion. Since no moderator is required a super critical sphere of pure uranium-235 or plutonium-239 is the logical configuration to achieve an explosion. To determine such a device, it is necessary to assemble two or more non-critical pieces of a fissionable material into a super-critical configuration. Before the assembly, the pieces are perfectly safe. The assembly must be done very quickly to obtain most efficient reaction since it is clear that, if assembled slowly, the individual pieces will just heat up and expand and tend to blow themselves apart before reaching a highly super-critical state.

Two methods of assembly have been described in the open literature, the gun-type and the implosion-type. The mode of assembly is a closely guarded secret by each nuclear nation. In the gun-type, two pieces of fissionable material that will become super-critical when assembled. The detonation is accompanied by firing one by means of a high explosion into the other, presumably much the way a projectile is fired by a gun. To assure that a chain reaction will actually occur instantaneously, however, it is also necessary to provide a source of neutrons at the time of assembly. Exactly how this is done is not made public, but there are a number of ways for doing it. The following are some of the gun-type fission bombs.

In fig.10. is shown two different types of assemblies. Fig.(a) shows a gun-type fission bomb. In order to perform the assembly process fast enough, we must shoot the sub-critical piece on the left at a high speed by ignition of a conventional chemical explosive such that the two sub-critical masses of uranium-235 becomes super-critical and will explode.

In Fig.(b) is shown an implosion type assembly which operates on a different principle. In this case, a sphere of fissionable material with a non-critical density, is surrounded by a spherical shell of high explosive such as TNT. Now, if the entire shell of high explosive can be detonated simultaneously, there will be an inward shock that will compress the inner sphere into the super-critical geometry. Again, if a neutron source (not shown) is present, the conditions necessary for a nuclear explosive have been produced. In order to achieve a symmetrical implosion, the high explosive must be detonated at a large number of points simultaneously so as to achieve a violent explosion. If the detonation were to occur at only one point, the implosion would be asymmetric and will simply blow the inner sphere apart rather than together and no explosion would result. This feature greatly reduces the chance of accidental nuclear detonation in devices of this type. The tremendous energy release of such a device can only be fully realized by those who have actually seen and heard one detonated. The peculiarity of the implosion-type device is that the explosion takes place inward and not outward and hence there will be less radioactive fall-out. After having known how to make a bomb, let us see the bomb in action.

The Bomb in Action The action of an atomic bomb (The terms 'atomic bomb' and 'nuclear bomb' are synonymously used. It is the nucleus that explodes along with the atom) depends on the conditions in which it is produced, whether high above the Earth, at the surface of the Earth or under water. The first stage of explosion in air, which we call as the atmospheric explosion (Fig.11). shows the characteristic ball of fire. The reaction products are under very high pressure. The temperature in the zone of the reaction exceeds a million degrees. The air above the bomb heats up to incandescence, and the light flash is seen at a distance of over 100 kilo meters. The ball of fire grows up rapidly reaching about 13 meters in diameter. As it expands it moves upwards like a balloon at a speed of several tens of

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meters per second. At a height of 12 to 15 km, where the density of the surrounding air is roughly equal to the density of the ball, it takes the shape of a mushroom, forming a flat cloud with a radius of several kilometers, which lasts until it is dispersed by the wind. Simultaneously with the formation of the ball of fire, in the center of the explosion, there appears a shock wave. This wave propagates from the center through the ball of fire at a speed exceeding that of sound.

An under-water bomb explosion some 90 feet (27m) deep known as “*Helen of Bikini*” was carried out by the United States under a code name ‘Operation Cross Roads’ on 25 July 1946 in Bikini harbor of the Marshall Islands. The mushroom cloud of the explosion is shown Fig.12. An enormous gas bubble is observed in place of the ball of fire. The bubble is developed from the rapid evaporation of water and busts the water surface at the same time that the shock wave arises. In the act, an enormous volume of water rises up forming a dome-shaped cloud. A wave reaching 30 meters in height appears on the water surface. The wave creates a serious hazard to ships and structures on the shore. As it busts on the water surface, the gas bubble produces a column of water called “Plume”. The

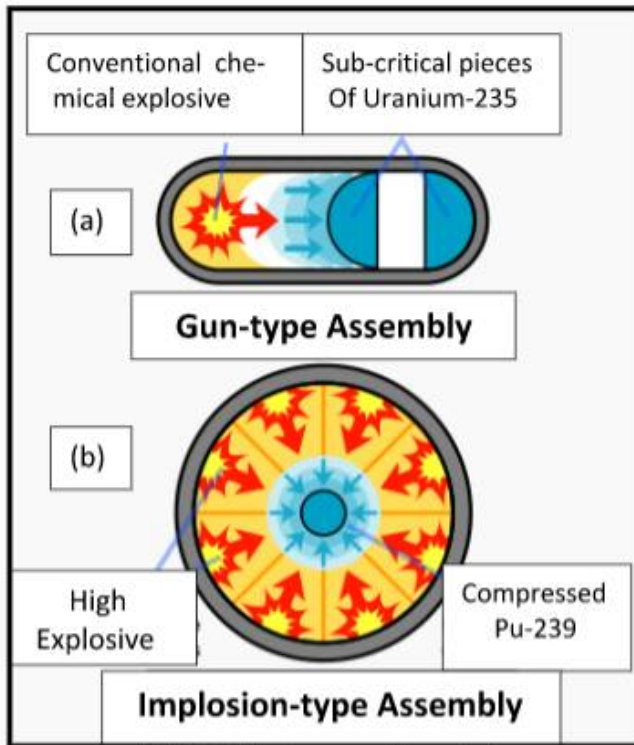


Fig 10. (a) Gun-type assembly method
(b) Implosion assembly method



Fig.11 An Atmospheric Explosion

Plume is in the form of a hollow cylinder with a maximum diameter of the order of 600 meters and walls about 90 meters thick. In the process up to one million tons of water are thrown up in the air. The plume rises to a height of 1000 to 2400 meters where it encounters with the colder layers of air, the upper part is in the form of a cloud resembling a cauliflower. As the rise of plume slows down, the lower part begins to fall back into the sea, and at the base of the plume there develops a gigantic wave 250 to 300 meters in height that consists of a cloud of mist. This wave is known as the ‘base surge’. The base surge travels outward from the site of the explosion and gradually lifts above the surface of the sea merging with low clouds over the site of explosion. If there is wind, such clouds travel great distances. Then begins a rain of radioactive water.

When a nuclear bomb is exploded deep underground as India did in 1974 in the deserts of Pokran in the state of Rajasthan at a depth of 100 meters, the sequence of events are roughly illustrated in Fig. .

(a) This shows the bomb in its cavity, before the explosion.

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- (b) A few microseconds after the explosion, the energy of the bomb has ionized all the matter in the cavity and the enormous pressure exerted by the dense plasma has forced out the walls. The shock wave has travelled out through the rock, getting weaker as its radius increases. The rock behind the shock front is now partly vaporized and partly molten with the heat generated by the shock.
- (c) This shows the situation when the walls of the cavity have been pushed out to their ultimate position and this takes only a fraction of a second. The molten rock is at a temperature of 1000°C and the cavity is filled with hot water vapor (from the water in the rocks) to a pressure of several tons of atmospheres. Outside the cavity the rock has been crushed and broken for a considerable distance



Fig.12. An under-water explosion in the Bikini Harbor in Marshall Islands

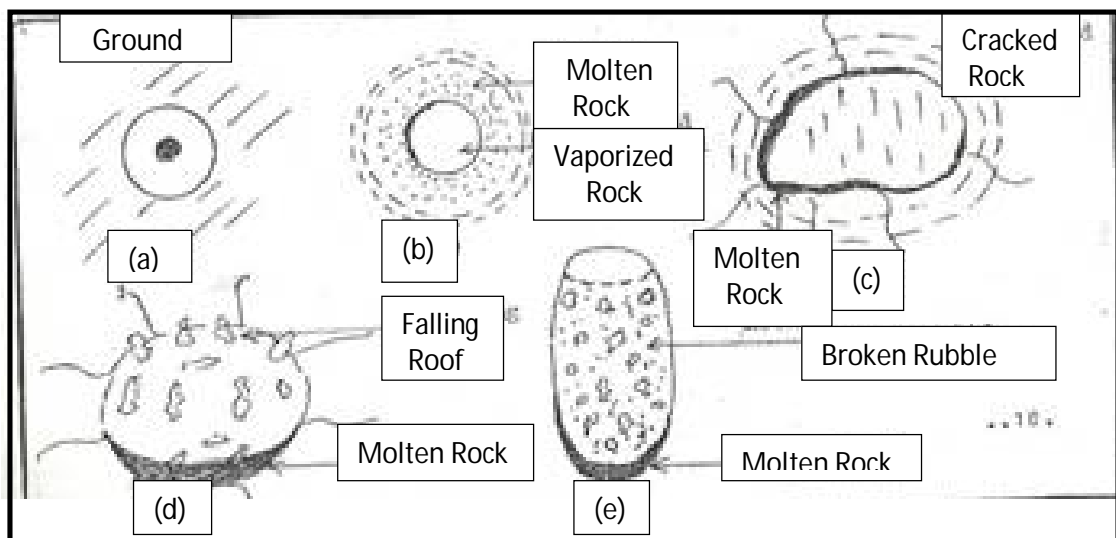


Fig.13. Various stages in an underground Nuclear explosion

- (d) After a time which depends on the material of the rock and the yield of the bomb (By 'yield' of the bomb is meant, the total energy given out in the explosion and the same theoretically worked before the

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assembly of the bomb), the molten rock will have flown down the sides of the cavity and accumulated on the floor. Meanwhile, the roof will be collapsing under the pressure of the crust of the Earth above and part of it will be falling into the cavity.

- (e) Finally, in most types of ground, the rock above the cavity breaks up and fills the cavity, leaving a chimney of rubble above. The height of this varies with the nature of the ground and of course the yield of the bomb.

This is the typical picture of a bomb which is buried at great depth. If the depth is such that the top of the chimney of rubble would be near the surface, we may find that this subsides into a shallow hollow over the explosive point, and in some cases the chimney may vent allowing gases containing fission products to escape into the atmosphere. It is clearly very important to know how to make sure that the depth is chosen so that this does not happen unless we wish for it, as for example, if we form a large crater, it can be shown by dimensional analysis that the law connecting the minimum 'Safe Depth' with the fission yield is of the form

$$\text{Safe Depth} \propto (\text{Yield of Bomb})^{\frac{1}{3}}$$

That is, the safe depth is proportional to the cube root of the Yield.

In Fig.14. is shown a typical crater. The part which is visible from the surface is called the 'apparent crater' and quoted dimensions usually refer to this. In the case of India's first explosion done in 1974, the crater diameter was 200 meters. The true crater is somewhat deeper because it contains loose material which has fallen back into it. Underneath the true crater is a considerable layer of broken and crushed rock, which has not, however been hurled into the air. This is usually called the 'rupture zone', and it merges gradually into the 'plastic zone' where the material has undergone considerable irreversible movement, but has not fractured. This, in turn merges into the 'elastic zone' where ordinary, reversible elastic motion has taken place.

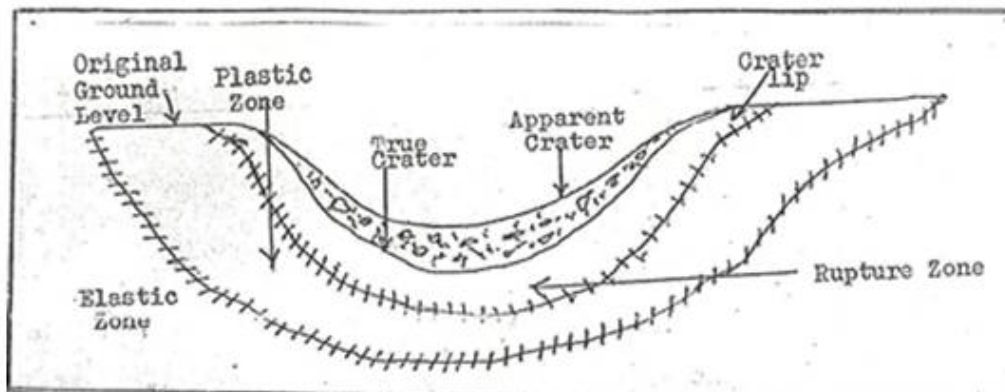


Fig.14. A typical Crater formed in an underground Nuclear explosion

C. HISTORY OF WORLD'S FIRST NUCLEAR BOMB TESTED AND EXPLODED BY US

If we apply the "Cause and Effect" formalism to the history of the Bomb, the cause is Second World War and the effect is, not only making the bomb, but also using to kill thousands of people. When Japan attacked Pearl Harbor (US) Fig.15 on 7th December 1941, the turmoil started even before the idea of making a bomb The US joined UK and France forming an Allied Force and fought against Japan which was aligned with the Nazis of Germany under the command of Adolf Hitler(Fig.16). Most of the physicists in Germany majority of whom

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Fig.15 Attack on Pearl Harbor (US)



Fig.16 Adolf Hitler (1889-1945)

were Jews sought asylum in US and UK. A well known Quantum Nuclear physicist, Werner Heisenberg (Fig.17) known for his famous 'Uncertainty Principle', remained in Germany. Hitler, after capturing the uranium mines in the Czechoslovakian border, approached Heisenberg in the year 1942 and in the midst of the war and sought his help in the making of a bomb. Heisenberg reluctantly accepted Hitler's request. He gave him \$80,000 for the project to be taken up in the making of a reactor.

Heisenberg took the help of another physicist Weizaker who told him that "*My dear colleague, no one ever invents anything he doesn't really want to invent.*" They, knowing fully well, the after-effects of the bomb which will go in the hands of Hitler went deliberately slow in the work and they pacified Hitler by saying that the large number of war heads such as V-2 Rockets and jet planes in the possession of Germanycan thwartany attackby the enemy. Another Germanscientist Fritz Houtermanswho was working on nuclear chain reactions in the fission of uranium, kept his results secret. The reactor (Fig.18) was made but failed to work and was not successful in the operation. Jim Baggot, a popular British writer mentions in his book titled, "The First War of Physics", the story of the early stages of nuclear arms race. The primary motivation that propelled the race was 'fear'. Fear that Hitler's Nazi Germany might be the first to build an atomic bomb. Fear that America miught threaten a nuclear strike against the Germans. When the war ended, the western allies captured most of the leading German scientists and interned them in Farm Hall, a manor house in Cambridge, England where their conversations were bugged. They were stunned and bewildered when they heard the news of the

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Fig.17. Werner Heisenberg (1901-1976)

Hiroshima bomb. Forced to explain why they lost to the nuclear race, one of the scientists, Carl Von Weizsacker, the brother of a future German President then came up with an explanation and said that *“The reason we didn’t do it was because all of us didn’t want to do it on principle. If we had all wanted Germany to win the war, we would have succeeded.”* meaning thereby that the failure of Nazi’s \$80,000 reactor by Heisenberg was a deliberate attempt. Heisenberg later wrote that he turned the official Nazi slogan, *“We must make use of Physics for Warfare”* on its head. Rather he sought to *make use of warfare for Physics*. He identified himself in a somewhat difficult context, as a lack of moral courage and not to sacrifice his love for Physics. Given sufficient time and had he taken keen interest, his work would most likely resulted in a Nazi Bomb. Had Heisenberg done what his counter parts in the US did and pushed for an all-out efforts, history might have been different.

Let us now see what the Americans did. With the influx of refugee scientists mostly from war-torn Germany and Italy, the US became dominant in the field of Physics. The Italian physicist Enrico Fermi (Fig.20), who had a Jewish wife escaped from the ruler, Mussolini in Italy and sought asylum in the US. Fermi had worked with one Emilio Segre who was an expert in slowing down neutrons by passing through water or paraffin. Leo Szilard, a Hungarian physicist who realized that a chain reaction could be triggered in a suitable radioactive substance. He became concerned that nuclear weapons might be developed by the Nazis and he along with Edward Teller (Fig.19) and Eugene Wigner prepared a letter on behalf of Albert Einstein and addressed to Franklin Roosevelt, the President of the United States (The copy of letter is given below):

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Fig.18. The last German experimental Reactor which failed



Fig.19. Edward Teller (1908-2003)



Fig.20. Enrico Fermi (1901-1954)

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Einstein's Letter to President Roosevelt

Albert Einstein

Old Grove Road
Nassau Point
Peconic, Long Island

August 2nd, 1939

F. D. Roosevelt,
President of the United States,
White House,
Washington. D.C.

Sir,

Some recent work by E. Fermi and L. Szilard which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation which has arisen seem to call for watchfulness and, if necessary, quick action on the part of the Administration. I believe therefore that it is my duty to bring to your attention the following facts and recommendations:

In the course of the last four months it has been made possible – through the work of Joliot in France as well as Fermi and Szilard in America – that it may become possible to set up a nuclear chain reaction in large mass of uranium, by which vast amounts of power and large quantities of new radium-like elements would be generated. Now it appears almost certain that this could be achieved in the immediate future.

This new phenomenon would also lead to the construction of bombs, and it is conceivable – though much less certain – that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory.

However, such bombs might very well prove to be too heavy for transportation by air.

The United States has only very poor ores of uranium in moderate quantities. There is some good ore in Canada and the former Czechoslovakia, while the most important source of uranium in Belgium Congo. In view of this situation you may think it desirable to have some permanent contact maintained between the Administration and the group of physicists working on chain reactions in America. One possible way of achieving this might be for you to entrust with this task a person who has your confidence and who could perhaps serve in an unofficial capacity. His task might comprise the following:

- a) To approach Government Departments, keep them informed of the further development, and put forward recommendations for Government action, giving particular attention to the problem of securing a supply of uranium ore for the United States.
- b) To speed up the experimental work, which is at present being carried on within the limits of the budgets of University laboratories, by providing funds, if such funds be required, through his contacts with private persons who are willing to make contributions for this cause, and perhaps also by obtaining the co-operation of individual laboratories which have the necessary equipment.

I understand that Germany has actually stopped the sale of uranium from the Czechoslovakian mines which she has taken over. That she should have taken such early action might perhaps be understood on the ground that the son of the German Under- Secretary of State, Von Weizsacker, is attached to the Kaiser-Wilhelm-Institute in Berlin where some of the American work on uranium is now being repeated.

Yours very truly,
(Albert Einstein)

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With the above letter, Leo Szilard along with Edward Teller and Eugene Wigner approached Albert Einstein (Fig.21) the father and author of the famous equation, $E = m c^2$ persuading him to send the letter to American President Franklin Roosevelt regarding the seriousness of the problem.



Fig.21. Leo Szilard showing the letter addressed to President Roosevelt to Albert Einstein

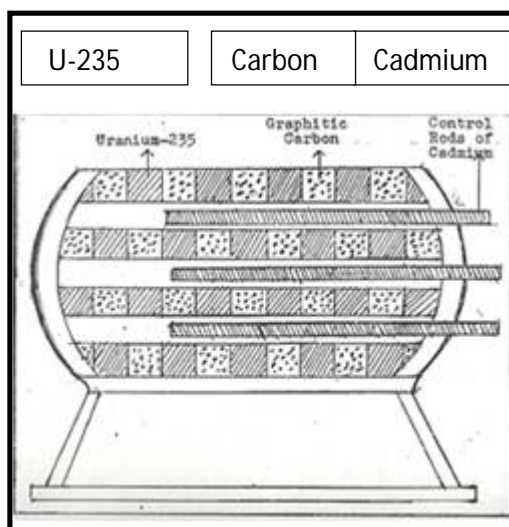


Fig.22 The Structure of Fermi's Pile

Before assigning the task of making the bomb, a controlled self-sustaining nuclear reaction, capable of being switched on and off as and when needed, was necessary. This task was assigned to a team of scientists led by Enrico Fermi (Fig. 23). The experimental reactor was built in a squash court at the west viewing stands of the original Stagg Field in the University of Chicago and a front view of which is shown in Fig.24. It is Fermi who christened the unit as a "Pile" and called it Chicago Pile No.1 or CP-1 for short. The pile consisted of 40,000 graphite blocks weighing 400 tons that enclosed 19,000 pieces of uranium metal weighing 6 tons and uranium oxide fuel weighing 50 tons. Beneath the bleachers of the Stagg Field was the Metallurgical Lab (Met Lab) where measurements were carried out. The graphite

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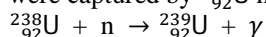
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layers were arranged within a 24 square feet wooden frame work. The neutrons were controlled by inserting cadmium rods between the combined layers of uranium and graphitic carbon. In short, it was a crude massive lattice pile of black bricks and wooden timbers. The scientists were eagerly waiting for the pile to go critical each time a graphitic brick is being laid. After the 57th layer of graphitic brick was being laid, the pile went critical exactly at 3.20 PM on December 2, 1942. The print-out of neutron intensity in the pile as recorded by a galvanometer when CP-1 went critical is shown in Fig.25. In Fig.26 is shown the team of scientists working with the Fermi's Pile where you find them removing the cadmium rods so as to attain chain reaction. Immediately after success of the chain reaction, scientist Compton reported to Conant in a code message: *"The Italian navigator has just landed in the new world"*. To Conant's question, Were the natives friendly? Compton answered: *"Every one landed safe and happy"* The meaning of the code message being that the first successful nuclear chain reaction has been achieved. On the success, the great scientist Leo Szilard commended thus: *"This will be the blackest day in the history of mankind"*



Fig.23 Enrico Fermi with the Manhattan team. In the front row standing extreme left is Enrico Fermi (Photo taken on the steps of Eckhart Hall on the campus of the University of Chicago on 2nd December 1946, the 4th Anniversary of the world's first successful nuclear reaction achieved on 2nd December 1942.

Although the pile went critical, the energy released in the fission of $^{235}_{92}\text{U}$ nuclei could not be utilized, and was literally sent down the drain by means of the cooling system, it was found that a new fissionable element was produced inside the pile during its operation. The neutrons that were not used in the maintenance of the chain reaction in $^{235}_{92}\text{U}$ nuclei were captured by $^{238}_{92}\text{U}$ nuclei, producing a heavier isotope, thus:



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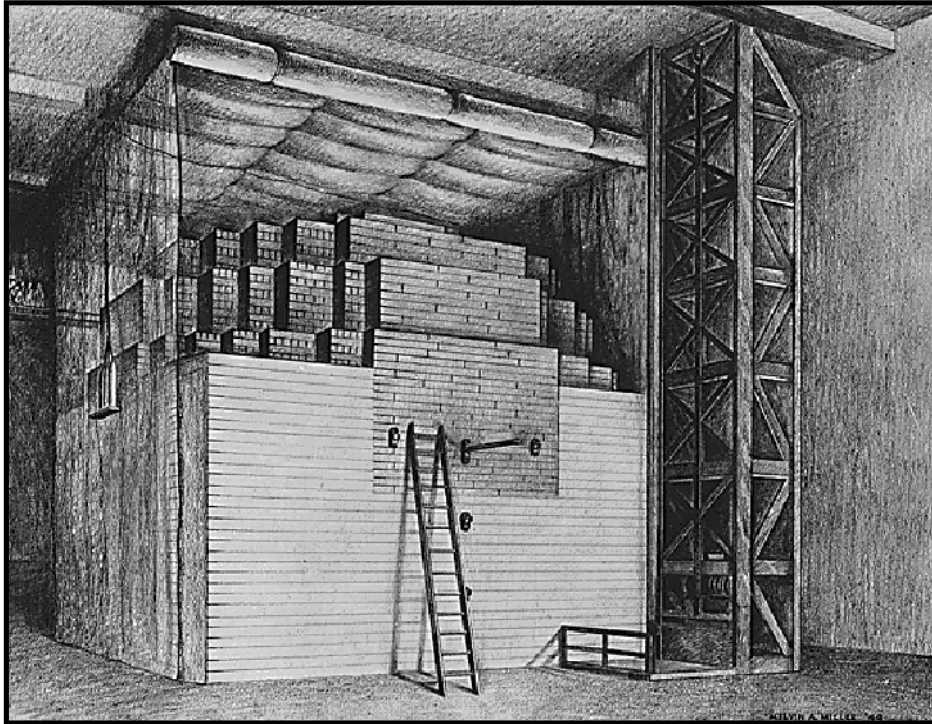


Fig.24. Front view of Fermi's Chicago Pile-1 (CP-1)

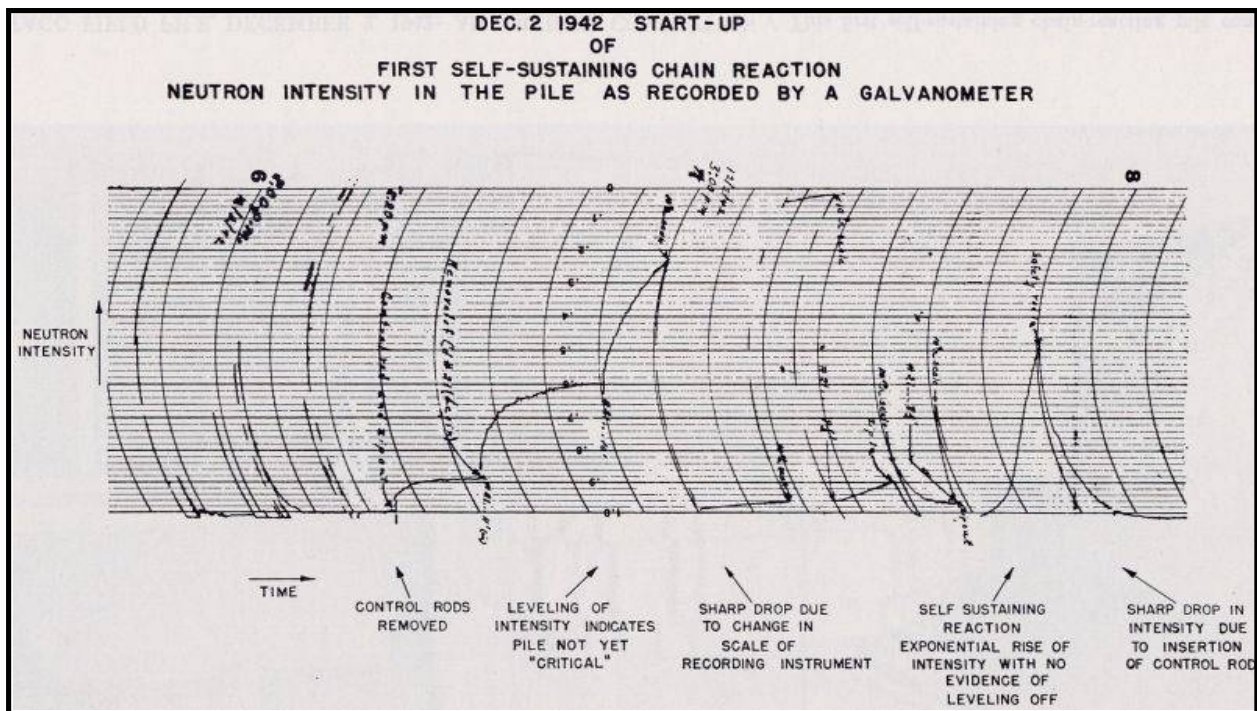


Fig.25. Print-out showing neutron intensity in the Pile.

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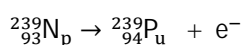
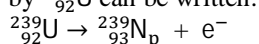
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Fig.26. Team of scientists working with the Fermi's Pile (Cadmium rods are being removed from the core)

having excess of neutrons, the nuclei of $^{238}_{92}\text{U}$ underwent two successive β -transformations, giving rise to elements with atomic numbers 93 and 94. These two elements, which do not exist in nature but have been produced artificially by human genius, were given the names, 'Neptunium N_p ' and 'Plutonium P_u '. The reactions following the neutron capture by $^{238}_{92}\text{U}$ can be written:



Being chemically different from uranium, the plutonium produced in the Fermi pile can be separated and purified with much less effort than it takes to separate light uranium isotope from the heavy one, and this element turned out to be even more fissionable than $^{235}_{92}\text{U}$. In fact, whereas $^{235}_{92}\text{U}$ gives rise to 2.5 fission neutrons, the corresponding figure for $^{239}_{94}\text{P}_u$ is 2.7 fission neutrons.

- After Fermi achieved the world's first sustained and controlled nuclear chain reaction, with the creation of the first atomic pile, massive reactors were secretly constructed at what is now known as Hanford Site to transform uranium-238 into Plutonium for a bomb. In view of the remarkable achievement of Fermi, the Chancellor of University of Chicago Robert Maynard Hutchins honored and felicitated Fermi along with his colleagues in December 1947 by dedicating a plaque installed on the walls of the University of Chicago stadium (Stagg Field) memorizing the world's first controlled nuclear reaction (Fig.27). The plaque reads:

"On December 2, 1942, man achieved here the First self-sustaining chain reaction and thereby initiated the controlled release of nuclear Energy"

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Fig.27. The University of Chicago chancellor, Robert Maynard Hutchins (right) gathers with Enrico Fermi (second from right) and his colleagues during the unveiling of plaque, December 1947.

More than a year has passed between the attack on Pearl Harbor (7 December 1941) and the success of chain reaction (2 December 1942) and the war with Japan continued unabated. The scientists are all on the run and at the same time the time is running out. The bomb has to be made in the quickest possible time. Success has been seen with the Americans even though the turmoil in the mind still persists because even after you make the bomb, it has to be successfully tested. Let us now go with the making of the bomb and testing it. You see, it is a long process!

The Manhattan Project

The bomb making was done under a project code named: "Manhattan Project". Manhattan is an industrial place in New York. The bomb making has to be done jointly by the scientists specially physicists and Army personnel. In the year 1943, Scientists selected a place direction of Major General Los Alamos which is a plateau in the state of New Mexico in the southern part of US and established a national laboratory for the Manhattan project under the Leslie Groves of the US Army Corps of Engineers and physicist Robert Oppenheimer(1904-1967)(Fig.28). The main aim of the scientists working for the project is that the bomb which is a 'magnificent' creation of science should not go to Hitler's hands.

. It should be necessarily built on US soil. When a large team of scientists, most of them physicists, working on the project, an eminent physicist Langevin said: "*The Pope of Physics and the entire Vatican has moved to the United States.*"

At Los Alamos, the military were just administrators. The jet engine, the radar, the magnetrons and the inertial gyros to quick missiles were developed by pure scientists. The world is ruled by technology. Power among nations is essentially decided by science. Weapons are only a by-product. International legislation and sanctions aimed at

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Fig.28. General Leslie Groves (Left), military head of the Manhattan Project and Robert Oppenheimer (Right) Wikimedia

only weapons to cure symptoms rather than the disease. The much awaited first atomic bomb was born out of the Einstein-inspired Manhattan project and is nick-named “The Gadget” (Fig29.). It is a plutonium implosion fission bomb expected to have an yield of 22 kilo tons of TNT (~92 TJ). The original \$6000 program budget skyrocketed to a cool \$2 billion after Einstein raised multiple concerns that the Nazis were very close to perfecting their own game-changing weapon.

The Testing – “Trinity”

The testing was code-named “Trinity” as suggested by Robert Oppenheimer and to be carried out in a dry land in New Mexico some 50 miles from Alamogordo. As per the pre-planning, the test has to be necessarily an atmospheric test, the crews built a 100-foot steel tower

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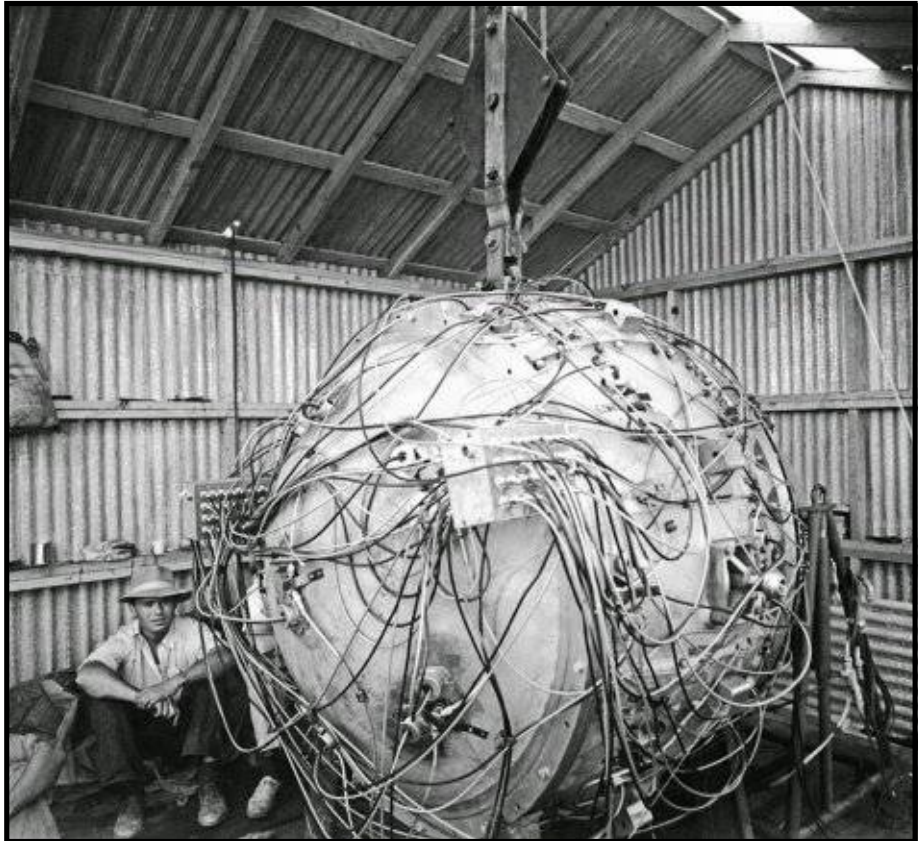


Fig.29. The Gadget world's first Atomic bomb

(Fig.30) to launch Gadget and three observational bunkers built 10,000 yards around the steel tower. Morning of 16 July 1945 was fixed for the explosion and the day before testing, a team hoisted the Gadget up the center of the tower and set in position. As an invocation, a poem was inspired by John Donne and detonated the Gadget exactly at Mountain War Time 5:29:45 AM, July 16, 1945. Immediately after the blast, Oppenheimer reportedly exclaimed, "*It worked*"

According to the Department of Energy, US, the explosion vaporized the steel tower, sent a massive shock wave which was felt over 160 km across the desert sand, and produced a mushroom cloud (Fig.31) soaring 12 km in height into the air. The roar of the shock took 40 seconds to reach the observers. The flash lighted the skies 400 km away and brightened ground zero with dazzle of many Suns. The surrounding mountains were illuminated brighter than day time for about 2 seconds and the heat at the base camp was as hot as an oven. The colors of the illumination ranged from purple to green and eventually to white. Men who looked directly at it against orders were temporarily blinded. The Earth shook and a blast of hot air was vaporized. At ground zero there was a crater of radioactive glass in the desert about 3 meter deep and 340 meter wide. Far away, a blind woman cried out that she had seen a light.

After the initial euphoria of witnessing the explosion had passed, the test director Kenneth Bainbridge commented to Los Alamos director, Robert Oppenheimer, "*Now, we are all sons of bitches*". Oppenheimer later stated that, while watching the test, he was reminded of a line from

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Fig.30 The 100-foot Tower on top of which the Gadget will be exploded



Fig.31 The Gadget within seconds after the explosion (After 16 ms the highest point of the viewed hemisphere is about 200 meters)

The Bhagavad Gita, a Hindu scripture: *“If the radiance of a thousand suns
Were to burst at once into the sky,
That would be like the splendor of the Mighty One....
I am become Death,
The shatterer of Worlds.”*

Based on the scripture, Oppenheimer said, *“Now I am become Death, the destroyer of Worlds.”*

To avoid doubts and suspicion among the villagers and citizens staying around, a press release prepared in advance with a fake explanation for the un-earthly eruption, was handed over to newspaper men for publication:

“An ammunition magazine exploded early today in a remote area of the Alamogordo Air Base Reservation producing a brilliant flash and blast which were reported to have been observed as far away as Gallup, 235 miles of north-west.”

With the successful testing, the next work is to manufacture the real weapon for a disaster which will certainly be a flash point for a turmoil. At Los Alamos, with the military intelligence and utmost secrecy maintained by scientists, two bombs were prepared one to be dropped in Japanese cities Hiroshima and Nagasaki. I shall give the details of dropping of the Hiroshima bomb and in order to maintain brevity of this paper, I shall skip the details of bombing of Nagasaki. In the following is given the structural details of both the bomb in brief.

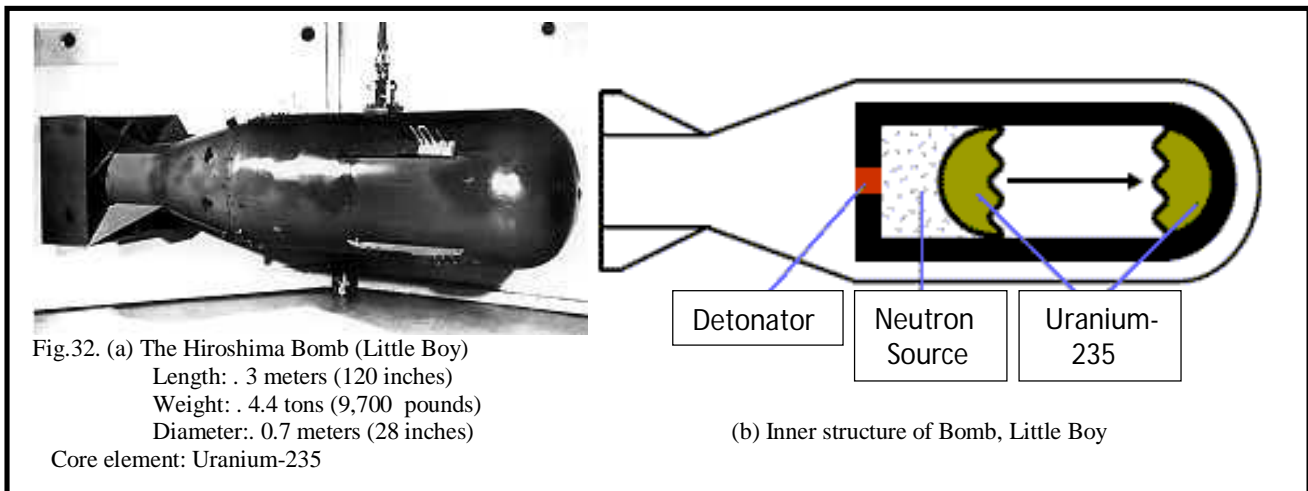
The Hiroshima Bomb–“Little Boy”

In Fig.32 is shown the picture of the bomb that was dropped in Hiroshima. Because of its long thin shape, it was named “Little Boy”. No doubt, Little Boy, but it could kill nearly a lakh of people. We shall see how this Little Boy turned out to be a giant killer. The bomb in a casing 14 feet long and 5 feet in diameter weighed about 10,000 pounds. It was scheduled to explode at a height of 1850 feet from the ground at Hiroshima. When the bomber attained a height of 1850 feet, a fuse would detonate and two cup-shaped sub-critical pieces of $^{235}_{92}\text{U}$ will come together at a speed of 5000 feet per second thereby attaining super-criticality and in the presence of neutron source, the explosion will occur and expected to yield 15 kilo Ton of TNT (~63 TJ). Thus, the device properly enclosed is ready to be transported and carry out the bombing.

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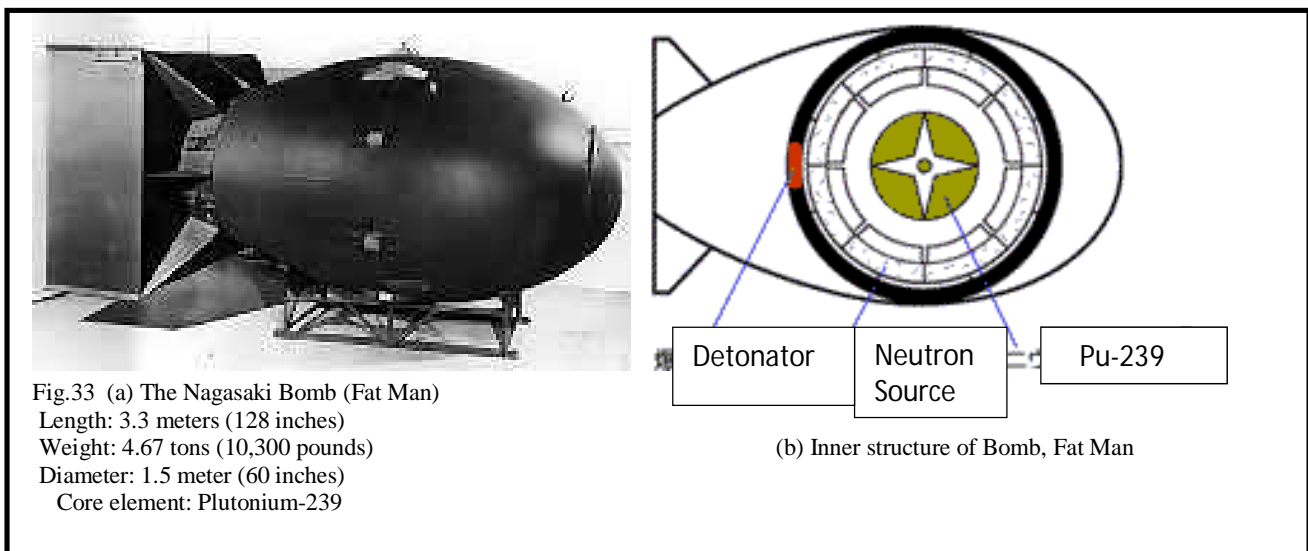
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The Nagasaki Bomb – “Fat Man”

In Fig. is shown the picture of the bomb that was dropped in Nagasaki. It was rounder and cylindrical, bulging at the center and hence named as “Fat Man”. A diagrammatic sketch of this bomb is shown in Fig.33. The core is Plutonium-239 divided into sub-critical portions and packed into a spherical case. To cause the chain reaction,



gun powder (Detonator) around the periphery of the case was used to force the units to the center making the sub-critical portions super-critical and in the presence of neutrons, the explosion occurs. As the pieces move inward, this bomb was an implosion type bomb. Thus, the second bomb is also ready for explosion.

Bombing of Hiroshima

The US with the consent of UK as laid down in the Quebec Agreement decided to bomb Japan. Accordingly, the US President Harry S Truman passed on orders for the same on August 4, 1945 and was approved by Curtis Emerson Le May the Commander-in-Chief of US Air Force. The date for bombing was fixed as morning of 6 August 1945. Before the dead line for bombing, scientist Robert Oppenheimer had discussions with the great mentor, Albert Einstein (Fig.34).

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Three cities Hiroshima, Kokura and Nagasaki were chosen. If any one of them is fogged, the other two will be bombed. It is the bombing mission No.13 code-named, "Operation Centerboard" with a 65 ton B-29 bomber named, Enola Gay named after the mother of the commander, Paul Tibbets (Fig.35) and will carry the bomb Little Boy on early morning of 6th August 1945. The bomber will start with 7000 gallons of fuel and about 5 ton atomic bomb from Iwo Jima in the Tinian island situated in the western Pacific and captured earlier by the US forces. Along with Tibbets, Co-pilot Robert Lewis, bombardier Tom Ferebee, Navigator, Theodore Van Kirk and tail gunner, Robert Caron

Were among few scientists the prominent among whom was Robert Oppenheimer. Six planes of the 509th Composite Group participated in the mission. One (Enola Gay) to carry out the bombing, one to take scientific measurements of the blast named the "Great Artist". The third to take photographs named "Necessary Evil" while the others flew approximately an hour ahead to act as weatherscouts as bad weather will disqualify the target and also to act as a spare plane in case the bomber Enola Gay developed any trouble. In other words, the scientists and the military didn't take any chance of failure of the mission.

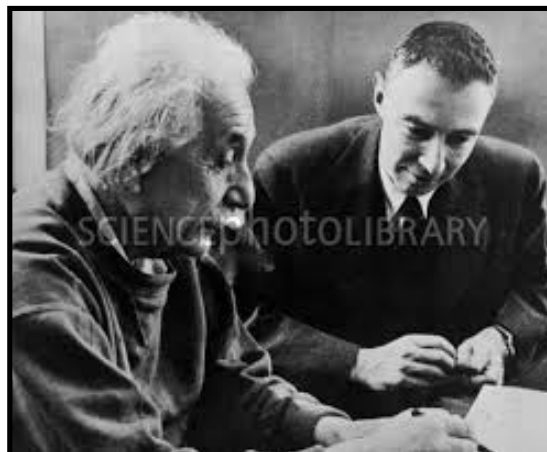


Fig.34. Robert Oppenheimer having discussions with Albert Einstein



Fig.35 Colonel Paul Tibbets (center) with crew of B-29 Bomber, Enola Gay

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Fig.35 Brigadier General, Paul W Tibbets (Rank of Colonel at time of War)

A few hours before the plane took off, colonel Tibbets addressed his team: *"I am going to keep this short because there is not much to say. I want you to remember that this bomb that we are going to drop is different from many you have seen or heard about. Secondly, I want you to remember that it contains a destructive power equal to about 20,000 tons of TNT"*. He then distributed cyanide capsules, which were to be consumed in case they ran into trouble while over-flying Japan. On this fateful day of 6th August 1945 at 8.15 AM plus 17 seconds the cargo with the Little Boy was let off the plane and the aircraft lurched up due to loss of cargo. 42 seconds after the drop, the explosion took place at a height of 1800 feet above the land at Hiroshima. By this one can understand the precise calculation of a physicist. A picture of the Hiroshima explosion is shown in Fig.36.

As I indicated earlier I shall be very brief on the second bomb dropped on the city of Nagasaki in Japan. At 3.47 AM on August 9, 1945 a B-29 Super fortress named Bockscar flown by major Charles W Sweeney took off with the already prepared bomb, "Fat Man" under the command code-named Operation Centerboard-II from the American air base on the Tinian island in the North Pacific Ocean

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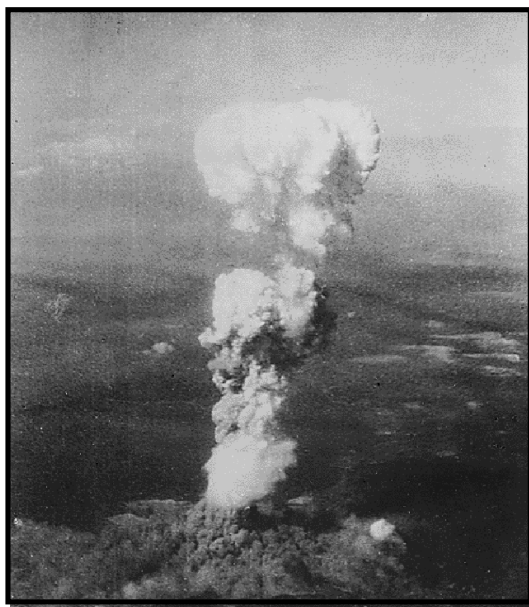


Fig.36. The Hiroshima Explosion

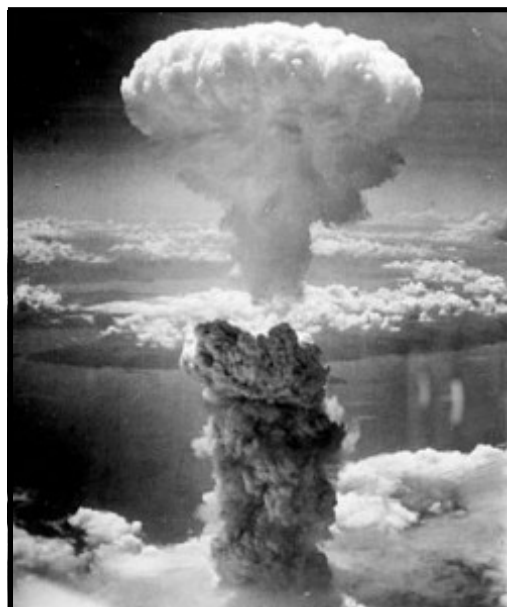


Fig.37. The Nagasaki Explosion.

.City of Kokura was also a target, but as it was fogged, when the bomber overflew Nagasaki, the bomb was dropped exactly at 11.02 AM. The explosion of the Fat Man dropped over Nagasaki is shown in Fig.37. The estimates of casualties is shown in Table No.2

The loss of properties is not included in the table. Other than Japan, the entire world was in turmoil thinking about their future life in case of use of such deadly weapons.

Table No. 2

Particulars	Hiroshima	Nagasaki
Pre-bomb Population	2,55,000	1,95,000
Dead	66,000	39,000
Injured	69,000	25,000
Total casualties	1,35,000	64,000

The immediate reaction in the war arena was that Hirohito, the adamant emperor of Japan who determined against all precedent, himself convened an Imperial Conference on 15 August 1945 and at noon on that day announced Japan's surrender which was officially signed on 2 September 1945 aboard the USS Missouri. The war was over.

Reaction and comments of dignitaries and world leaders

I shall mention in brief the comments of few dignitaries and world leaders. I shall start with the crew of Enola Gay which dropped the Hiroshima bomb. Immediately after bombing, the pilot Col. Paul W Tibbets said that as an Air Force pilot he performed his duty and hence had no regrets. Bombing certainly avoided invading Japan and further loss of lives.

Captain Robert Lewis, the co-pilot said that they saw an entire city disappear. *“My God, What have we done?”* The navigator, Theodore Van Kirk said that a ground war would have killed many Japanese. In the year 2005 he regretted the bombing and said: *“I pray no man will have to witness that sight again. Such a terrible waste, such a loss of life. We unleashed the atomic bomb, and I hope there will never be another. I pray that we have learned a lesson for all time. But I am not sure that we have.”*

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Albert Einstein, even though he sent the letter for bomb making to Franklin Roosevelt, condemned the use of atomic bomb against Japan.

All theoretical physicists in the world were mentally satisfied of the proof of Einstein's mass-energy equation Robert Oppenheimer said: *"It is a turn of the screw. It made the prospect of a future war unendurable."* Richard Feynman a prominent physicist of the Manhattan project partied with others and got himself drunk. The physicist, Hans Bethe who was also participated in the Manhattan project, said: *"I think it was necessary to drop one, but the second one could have easily been avoided. I think Japan would have capitulated anyway."* The US President, Harry S Truman was on board the US Augusta when he was told of the bombing of Hiroshima. He told the ship's crew: *"This is the greatest thing in history"*.

Polls taken in US after the war, a majority of about 85% approved the bombing.

General Dwight Eisenhower said that *"Japan was at the time seeking some way to surrender with minimum loss of 'face'. It wasn't necessary to hit them with that awful thing"* Bertrand Russell said: *"One must expect a monster bomb between USA and USSR which will begin with the total destruction of London and will last for 30 years and the re-building will take 500 years."* In 1946, H.G. Wells wrote that, *"It is the end."*

A uranium refinery in Ontario, Canada supplied the uranium fuel for the Manhattan Project and hence had no comments.

News from Philippines: *"Horrible atomic bomb brought Japan to her knees"*

Mahatma Gandhi's Reaction:

According to Dr. Dietmar Rothermund, a German historian from Heidelberg University, and an expert on Indian economy, Gandhiji did not immediately condemn the bombing but kept silent. He came out strongly against nuclear weapons only when it became clear that India would become independent.

On 21 September 1945, Gandhi sent a telegram to the London Times contradicting some pronouncements attributed to him and said: *"Never made any public statement about the atomic bomb"*. Gandhiji replied to Mr. Peston Grove: *"The more I think the more I feel I must not speak on the atomic bomb"*.

In November 1945, Gandhiji said: *"Those nations who have atomic bombs are feared even by their friends"*

On 17 February 1946, Gandhiji wrote in the Harijan: *"Today, you have to reckon not with Britain alone, but with big three After all, you cannot go beyond the atom bomb..... But, non-violence knows no defeat. Unless now the world adopts non-violence, it will spell certain suicide for mankind."*

Again, on 9 May 1946, he once more wrote in the Harijan: *"The atom bomb has not stopped violence. People's heart are full of it and preparation for a third world war may even said to be going on."*

Gandhiji told a journalist: *"You can proclaim to the whole world without hesitation that I am beyond repair. I regard the employment of the atomic bomb for the wholesale destruction of men, women and children as the most diabolical use of science."*

Two days before his assassination, Gandhiji said: *"The atom bomb could not crush the spirit of Nations"*.

What Jawaharlal Nehru said?

For a question, Would the future government of India have an atom bomb in its armoury?, Nehru answered: *"So long as the world constituted as it is, every country will have to devise and use the latest scientific methods for its protection. I have no doubt India will develop its scientific researches and I hope Indian scientists will use the atomic force for constructive purposes. But, if India is threatened, it will inevitably try to defend itself by all means at its disposal. I hope India in common with other countries will prevent it being used."*

So, ladies and gentleman, it was chaos after the bombing and the political overtones changed the nature of the world. Joseph Stalin of the Soviet Union gave up his intentions to capture Japan. The United Nations was formed. Some small nations like Indonesia and some island nations declared themselves as independent. The hydrogen bomb also known as the fusion bomb or thermo-nuclear bomb founded by Edward Teller also was tested. Major powers such as Great Briton, USSR, France, China, India and Pakistan became nuclear by testing their own nuclear devices. I shall now deal

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with the Indian nuclear tests which really created a turmoil specially more turmoil in the neighboring Pakistan as the same was un-expected and surprised the world.

(D). The Indian Bombs and After

Indians who are taken to be ‘Magicians’ and ‘Snake Charmers’ (Fig.38) could explode a nuclear device by conducting a test on 18th May 1974 in the Pokharan desert (Fig.39) of Rajasthan, India. Thus, India became nuclear in world politics. The pioneer in the development

of atomic energy was the physicist, Dr. Homi J Bhabha. (Fig.40). The first Prime Minister of independent India, late Pundit Jawarlal Nehru made him the Chairman of Atomic Energy Commission. But, unfortunately, Bhabha died in an air crash in the Swiss Alps in the year 1966. His followers, to mention few, Dr. Homi N Sethna, Dr. Raja Ramanna (Fig.41), Dr. P.K. Iyengar, Dr. Rajagopala Chidambaram, Dr. M.R. Srinivasan, Dr. Anil Kakodkar and others carried out Bhabha’s work and successfully exploded a nuclear device on 18 May 1974. Two more explosions were also successfully carried out in Pokharan on 11 and 13 May 1998. These tests carried out on two different occasions are referred to as Pokharan-1 and Pokharan-2. Pokharan-1 is code-named as “Smiling Buddha” and Pokharan-2 as “Operation Shakti”. A summary of all the tests conducted by India is given in Table No.3. The table



Fig.38. An Indian snake charmer imagines the mushroom cloud of a nuclear explosion



Fig. 39. Location of Pokharan in Rajasthan, India

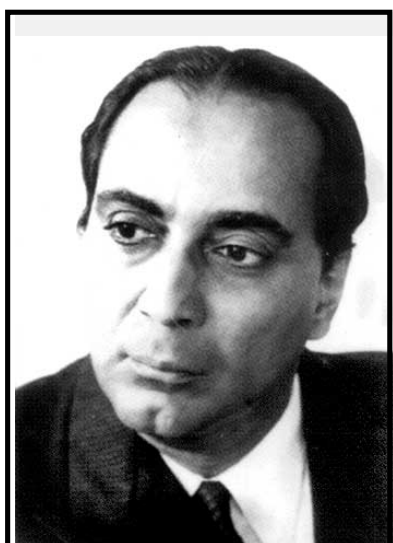


Fig.40. Dr. Homi J Bhabha (1909-1966)

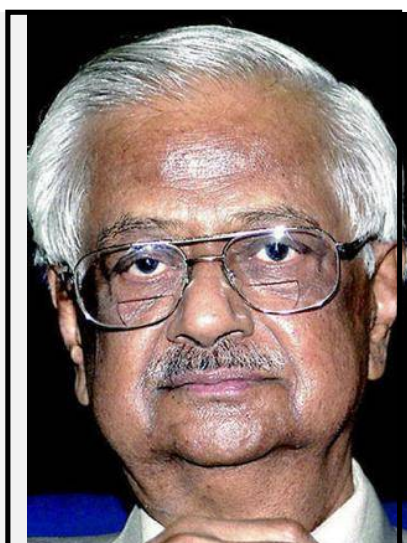


Fig.41. Dr. Raja Ramanna (1925-2004)

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gives a clear picture of all the tests conducted by India In the following I will be showing you more pictures than talking. Fig.42 shows the crater formed by Pokhran-1 and in the following Fig.43. is shown Dr. H.N.Sethna along with Dr. P.K. Iyengar showing the Pokhran-1 explosion site to Indian Prime Minister Indira Gandhi. The three tests of 11 May 1998 were conducted simultaneously to prevent the loss of valuable data that could have been resulted from the gap caused by the blasts

Table No. 3 *

Particulars	Pokhran-1	Pokhran-2				
Date and time of Explosion	18 May 1974 at 8.05 AM	11 May 1998 at 3.45 PM 13 May 1998 at 12.21 PM				
Code name and No. of tests conducted	“Budhha Smiles” Only one test	Operation “Shakti” 1 to 3 Operation “Shakti” 4 to 5				
Material used as fuel	Plutonium-239	Not disclosed				
Type of Explosion	Implosion	4 Fission bombs, type not disclosed. 5 th one a Fusion (Thermo-nuclear) bomb due to the reaction of Deuterium (Heavy Water) with tritium				
Yield	About 15 kilo Ton of TNT	<table style="border: none;"> <tr> <td style="border: none;">i)0.2 kT of TNT ii)12 kT of TNT iii)43kT of TNT</td> <td style="border: none;">} Tests of 11 May 1998</td> </tr> <tr> <td style="border: none;">i)0.3 kT of TNT ii)0.5 kT of TNT</td> <td style="border: none;">} Tests of 13 May 1998</td> </tr> </table>	i)0.2 kT of TNT ii)12 kT of TNT iii)43kT of TNT	} Tests of 11 May 1998	i)0.3 kT of TNT ii)0.5 kT of TNT	} Tests of 13 May 1998
i)0.2 kT of TNT ii)12 kT of TNT iii)43kT of TNT	} Tests of 11 May 1998					
i)0.3 kT of TNT ii)0.5 kT of TNT	} Tests of 13 May 1998					
Scientists involved	i)Dr. H.N. Sethna, then Chairman, Atomic Energy Commission ii)Dr. Raja Ramanna, Director, BARC and iii)Dr. P.K. Iyengar, Director, Physics Group, BARC	i)Dr .Rajagopala Chairman, BARC®, ii) Dr. A.P.J. Abdul Kalam, Chairman, DRDO, iii) Dr. Anil Kakodkar, Director, Physics Group, BARC and iv)Dr. K. Santhanam, Project Director, Operation Shakti 1 to 5				

@ Bhabha Atomic Research Center

*Numerical in the above Table may slightly vary in literature found elsewhere

In Fig. 44 is shown the Pokhran-2 bomb, Shakti-1. readying for detonation. The yield of the thermo-nuclear device was so chosen that is minimal seismic damage to the surrounding village, the nearest one being just 5 km away. The depth emplacements were fixed so that the explosions were fully contained and no radioactive venting.

As in the case of Pokhran-1, there were four ground motion measurements and a close array of seven accelerometers and five three component geophones at various distances. About 20 seismometers kept at Gauribidnur, Karnataka recorded the explosions. 45 national seismological observations run by the Indian Meteorological Department gave body wave magnitudes between 5 and 5.4 Richter scale. The International Data Center at Airlington in the United States initially classified the event as an earthquake.

Now, coming to Pokhran-2, the 12 kT test produced a sand mount, the 43 fusion test resulted in a crater and the other three sub-kilo ton tests resulted in the blow of sands out of the shafts up to varying depths.

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The Indian scientists have shaken up the international scientific community by obtaining tritium (Triton) the radioisotope of hydrogen using an equipment of detritiumization (heavy water) used as a moderator in nuclear power stations. India can produce hundreds of kilograms of tritium in just few months and its production is not covered by the Nuclear Poliferation Treaty (NPT). The detitriumization plant at BARC is kept open for scientists to do further research. As the details of detitiumization are kept a secret, the western scientists were at a loss. The ground zero was inspected by radiation experts and health physics scientists under the leadership of Dr. S.K. Sikka, chief of Solid State Spectroscopy. The 43 kilo ton thermo-nuclear device (fusion) was i) Fission primary (15 k ton) and thermo-nuclear secondary (28 k ton).



Fig. 42 The Crater formed by Pokaran-I Nuclear Blast



Fig.43. Dr. H.N. Sethna then Chairman of Atomic Energy Commission showing the Pokaran-I site of Nuclear explosion to Prime Minister Indira Gandhi

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A news item by Reuters from Washington D.C dated 23 May 1998 appeared in the Indian Express, Mumbai dated 24 May 1998 quoting Edward Teller (Fig.19) the maker of the hydrogen bomb telling the world to accept India as a Nuclear Power. In Fig.45 is shown the Prime Minister Atal Behari Vajpayee with Defense Minister George Fernandes at the Pokhran-2

In Fig.45 is shown the Prime Minister Atal Behari Vajpayee with Defense Minister George Fernandes at the Pokhran-2 site after the explosion. Next day after the Pokhran-2 explosion, report in the Times of India, Mumbai reads: “*Earth rocked thrice.....it was over in 5 sec.*” The media reports from London praised Indian nuclear scientists for their achievement. A meaningful cartoon in connection with the reaction in United States that appeared in the Indian Express, Mumbai on Thursday the 21st May 1998 is shown in Fig.46. The cartoon on the top is an American couple on a visit to the Taj Mahal suspects the minarets to be some nuclear war-head. The cartoon at the bottom is an official of the Central Intelligence Agency (CIA) of the US (Top) with the mushroom of the Indian explosion at the background getting surprised and speaking to another CIA official elsewhere (Bottom) who closes his ears to avoid the noise of the blast. Reports from London were all praise for the Indian scientists for their achievement. According to NATO, the nuclear test carried out by India brings out a world nuclear imbalance and the NATO military experts were quoted by the Romanian paper as saying: “*Time has come for the world to ponder over such discrimination and make a movement towards genuine global disarmament*”

With the successful explosion of 11 May 1998, the Government of India declared 11 May as “National Technology Day”.

So, coming to an end, that was the turmoil after the Indian explosion

III. CONCLUSION

So, Ladies and Gentlemen, my lecture has become too exhaustive and I hope I have covered the entire matter right from the fundamentals to the very end. At every stage you must have felt the pulse of the turmoil even before the explosion. Even though more than 7 decades have passed after the two bombings, the turmoil still remains in the minds of general public and politicians of different countries of the world. It was a herculean task for me to make this lecture into a Research Paper and the entire



Fig.44 Cylindrical shaped nuclear bomb, Shakti-1 of Pokhran-2 readying for detonation

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Matter on reading, the reader might find the same like an epic of ancient times where a powerful mighty Giant is killed by a most powerful weapon known to man. Among all branches of Physics, it is Nuclear Physics, the fore-runner in the making of the bomb and what is 'UNCLEAR' for others, it is 'NUCLEAR' where I have interchanged the first two alphabets of the word. But, I am sure, I have made everything perfectly CLEAR for your understanding.



Fig.45. The Indian Prime Minister, Atal Behari Vajpayee with the scientists at the Pokharan-2 Explosion site

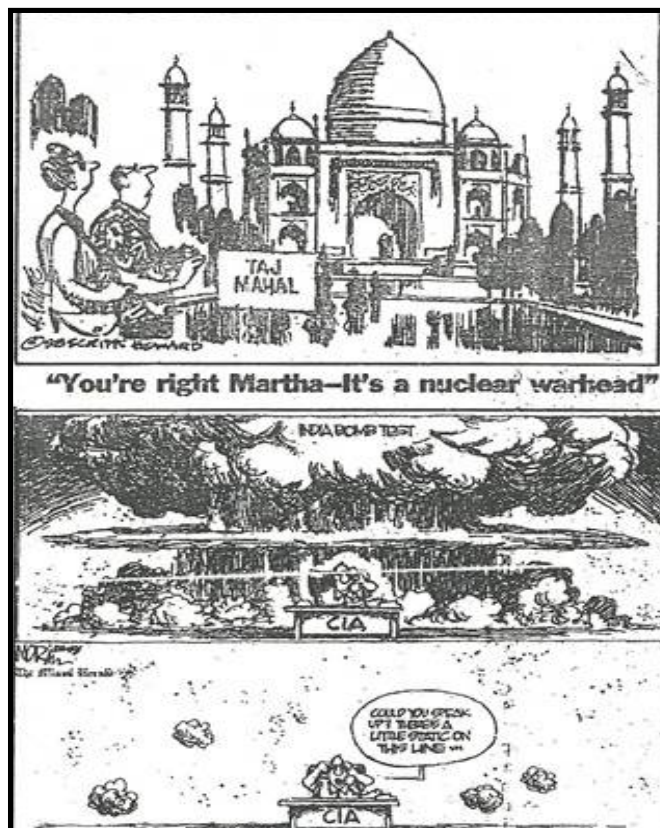


Fig.46. A cartoon that appeared in the Indian Express, Mumbai on Thursday, 21 May 1998

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IV. APPENDIX

A. COST OF NUCLEAR WEAPONS

The cost of a nuclear device and its use will depend upon the mode of use of the weapon. If it is used as a weapon, the cost will be less because the cost involves only two parts: the manufacturing cost and the cost of transport to drop the weapon as a bomb like the bombing of Hiroshima or Nagasaki. The cost will be more if the device is used for testing as it involves lot of civil works and the same can be enumerated as follows:

- (a) Cost of surveys, planning and acquisition of land
- (b) Cost of safety precautions and evacuation of areas near the site of explosion, if necessary.
- (c) Cost of drilling hole, installation of cables, etc.
- (d) Cost of conventional engineering for example, there has to be a mini workshop with essential tools near the site of explosion and above all
- (e) The cost of the bomb itself (complete material)

All the above will vary from one project to another according to the size and depth of the hole, yield of the explosion, population requiring temporary evacuation, cost of the land, etc. An important feature to be emphasized is that the cost of the bomb itself is almost independent of the yield. Further, if it is a thermo-nuclear device (Fusion bomb) fission is the trigger for fusion and hence the cost will further increase. The amount is not worth quoting, but, however, the cost as on 1974 when India exploded its first nuclear device, an approximate cost for a low yield bomb may be 5 crores of Indian Rupees.

B. PEACEFUL USES OF A NUCLEAR EXPLOSION.

The following are the uses of nuclear explosions:

- (a) Nuclear explosions lead to the invention of transuranic elements
- (b) New particles are detected after nuclear explosions
- (c) Nuclear explosions are used in the building of dams, creating artificial ravines and valleys, to blow up a hill or even a mountain, changing the course of a river, creating artificial lakes, etc.
- (d) A nuclear explosion would be expected to break up the rock over an oil belt and stimulate a flow of oil.
- (e) The results and data obtained from a nuclear explosion may be useful for the improved working of nuclear reactors and power plants.
- (f) Apart from all the above, a great use of nuclear explosion is that it puts a large team of scientists to work. After an explosion, the theoretical physicists will be confronted to their cabins and the experimentalists will be busy with their instruments.

C. BIOLOGICAL EFFECTS OF NUCLEAR RADIATIONS

You know, radiation is as old as the universe. The normal radiation which we receive from the Sun and the surroundings is absolutely essential for life. But, the radiation that emanate from a nuclear explosion is certainly hazardous to life and it affects the entire thermodynamics of life. According to reports from the press, there was no radioactivity from the Pokharan-1 explosion as Ramanna and Sethna could watch the explosion from a distance of 100 meter away. The main reason for the absence of radioactivity was that it was an implosion with the shock wave travelling inward and other techniques which are not disclosed. Further, the explosion was perfectly guarded. I think the holes must have been plugged by thick lead plates.

The atomic bomb explosion is a source of diverse radiations. Large quantities of neutrons and gamma rays, and also visible infra-red and ultra-violet radiations are emitted at the time of explosion. The neutrons and gamma rays are produced in the process of fission while the light radiation due to intense heat. After the explosion, the affected site exhibits gamma and beta rays origination from the beta-decay of the fragments and also alpha particles from the un-split uranium nuclei. The ionizing effects of such radiation can cause the breaking of some of the chemical bond and destroy some of the molecules in the cells of the human body.

The damage, however, depends upon factors such as the dose of radiation and the distance from the source of explosion. That is why thousands were killed near the source of explosion in both the Hiroshima and Nagasaki bombings. In order to understand the dosage and the damage, let us know something about the unit of radiation. There are two units of radiation, the 'rad' standing for 'radiation absorbed dose' and 'rem' standing for 'roentgen equivalent man' The rad is equal to the energy absorption of 100 ergs per gram of irradiated. The rem is the absorbed dose of ionizing radiation that produces the same biological effect as one rad of X-rays or gamma rays. Another frequently used unit is the 'milli rem' (0.001 rem). In the SI System, the 'gray' and the 'sievert' are used. The relations are:

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1 gray (Gy) = 100 rad; 1 sievert = 100 rem

Depending upon the energy level, for neutrons, 1 rad = 5 to 20 rem

In the following table is given the dose required to produce certain effects in the human body.

Dose, rad	Area affected	Effect
50	Whole body	Reversible blood change
50	*Gonads	Doubles mutation rate
10 to 100 per day up to 200	Local area	Carcinogenic(Cancer)
200	Whole body	Nausea
400	Whole body	Death in 50% cases
500 to 800	*Gonads	Sterilization
1000	Eye	Cataract
3000	Local area	Radiative cancer

*Testis of the male or ovary of the female

D. NUCLEAR EVENTS IN ANCIENT INDIA

1. Evidence at Mohenjo-Daro (Fig.A)

When excavations at Harappa and Mohenjo-Daro, Pakistan were carried out skeletons with holding hands (Fig.B) and lying scattered in the streets as if some instant horrible doom similar to an atomic explosion had happened. The carbon dating of the skeletons indicated to 2500 BC. Another highlight of the theory is that two British researchers, Lord David William Davenport and Ettore Vicenti (Fig. C) who spent almost 12 years studying ancient Hindu scripts and evidence at the site where the great heavily populated city, Mohenjo-Daro once stood



Fig. A. View of Mohenjo-Daro



Fig. B Skeletons with folding hands

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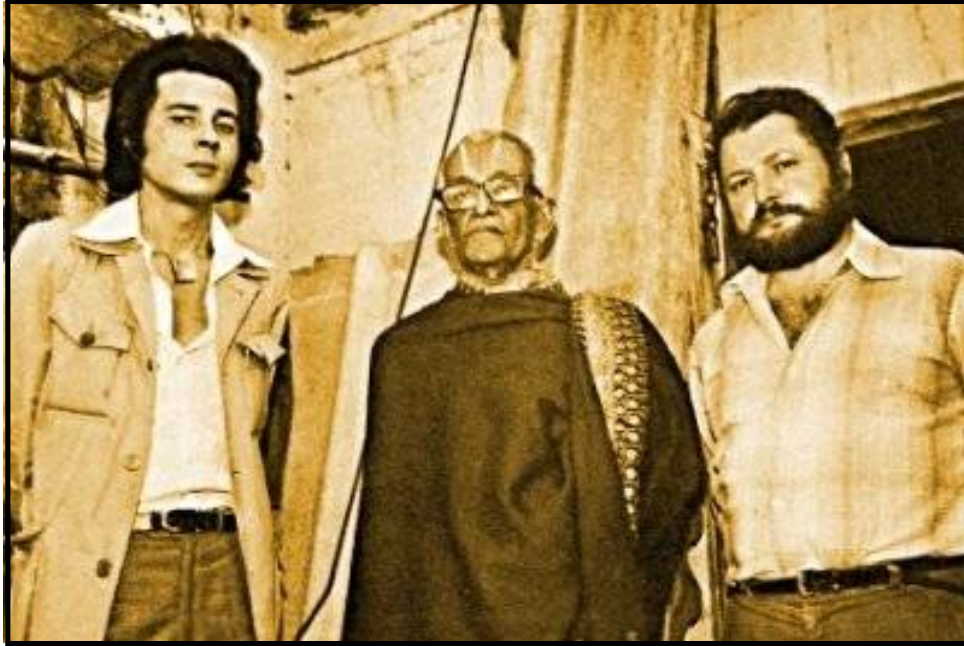


Fig.C Lord David William Davenport (left) with Ettore Vicenti (right), in Pakistan.

.This city, according to them, was instantly destroyed some 2000 years before Christ by an incredible explosion that could have only been caused by an Atomic Bomb. That was their mind boggling conclusion. What was found at the site of Mohenjo Daro corresponds exactly to Nagasaki. There was an epicenter 50 yards wide where everything was crystallized, fused or melted, declared Davenport, who published his startling findings in an amazing book, "*Atomic Destruction in 2000 B.C.*", Milan, Italy, 1979.

2. Giant un-explained crater near Bombay

An indication of an ancient nuclear warfare in India is the sign of a giant crater 2154 m diameter known as Lonar crater located at about 400 km North-East of Bombay and aged about 50,000 years could be related to a nuclear warfare of antiquity.

....(From Nexus Magazine by David Hutcher Childress)

3 A nuclear catastrophe in Paleolithic Times by Richard B Firestone, a nuclear scientist at

Lawrence Berkeley Nuclear Laboratory and William Topping a consultant published in an off mainstream journal by the Center for the Study of the first Americans 355 Weniger Hall, Oregon State University, Corvallis, OR 97331-6510. Reveal with evidence a remarkable theory of a past terrestrial catastrophism which reset radio carbon clocks in north-central North America and – potentially – elsewhere in the planet. According to the authors, the catastrophic nuclear radiation produced secondary thermal neutrons from cosmic ray interactions. The neutrons produced unusually large quantities of Pu²³⁹ and substantially altered the naturally occurring uranium U²³⁵ and U²³⁸ in artefacts and other exposed materials including cherts, sediments and the entire landscape. These neutrons necessarily transmuted residual nitrogen (N) in the dated charcoals in radiocarbon, thus explaining anomalous dates which are as much as 10,000 years and hence not a trivial phenomenon. The authors further claim that the burst of radiation from a nearby Supernova, circa 12,500 years ago, not only reset radiocarbon clocks, but also heated the planet's atmosphere, melted ice sheets and led to biological extinctions. These claims, if verified, might reset archeological models of the settlement of North and South America.

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4. Evidence at Rajasthan, India.

The presence of radioactive ash covering about three square mile area some ten mile west of Jodhpur indicates some atomic blast similar to the bombs dropped in Japan occurred some 8 to 12 thousand years ago and this has been confirmed by archeologists Francis Taylor and Lee Hundley and also by an Indian historian Kisari Mohan Ganguli

5. The Hindu Epic Mahabharata clearly describes a catastrophic blast that rocked the continent.

“A single projectile charged with all power in the Universe – an incandescent column of smoke and flame as bright as 10,000 Suns rose in all its splendor – it was an unknown weapon, an iron thunderbolt, a gigantic messenger of death which reduced to ashes an entire race – The corpses were so burned as to be unrecognizable. Their hair and nails fell out, pottery broke out without any apparent cause, and the birds turned white. After few hours, all foodstuffs were infected. In order to escape from this danger, the soldiers threw themselves into a river

V. EPILOGUE

Due to the intensity of the turmoil, I am not in a position or rather unable to end this article. But, however, I have to end it as it has already run into pages.

Looking upon the equation, $E = mc^2$ that created the Bomb which killed so many people, I had the desire of just seeing the great physicist who created the equation, but it was too late. I was hardly 16 a student in SSC when Einstein died on 13 April 1955. Those times, not knowing what a nuclear bomb is, and as only a decade had passed after the bombings on Japan the idea of the bombs dropped in Japan was afresh in my mind. After a very long period of many years, sometime in the year 2007, I travelled to Princeton, New Jersey, US from India almost like a pilgrimage and visited the famous University of Princeton where the great scientist spent more than a quarter of the century of his time in research. On another occasion during the visit to the US in 2009, I was at the Discovery Center which is a part of the Lawrence Livermore National Laboratory at Livermore, California wherein I saw a life-size PORTRAIT of the scientist looking lively and as if explaining “What is Physics?” a legible note kept on the right side of the portrait. With permission a photograph was taken with me and the portrait with the note at the center. (See Fig.)

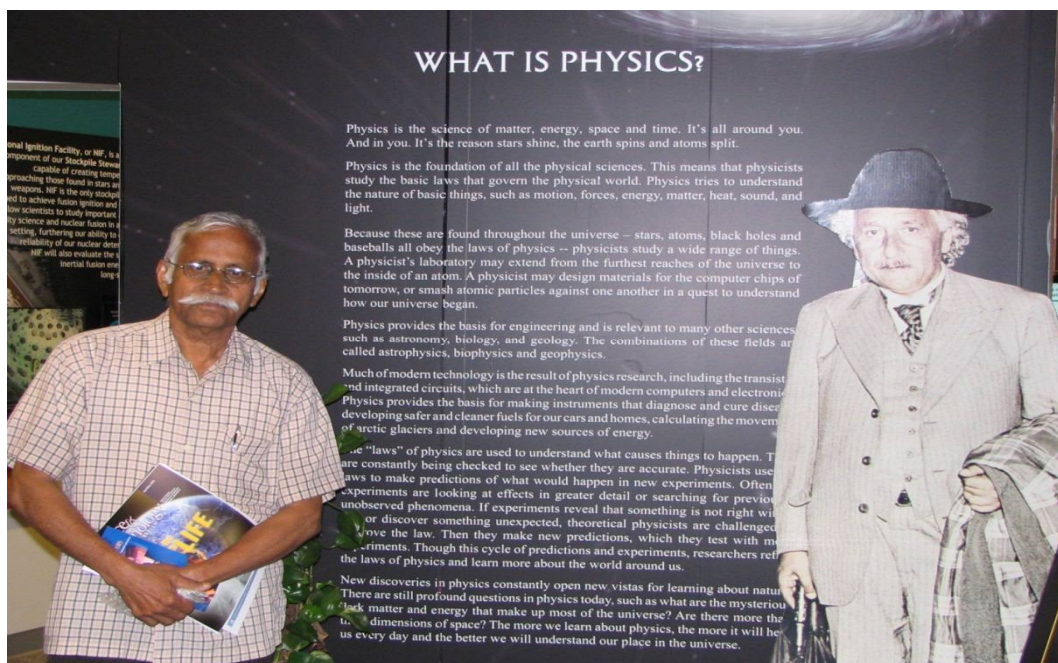


Fig. Prof. V.C.A. Nair standing near a PORTRAIT of Dr. Albert Einstein, the great theoretical Physicist at “Discovery Center”, Lawrence Livermore National Laboratory, Livermore, California, USA, 9th July 2009.

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BIOGRAPHY



Dr.(Prof.) V.C.A. Nair (b. 15th Aug. 1939) is an Educational Physicist, Counselor, Research Guide and Consultant. He did his Masters from Mumbai University, India and Ph.D. from JJT University, Rajasthan also in India. He has to his credit over 4 decades of teaching Applied Physics in eminent Polytechnics in Mumbai and having taught nearly 16,000 students since 1965. He has published a number of research papers in Physics and is a Life Member of Indian Society for Technical Education which is an all India body. He had been to USA a number of times and visited eminent Universities such as Stanford, Harvard, MIT, University of California both at Berkeley and Los Angeles and University of San Francisco. At present Dr. Nair is a Research Guide at JJT University, Rajasthan-333001, India. His Ph.D. Thesis is in Geophysics and he is working on topics such as Tides, Clouds, Global Warming and Climate Change.

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